Department of Energy

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SEP 25 2012

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

PPPO-02-1564738-12B

Ms. Jennifer Tufts
Remedial Project Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

Dear Mr. Mullins and Ms. Tufts:

TRANSMITTAL OF THE 60% REMEDIAL DESIGN REPORT *IN SITU* TREATMENT USING DEEP SOIL MIXING FOR THE SOUTHWEST GROUNDWATER PLUME VOLATILE ORGANIC COMPOUND SOURCE AT THE C-747-C OIL LANDFARM (SOLID WASTE MANAGEMENT UNIT 1) AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY (DOE/LX/07-1276&D1)

Please find enclosed the 60% Remedial Design Report In Situ Source Treatment Using Deep Soil Mixing for the Southwest Groundwater Plume Volatile Organic Compound Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky, DOE/LX/07-1276&D1, for your review. The document incorporates responses to the 30% design review comments received from the U.S. Environmental Protection Agency on July 13, 2012. Enclosed also for your use is a redline version of the document and a comment response summary.

Section XX.G.2 of the Federal Facility Agreement provides for a 90-day review cycle for a secondary document; however, to accommodate the current project schedule for submittal of the 90% Remedial Design Report on February 16, 2013, the U.S. Department of Energy requests a 45-day review cycle. Receipt of regulatory comments within 45 days will allow adequate time for resolution and incorporation of comments prior to transmittal of the 90% Remedial Design Report.

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

Sincerely,

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

Enclosures:
60% Remedial Design Report

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DOE/LX/07-1276&D1
Secondary Document

60% Remedial Design Report *In Situ* Source Treatment Using Deep Soil Mixing for the Southwest Groundwater Plume Volatile Organic Compound Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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DOE/LX/07-1276&D1
Secondary Document

60% Remedial Design Report *In Situ* Source Treatment Using Deep Soil Mixing for the Southwest Groundwater Plume Volatile Organic Compound Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—September 2012

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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CONTENTS

FIGURES

TABLES

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ACRONYMS

ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
DOE	U.S. Department of Energy
E/PP	excavation/penetration permit
FFS	focused feasibility study
FID	flame ionization detector
GAC	granular activated carbon
GC	gas chromatograph
HU	hydrogeologic unit
KO	knock-out tank
LDA	large diameter auger
LUC	land use control
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PGDP	Paducah Gaseous Diffusion Plant
PID	photoionization detector
RA	Remedial Action
RAO	remedial action objective
RAWP	remedial action work plan
RDR	remedial design report
RDSI	remedial design support investigation
RDWP	remedial design work plan
RG	remediation goal
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROD	record of decision
SI	site investigation
SPT	standard penetration test
SWMU	solid waste management unit
TCE	trichloroethene
UCRS	Upper Continental Recharge System
VCS	vapor conditioning system
VOC	volatile organic compound
WAG	waste area grouping
ZVI	zero-valent iron

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EXECUTIVE SUMMARY

This Remedial Design Report has been prepared for the *In Situ* Source Treatment Using Deep Soil Mixing with Interim Land Use Controls (LUCs) Remedial Action (RA) for the Southwest Plume volatile organic compound (VOC) source area, Solid Waste Management Unit 1 at the Paducah Gaseous Diffusion Plant (PGDP) in Paducah, Kentucky. This remedial design report was prepared in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act, and is the response action selected in the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2/R1 (ROD) (DOE 2012a).

The response action for VOCs selected in the ROD is required to address the release of hazardous substances into the environment that are sources of groundwater contamination and present unacceptable risk from direct exposure to residual VOCs and non-VOCs. Removal of VOCs, like trichloroethene, from the soils in the Southwest Plume source areas will contribute to the final cleanup of the Groundwater Operable Unit at PGDP.

The ROD specified an *in situ* source treatment using deep soil mixing with interim LUCs. The RA also will include the implementation of interim LUCs consisting of the Excavation/Penetration Permit Program and the posting of warning signs at the source areas.

This report contains information regarding the preliminary design of the remediation system, including discussions of the following:

- Mixing of soil using large diameter augers
- Injection of hot air and steam to volatize targeted contaminants
- Injection of zero-valent iron as a polishing step for treating residual VOCs
- Treatment of recovered vapor through a vapor conditioning/treatment system
- Treatment of condensate via localized air stripping and/or granular activated carbon
- Data collection and monitoring

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1. INTRODUCTION

This Remedial Design Report (RDR) presents the 60% conceptual design for the remedial action (RA) to be implemented at the Southwest Groundwater Plume source area at PGDP at Solid Waste Management Unit (SWMU) 1. The remedy planned for SWMU 1 is documented in the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0365&D2 (ROD) (DOE 2012a). The overall design process is described in the *Remedial Design Work Plan for Solid Waste Management Units 1, 211-A, and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1268&D2/R1 (DOE 2012b).

Conceptual design information provided in this report includes the following:

- Site description
- Technology description
- Remedial action objectives
- Design requirements
- Construction requirements

PGDP, located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County, is an active uranium enrichment facility owned by the U.S. Department of Energy (DOE) (Figure 1). Bordering PGDP to the northeast, between the plant and the Ohio River, is the Tennessee Valley Authority Shawnee Fossil Plant.

The Southwest Groundwater Plume refers to an area of groundwater contamination at PGDP in the Regional Gravel Aquifer (RGA), which is south of the Northwest Groundwater Plume and west of the C-400 Building (also known as the C-400 Cleaning Building). The plume was identified during the Waste Area Grouping (WAG) 27 Remedial Investigation (RI) in 1998 (DOE 1999). Additional work to characterize the plume was performed as part of the WAG 3 RI (DOE 2000a) and Data Gaps Investigation (DOE 2000b). As discussed in these reports, the primary groundwater contaminant of concern for the Southwest Groundwater Plume (hereinafter referred to as the Southwest Plume) is trichloroethene (TCE). Other contaminants found in the plume include additional volatile organic compounds (VOCs), metals, and the radionuclide technetium-99 (Tc-99).

DOE conducted a site investigation (SI) in 2004 to address the uncertainties associated with potential source areas to the Southwest Plume that remained after previous investigations. The SI further profiled the current level and distribution of VOCs in the dissolved-phase plume along the west plant boundary. Results of the SI were reported in the *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2/R1 (DOE 2007). The Focused Feasibility Study (FFS) (DOE 2010a) is based on the SI (DOE 2007), as well as previous investigations identified here. Existing analytical data from the SWMU 1 source area [prior to the Remedial Design Support Investigation (RDSI)] is included on a CD in the appendix.

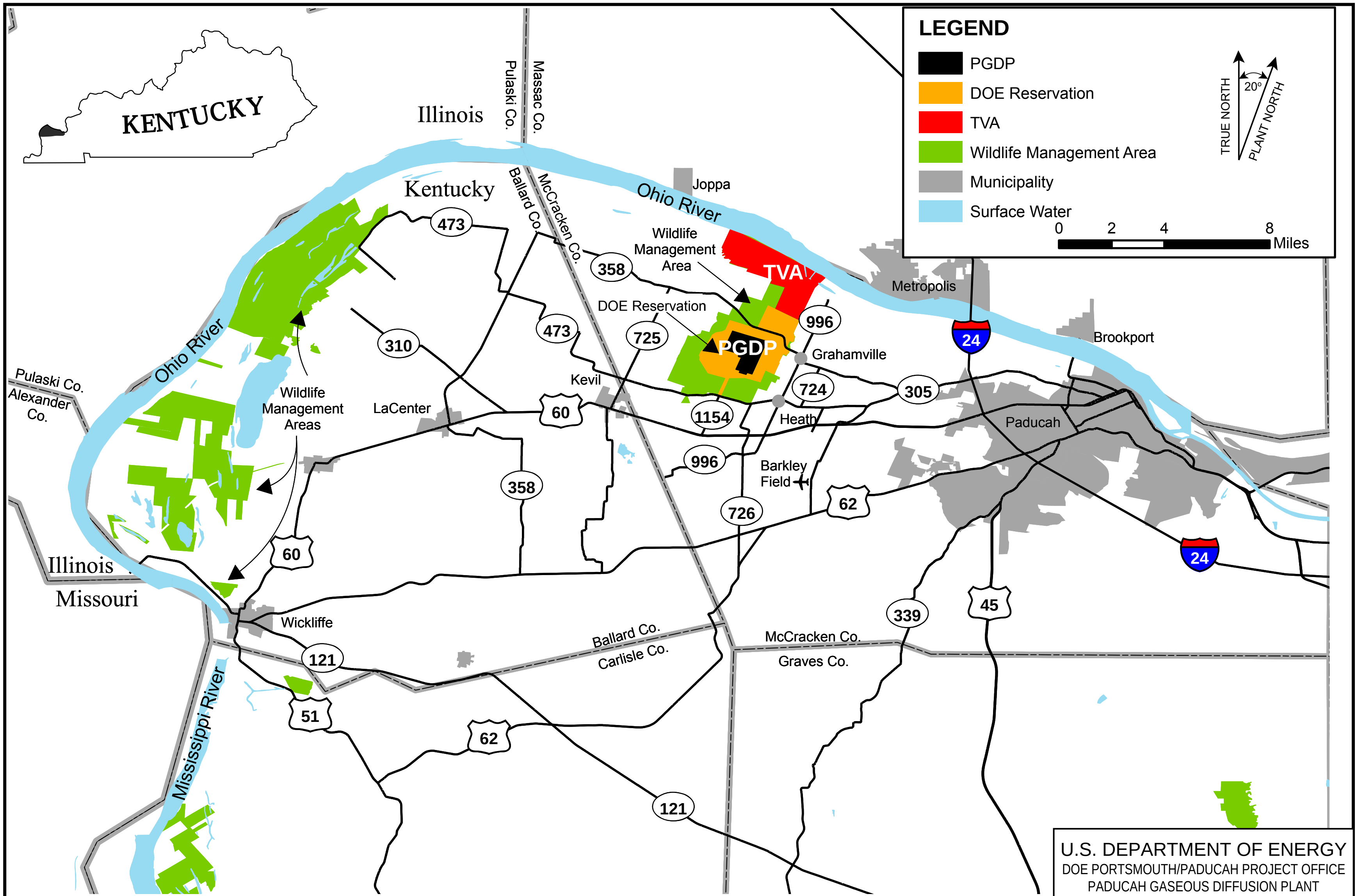

Figure 1. PGDP Site Location

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

LATA Environmental Services of Kentucky, LLC

The RA includes the implementation of *in situ* soil mixing with large diameter augers (LDAs) combined with the introduction of hot air and/or steam for thermal volatilization and stripping of VOCs in the soil and groundwater in the target treatment zone. The RA also includes the implementation of interim land use controls (LUCs) consisting of the Excavation/Penetration Permit Program (E/PP) and the posting of warning signs at the source areas.

An RDSI is included in the RA. The RDSI will help further delineate areas of high TCE concentration in the Upper Continental Recharge System (UCRS) soils and in the upper RGA [hydrogeologic unit (HU4)] and allow refinement of the remedial design. Preliminary RDSI characterization data available at the time of preparation of this 60% RDR are discussed in this report. The preliminary data shown should be considered "information only" because it has not yet been evaluated as part of the data verification and assessment process. Final RDSI results will be available prior to completion of, and appropriately included in, the D1 (90%) RDR. Refer to Section 1.3 for more detailed information regarding the RDSI and preliminary data.

This 60% design report provides information regarding the preliminary design of the remediation system, based on unit processes and activities likely to be included in the selected *in situ* source treatment. These processes and activities are likely to include the following:

- Mixing of soil using LDAs
- Heating of soil *in situ* by application of hot air/steam
- Removal of VOCs and steam from heated subsurface zones by vacuum extraction
- Treatment of recovered vapor off-gas via vapor conditioning/treatment systems
- Injection of a zero-valent iron (ZVI) slurry mixture
- Treatment of condensate via localized air stripping and/or granular activated carbon
- Real-time data collection and monitoring

1.1 REGIONAL GEOLOGY AND HYDROGEOLOGY

PGDP is underlain by a sequence of clay, silt, sand, and gravel layers deposited on limestone bedrock. The sediments above the limestone bedrock are grouped into three major stratigraphic units (loess, continental deposits, and McNairy Formation) and three major HUs (the UCRS, the RGA, and the McNairy Flow System).

The upper-most stratigraphic unit consists of fill and a layer of wind-deposited, silty clay, or loess, extending from the surface to a depth of approximately 20 ft below ground surface (bgs). Beneath the loess, the upper continental deposits, a subunit of the continental deposits consisting of discontinuous sand and gravel layers interbedded with silt and clay, extend to an average depth of 55 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the UCRS. The lower continental deposits, also a subunit of the continental deposits, is a highly permeable layer of gravelly sand or chert gravel, typically extending from approximately 55 to 92 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the RGA. Below the continental deposits is the McNairy Formation, a sequence of silts, clays, and fine sands that extends from approximately 92 to 350 ft bgs. These deposits comprise the local hydrostratigraphic unit known as the McNairy Flow System.

The UCRS is subdivided into the HU1, HU2, and HU3 units and consists of the loess (HU1) and the underlying upper continental deposits (HU2 and HU3). The sand and gravel lenses of the HU2 unit are separated from the underlying RGA by a 12- to 18-ft-thick silty or sandy clay interval designated as the HU3 aquitard. The aquitard reduces the vertical flow of groundwater from the sands and gravels of the HU2 unit to the gravels of the RGA. The RGA is the uppermost aquifer in the Southwest Plume source areas and consists of the lower continental deposits stratigraphic unit. Below the RGA is the McNairy Flow System, which corresponds to the McNairy Formation. The uppermost portion of the McNairy Flow System typically is a clay or silty clay, which restricts groundwater flow between the RGA and McNairy Flow System.

The depth of the water table within the UCRS varies considerably across PGDP, but generally is encountered at depths of approximately 40 to 50 ft bgs. Water within the UCRS tends to flow downward to the RGA. Groundwater flow in the RGA generally is to the northwest, although there is evidence for some divergent flow to the east and to the west as part of the Northeast and Southwest Plumes, respectively. Divergent flow is limited primarily to the area of the PGDP site and is influenced mainly by anthropogenic recharge due to loss of water from plant piping systems for raw, sanitary, cooling, and fire water and focused infiltration from engineered runoff controls, such as paved areas, building roofs, lagoons, and ditches.

1.2 TREATMENT SITE LOCATION

The potential Southwest Plume source areas investigated in the SI included the C-747-C Oil Landfarm (Oil Landfarm) (SWMU 1); C-720 Building Area near the northeast and southeast corners of the building [C-720 Northeast Site (SWMU 211A) and C-720 Southeast Site (SWMU 211B)]; and the storm sewer system between the south side of Building C-400 and Outfall 008 (Storm Sewer) (part of SWMU 102) (DOE 2007). As a result of the Southwest Plume SI sampling, the storm sewer subsequently was excluded as a potential VOC source to the Southwest Plume. The location of the SWMU 1 source area (Oil Landfarm) is shown in Figure 2 and is the focus of this RDR.

1.3 REMEDIAL DESIGN SUPPORT INVESTIGATION

The RDSI currently is being conducted to gather supplemental data necessary for the design and implementation of the *in situ* source treatment deep soil mixing remedial action for SWMU 1. Furthermore, this RDSI field effort also will support the collection of contaminant and engineering data to support the Federal Facility Agreement parties' decision regarding selection and implementation of either enhanced *in situ* bioremediation or long-term monitoring at the C-720 SWMUs and the subsequent remedial design. The design and implementation of either enhanced *in situ* bioremediation or long-term monitoring remedial action for the C-720 Building will follow the remedial action at SWMU 1 by an estimated two years.

An RDSI Characterization Plan was developed as part of the remedial design work plan to support the implementation of the selected alternatives for remediation at the Southwest Plume and to resolve data gaps identified through a data quality objectives process (DOE 2010b). Data collected during the RDSI, coupled with data from previous investigations, will allow for a more accurate delineation of high TCE concentrations in the UCRS soils and in the upper RGA (HU4) to better define the size and shape of the overall treatment area for this remedial action. The RDSI consists of 18 primary borings and 4 contingency borings. The contingency borings were incorporated to determine the lateral extent of the source treatment area. Preliminary RDSI results available at the time of preparation of this 60% RDR are included in Table 1 and are based on results received with a 24-hour laboratory turnaround time. A total of 12 boreholes contained an average TCE result that exceeded the soil cleanup level of 73 µg/kg. There were 12 boreholes that exceeded the soil cleanup level at the interval from 57.5–65 ft bgs. There were 19 exceedances of TCE breakdown products among four boreholes, in which the boring average for TCE

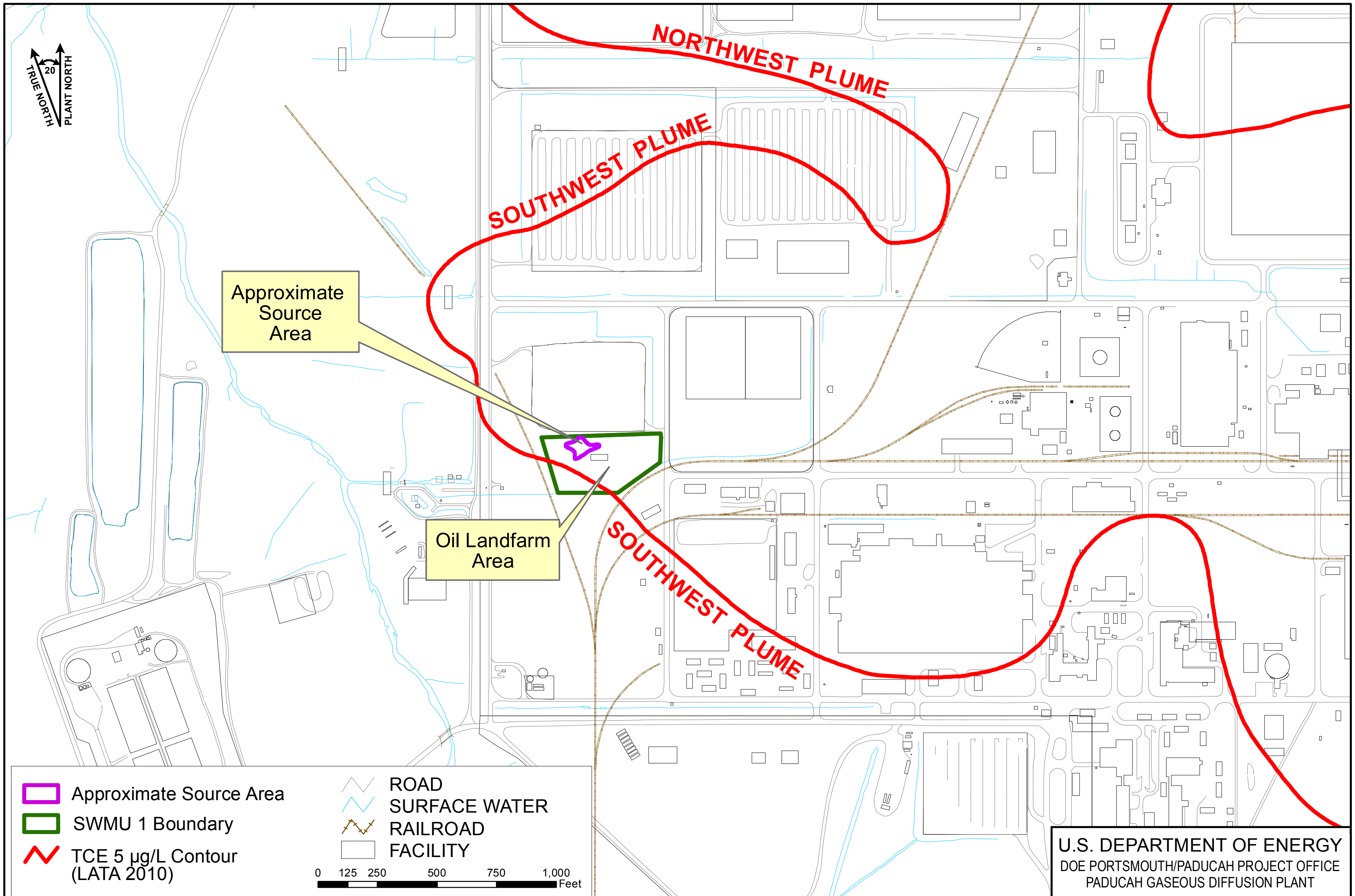

Figure 2. Southwest Plume Source Area Addressed by the Remedial Design

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Table 1. Southwest Plume Preliminary RDSI Characterization Data

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg) Reported	TCE (µg/Kg) Preliminary Average[1,2,3]	cis-1,2-DCE (µg/Kg) Reported	cis-1,2-DCE (µg/Kg) Preliminary Average[1,2,3]	trans-1,2-DCE (µg/Kg) Reported	trans-1,2-DCE (µg/Kg) Preliminary Average[1,2,3]	VC (µg/Kg) Reported	VC (µg/Kg) Preliminary Average[1,2,3]	1,1 DCE (µg/Kg) Reported	1,1 DCE (µg/Kg) Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-311	7/20/2012	5	NA	0	120	120	ND	0.24	ND	0.375	ND	0.17	ND	0.65
		10	8.0	200	290	290	ND	4.3	ND	3.35	ND	11.5	ND	10
		15	13.0	437	1100	1100	ND	4.3	ND	3.35	ND	11.5	ND	10
		20	15.5	399	670	670	ND	3.9	ND	3.05	ND	10.5	ND	9
		25	20.5	56	540	540	ND	3.8	ND	3	ND	10	ND	9
		30	27.0	1,717	5300	5300	360	360	ND	3.4	ND	11.5	ND	10
		35	34.9	19,820	6900	6900	420	420	ND	6.5	ND	11	ND	9.5
		40	35.1	2,650	4600	4600	310	310	ND	3.05	ND	10.5	ND	9
	7/23/2012	45	40.5	9,280	2100	2100	130	130	ND	3.2	ND	11	ND	9.5
		45D[4]	40.5	9,280	1000		78		ND		ND		ND	
		50	47.0	676	1200	1200	31	31	ND	3.05	ND	10.5	ND	9
		55	54.0	899	950	950	42	42	ND	3.45	ND	12	ND	10.5
		60	57.5	982	1300	1300	72	72	ND	3.3	ND	11.5	ND	10
		Prelim. Borehole Average Analytical Value (0-60')				2089		115		3		10		9
001-310	7/23/2012	5	3.5	0	5.8	5.8	ND	0.2505	ND	0.4	ND	0.18	ND	0.7
		10	9.9	1,556	840	840	460	460	ND	3.4	ND	11.5	ND	10
		15	12.0	3,408	7100	7100	2600	2600	ND	3.25	58	58	21	21
		20	16.0	312,000	890000	890000	ND	1300	ND	1050	ND	3500	ND	3050
		25	20.1	2,415	2900	2900	250	250	ND	3.5	ND	12	ND	10.5
	7/24/2012	30	29.5	41,290	380000	380000	ND	200	ND	155	ND	500	ND	460
		35	31.5	8,271	20000	20000	810	810	ND	23.5	ND	45.5	ND	40
		40	37.0	29,230	23000	23000	1300	1300	ND	33.5	ND	115	ND	100
		45	44.5	28,180	33000	33000	1500	1500	ND	18	ND	60	ND	55
		50	47.5	21,170	37000	37000	1300	1300	ND	17	ND	55	ND	50
		55	50.1	24,140	37000	37000	1500	1500	ND	17	ND	55	ND	50
		60	55.1	36,120	2400	2400	ND	4.85	ND	3.75	ND	13	ND	11
		Prelim. Borehole Average Analytical Value (0-60')				119437		935		111		369		322

BACK

TABLE OF CONTENTS

FORWARD

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-309	7/24/2012	5	4.0	0	19	19	ND	0.25	ND	0.395	ND	0.18	ND	0.7
		10	7.5	0	28	28	11	11	ND	0.38	ND	0.175	ND	0.65
		15	12.5	0	16	16	4.9	4.9	ND	0.18	ND	0.175	ND	0.65
		15D[4]	17.0	0	14		4.7		ND		ND		ND	
		20	17.0	28,100	2.6	2.6	0.6	0.6	ND	0.47	ND	0.215	ND	0.8
		25	22.5	2,402	3600	3600	1700	1700	ND	3.3	ND	11	ND	10
	7/25/2012	30	25.1	161	3800	3800	1700	1700	ND	3.35	ND	11.5	ND	10
		35	31.5	2,407	3700	3700	1300	1300	ND	3.25	ND	11	ND	10
		40	35.1	1,452	2600	2600	820	820	ND	3.05	ND	10.5	ND	9
		45	40.5	6,070	2100	2100	950	950	ND	3.15	ND	10.5	ND	9.5
		50	45.5	1,670	2500	2500	860	860	ND	3.15	ND	11	ND	9.5
		55	52.5	1,838	2500	2500	440	440	ND	3.3	ND	11	ND	10
		60	59.5	4,340	2000	2000	670	670	ND	3.4	ND	11.5	ND	10
		Prelim. Borehole Average Analytical Value (0-60')				1905		705		2		7		7
001-304	7/26/2012	5	3.5	0	ND	0.18	ND	0.275	ND	0.43	ND	0.195	ND	0.75
		10	9.5	292	0.52	0.52	30	30	ND	0.38	3.2	3.2	ND	0.65
		15	14.9	9,209	1900	1900	360	360	ND	3.7	ND	12.5	ND	11
		20	15.1	1,508	2300	2300	350	350	ND	0.41	9.4	9.4	2.7	2.7
		25	21.0	473	3.7	3.7	3	3	ND	0.37	ND	0.17	ND	0.65
		30	26.5	0	62	62	53	53	ND	0.355	3.7	3.7	ND	0.6
		35	30.5	527	50	50	44	44	ND	0.365	2.3	2.3	ND	0.65
		35D[4]	30.5	527	51		47		ND		2.3		ND	
		40	36.5	22	210	210	110	110	ND	0.36	ND	11	ND	9.5
		45	42.5	0	ND		ND	3.95	ND	3.1	ND	10.5	ND	9
		50	46.5	611	390	390	170	170	ND	4	ND	13.5	ND	12
		55	50.1	1,250	680	680	280	280	ND	3.4	ND	11.5	ND	10
		60	55.1	246	680	680	260	260	ND	3.7	ND	12.5	ND	11
		Prelim. Borehole Average Analytical Value (0-60')				571		139		2		8		6

BACK

TABLE OF CONTENTS

FORWARD

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-312	7/26/2012	5	3.5	0	ND	0.205	ND	0.31	ND	0.49	ND	0.225	ND	0.85
		10	9.5	0	ND	0.165	ND	0.25	ND	0.395	ND	0.18	ND	0.65
		15	12.5	0	0.78	0.78	ND	0.255	ND	0.4	ND	0.185	ND	0.7
		20	17.0	0	5.6	5.6	0.79	0.79	ND	0.4	ND	0.185	ND	0.7
		25	21.5	0	ND	0.19	ND	0.29	ND	0.455	ND	0.41	ND	0.8
		30	26.5	0	9.4	9.4	1.8	1.8	ND	0.365	ND	0.165	ND	0.65
		35	31.5	0	67	67	12	12	ND	0.38	ND	0.175	3.7	3.7
		40	39.0	0	80	80	14	14	ND	0.395	ND	0.18	4.7	4.7
		45	43.0	0	32	32	6.4	6.4	ND	0.415	ND	0.19	1.9	1.9
		50	49.9	0	4.5	4.5	1	1	ND	0.36	ND	0.165	ND	0.6
		55	54.5	0	58	58	11	11	ND	0.37	ND	0.17	3.2	3.2
		60	55.5	0	56	56	10	10	ND	0.38	ND	0.175	2.7	2.7
		Prelim. Borehole Average Analytical Value (0-60')				26		5		0.4		0.2		2
001-315	7/27/2012	5	4.0	0	ND	0.195	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		10	7.5	0	ND	0.175	ND	0.265	ND	0.415	ND	0.19	ND	0.7
		15	14.5	0	1.9	1.9	ND	0.255	ND	0.385	ND	0.175	ND	0.65
		20	16.5	0	11	11	0.66	0.66	ND	0.35	ND	0.16	ND	0.6
		20D[4]	16.5	0	11		0.69		ND		ND		ND	
		25	23.0	92	4100	4100	260	260	ND	3.4	ND	11.5	ND	10
		30	25.1	1,978	3400	3400	220	220	ND	0.325	ND	11	ND	10
		35	33.5	15,018	3500	3500	300	300	ND	3.5	ND	12	ND	10.5
		40	35.5	9,630	2100	2100	200	200	ND	3.15	ND	10.5	ND	9.5
		45	40.1	15,100	4200	4200	370	370	ND	3.45	ND	12	ND	10.5
		50	45.1	4,920	4000	4000	360	360	ND	3.4	ND	11.5	ND	10
		55	50.1	10,700	2800	2800	250	250	ND	4.05	ND	13.5	ND	12
		60	59.5	4,708	400	400	ND	4.8	ND	3.75	ND	12.5	ND	11
		65	62.5	3,487	2500	2500	120	120	ND	4.05	ND	14	ND	12
		Prelim. Borehole Average Analytical Value (0-60')				2078		160		2		8		8

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-318	7/30/2012	5	3.0	0	ND	0.195	ND	0.3	ND	0.47	ND	0.225	ND	0.8
		10	9.0	0	ND	0.195	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		15	13.0	0	ND	0.195	ND	0.3	ND	0.47	ND	0.415	ND	0.8
		20	19.0	0	ND	0.195	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		20D[4]	19.0	0	ND		ND		ND		ND		ND	
		25	20.5	553	0.55	0.55	0.66	0.66	ND	0.47	ND	0.215	ND	0.8
		30	29.0	0	110	110	67	67	ND	0.47	ND	0.215	3.3	3.3
		35	34.0	24	170	170	160	160	ND	3.4	ND	11.5	ND	10
		40[6]	35.5	58	170	170	160	160	ND	3.4	ND	11.5	ND	10
		45	41.0	4	110	110	64	64	ND	0.47	0.94	0.94	5.5	5.5
		50	46.0	16	29	29	8.2	8.2	ND	0.47	ND	0.215	2.3	2.3
		55	50.5	0	7.4	7.4	1.8	1.8	ND	0.47	ND	0.215	ND	0.8
		60	56.5	0	24	24	24	24	ND	0.47	ND	0.215	ND	0.8
		Prelim. Borehole Average Analytical Value (0-60')				52		41		1		2		3
001-317	7/30/2012	5	3.7	0	ND	0.195	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		10	8.5	0	4.5	4.5	2.3	2.3	ND	0.47	ND	0.215	ND	0.8
		15	12.0	0	7.9	7.9	6.2	6.2	ND	0.47	ND	0.215	ND	0.8
		20	15.5	0	9	9	11	11	ND	0.47	ND	0.215	ND	0.8
		25	21.0	2,176	11	11	27	27	ND	0.47	ND	0.215	ND	0.8
		30	29.9	506	190	190	350	350	ND	0.47	10	10	3.4	3.4
		35	30.5	895	140	140	250	250	ND	0.47	7	7	2.7	2.7
		40	38.5	2,607	3.5	3.5	2.4	2.4	ND	0.47	ND	0.215	2.7	2.7
		45	40.5	450	92	92	100	100	ND	0.47	ND	0.215	4.3	4.3
		50	47.0	4,926	87	87	37	37	ND	0.47	ND	0.215	5.1	5.1
		55	50.1	328	ND	0.195	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		60	56.0	0	29	29	8.1	8.1	ND	0.47	ND	0.215	ND	0.8
		Prelim. Borehole Average Analytical Value (0-60')				48		66		0.5		2		2

BACK

TABLE OF CONTENTS

FORWARD

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-316	7/31/2012	5	4.9	1,196	ND	0.165	ND	0.255	ND	0.4	ND	0.185	ND	0.7
		10	6.0	4,003	ND	0.165	ND	0.25	ND	0.395	ND	0.18	ND	0.65
		10D[4]	6.0	4,003	ND		ND		ND		ND		ND	
		15	10.1	6,571	ND	0.155	ND	0.255	ND	0.4	ND	0.85	ND	0.7
		20	17.0	0	ND	0.155	4.8	4.8	ND	0.37	1.3	1.3	ND	0.65
		25	23.0	9,091	320	320	430	430	ND	3.85	ND	13	ND	11.5
		30	29.9	6,875	2400	2400	1200	1200	ND	3.3	ND	11.5	ND	10
		35	31.5	4,443	2900	2900	1300	1300	ND	3.5	ND	12	ND	10.5
		40	35.5	8,915	1500	1500	410	410	ND	3.3	ND	11	ND	10
		45	41.0	2,242	12	12	3.6	3.6	ND	0.41	ND	0.185	ND	0.7
		50	46.5	14	52	52	7.7	7.7	ND	0.415	ND	0.19	2.1	2.1
		55	54.0	0	6	6	0.59	0.59	ND	0.39	ND	0.18	ND	0.65
		60	57.0	0	14	14	1.4	1.4	ND	0.415	ND	0.19	ND	0.7
		Prelim. Borehole Average Analytical Value (0-60')				600		280		1		4		4
001-314	7/31/2012	5	3.0	0	ND	0.175	ND	0.27	ND	0.42	ND	0.19	ND	0.7
		10	7.0	0	1.3	1.3	ND	0.265	ND	0.41	ND	0.19	ND	0.7
		15	14.0	0	1.8	1.8	ND	0.245	ND	0.38	ND	0.175	ND	0.65
		20	19.0	0	ND	0.18	ND	0.275	ND	0.435	ND	0.2	ND	0.75
		25	21.5	0	13	13	8.4	8.4	ND	0.375	ND	0.17	ND	0.65
		30	28.5	5,709	ND	0.75	81	81	ND	3.55	ND	12	ND	10.5
		35	32.0	695	220	220	120	120	ND	3.2	ND	11	ND	9.5
		40	36.5	511	240	240	ND	4.3	ND	3.35	ND	11.5	ND	10
		45	44.0	883	790	790	540	540	ND	3.45	ND	11.5	ND	10
		50	49.0	732	850	850	570	570	ND	3.5	ND	12	ND	10.5
		55	50.1	2,451	440	440	230	230	ND	3.35	ND	11.5	ND	10
		60	57.5	1,846	180	180	ND	4.4	ND	3.4	ND	11.5	ND	10
		65	60.5	137	350	350	170	170	ND	3.45	ND	11.5	ND	10.5
		Prelim. Borehole Average Analytical Value (0-60')				237		133		2		7		6

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-307	8/1/2012	5	4.5	0	ND	0.155	ND	0.24	ND	0.375	ND	0.17	ND	0.65
		10	8.0	0	ND	0.16	ND	0.245	ND	0.385	ND	0.175	ND	0.65
		10D[4]	8.0	0	ND		ND		ND		ND		ND	
		15	12.5	0	ND	0.17	ND	0.26	ND	0.41	ND	0.19	ND	0.7
		20	18.0	0	ND	0.16	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		25	23.5	0	ND	0.16	ND	0.24	ND	0.38	ND	0.175	ND	0.65
		30	26.0	0	0.98	0.98	1.8	1.8	ND	0.395	ND	0.18	8.4	8.4
		35	33.0	0	0.83	0.83	1.4	1.4	ND	0.395	ND	0.18	1.9	1.9
		40	37.0	0	ND	0.175	ND	0.275	ND	0.435	ND	0.195	ND	0.75
		45	43.0	0	7.2	7.2	3	3	ND	0.37	ND	0.17	2.1	2.1
		50	48.5	0	5.8	5.8	4.2	4.2	ND	0.39	ND	0.175	2.7	2.7
		55	52.5	0	7.1	7.1	4.4	4.4	ND	0.38	ND	0.175	3.5	3.5
		60	57.5	0	7.2	7.2	4.1	4.1	ND	0.385	ND	0.175	2.9	2.9
		Prelim. Borehole Average Analytical Value (0-60')				3		2		0.4		0.2		2
001-308	8/1/2012	5	4.9	0	ND	0.165	ND	0.155	ND	0.4	ND	0.185	ND	0.7
		10	9.0	0	2.3	2.3	ND	0.26	ND	0.41	ND	0.185	ND	0.7
		15	12.5	0	2.4	2.4	ND	0.24	ND	0.38	ND	0.175	ND	0.65
		20	16.0	0	5.1	5.1	1	1	ND	0.34	ND	0.155	ND	0.6
		20D[4]	16.0	0	2.2		ND		ND		ND		ND	
		25	23.5	0	38	38	15	15	ND	0.34	ND	0.18	ND	0.65
		30	29.5	659	270	270	66	66	ND	3.4	ND	11.5	ND	10
		35	34.0	5,998	0.66	0.66	ND	0.245	ND	0.385	ND	0.175	ND	0.65
		40	37.0	1,192	ND	0.4	ND	0.31	ND	0.485	ND	0.22	ND	0.85
		45	44.9	69	410	410	120	120	ND	3.55	ND	12	ND	10.5
		50	48.5	0	190	190	49	49	ND	3.35	ND	11.5	ND	10
		55	54.9	150	210	210	58	58	ND	3.2	ND	11	ND	9.5
		60	58.5	500	180	180	38	38	ND	0.4	ND	0.18	ND	4.25
		Prelim. Borehole Average Analytical Value (0-60')				109		29		1		4		4

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					**73**		**600**		**1080**		**34**		**130**	
001-303	8/2/2012	5	4.0	0	ND	0.165	ND	0.255	ND	0.395	ND	0.18	ND	0.7
		10	9.0	0	4.3	4.3	ND	0.25	ND	0.39	ND	0.175	ND	0.65
		15	14.5	0	15	15	6.5	6.5	ND	0.365	ND	0.165	ND	0.6
		20	19.5	0	0.38	0.38	ND	0.255	ND	0.4	ND	0.18	ND	0.7
		25	21.0	0	ND	0.16	ND	0.295	ND	0.385	ND	0.175	ND	0.65
		30	27.5	0	2.5	2.5	1.3	1.3	ND	0.39	ND	0.18	ND	0.65
		35	34.5	12	0.36	0.36	0.93	0.93	ND	0.42	ND	0.19	ND	0.7
		40	39.9	281	290	290	180	180	ND	3.45	ND	12	ND	0.7
		45	43.5	2,016	290	290	190	190	ND	3.45	ND	12	ND	10.5
		50	49.5	530	430	430	240	240	ND	3.4	ND	11.5	ND	10
		55	50.1	5,530	25	25	20	20	ND	0.405	ND	0.185	ND	0.7
		60	58.5	8,551	680	680	320	320	ND	0.395	13	13	6.6	6.6
		Prelim. Borehole Average Analytical Value (0-60')				145		80		1		4		3
001-305	8/2/2012	5	4.5	0	2.9	2.9	ND	0.265	ND	0.425	ND	0.19	ND	0.7
		10	8.5	0	29	29	ND	0.24	ND	0.375	ND	0.175	ND	0.65
		15	14.0	0	45	45	2	2	ND	0.365	ND	0.175	ND	0.65
		20	18.5	0	13	13	5.6	5.6	ND	0.365	ND	0.165	ND	0.65
		25	24.5	0	530	530	ND	4.45	ND	3.45	ND	12	ND	10.5
		30	25.1	246	130	130	ND	4.6	ND	3.6	ND	12	ND	10.5
		35	30.5	1,826	330	30	ND	4.2	ND	3.3	ND	11	ND	10
		40	39.9	870	1500	1500	ND	4.15	ND	3.25	ND	11	ND	9.5
		45	43.5	2,344	390	390	ND	4.3	ND	3.35	ND	11.5	ND	10
		50	45.5	28,514	3.5	3.5	ND	0.25	ND	0.395	ND	0.18	ND	0.7
		55	53.0	2,330	11	11	ND	0.26	ND	0.41	ND	0.19	ND	0.7
		60	55.1	224	160	160	3.5	3.5	ND	0.41	ND	0.19	ND	0.7
		Prelim. Borehole Average Analytical Value (0-60')				237		3		2		5		5

BACK
TABLE OF CONTENTS
FORWARD

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-306	8/3/2012	5	3.5	0	ND	0.155	ND	0.24	ND	0.375	ND	0.17	ND	0.65
		5D[4]	3.5	0	ND		ND		ND		ND		ND	
		10	8.0	0	ND	0.165	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		15	13.5	0	ND	0.155	ND	0.24	ND	0.375	ND	0.17	ND	0.65
		20	17.0	0	ND	0.16	ND	0.245	ND	0.38	ND	0.175	ND	0.65
		25	22.0	45	1.1	1.1	ND	0.23	ND	0.355	ND	0.165	ND	0.6
		30	25.1	1	30	30	1.5	1.5	ND	0.38	ND	0.175	ND	0.65
		35	32.0	0	27	27	1.5	1.5	ND	0.405	ND	0.185	ND	0.7
		40	39.0	50	58	58	3.8	3.8	ND	0.385	ND	0.175	ND	0.65
		45	40.5	0	75	75	5.1	5.1	ND	0.365	ND	0.165	ND	0.65
		50	49.5	0	64	64	ND	4.35	ND	3.4	ND	11.5	ND	10
		55	53.0	1,215	37	37	3.1	3.1	ND	0.385	ND	0.175	ND	0.65
		60	56.0	39	110	110	7.9	7.9	ND	0.39	ND	0.18	ND	0.65
		Prelim. Borehole Average Analytical Value (0-60')				34		2		1		1		1
001-313	8/6/2012	5	3.5	227	21	21	ND	0.28	ND	0.44	ND	0.2	ND	0.75
		10	7.5	599	83	83	1.4	1.4	ND	0.385	ND	0.175	ND	0.65
		15	10.5	1,419	46	46	3.1	3.1	ND	0.385	ND	0.175	ND	0.65
		20	19.5	22,230	150	150	7.3	7.3	ND	0.38	ND	0.175	ND	0.65
		25	21.5	54,270	ND	7	ND	4.45	ND	3.3	ND	11.5	ND	10
		25D[4]	21.5	54,270	120		14		ND		ND		ND	
		30	28.0	31,310	12000	12000	950	950	ND	6.5	ND	22.5	ND	19.5
		35	33.5	58,714	15000	15000	1000	1000	ND	17	ND	60	ND	50
		40	35.1	70,550	12000	12000	770	770	ND	7	ND	23	ND	20.5
		45	40.1	17,730	900	900	ND	4.3	ND	3.35	ND	11.5	ND	10
		50	45.5	5,745	220	220	ND	4.25	ND	3.3	ND	11.5	ND	10
		55	52.0	4,187	ND	7.5	ND	4.3	ND	3.35	nd	11.5	ND	10
		60	55.1	2,749	12	12	ND	0.26	ND	0.405	ND	0.185	ND	0.7
		62.5	60.5	2796	640	640	ND	4.25	ND	3.3	ND	11	ND	10
		Prelim. Borehole Average Analytical Value (0-60')				3161		212		4		13		11

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg) Reported	TCE (µg/Kg) Preliminary Average[1,2,3]	cis-1,2-DCE (µg/Kg) Reported	cis-1,2-DCE (µg/Kg) Preliminary Average[1,2,3]	trans-1,2-DCE (µg/Kg) Reported	trans-1,2-DCE (µg/Kg) Preliminary Average[1,2,3]	VC (µg/Kg) Reported	VC (µg/Kg) Preliminary Average[1,2,3]	1,1 DCE (µg/Kg) Reported	1,1 DCE (µg/Kg) Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-319[4]	8/6/2012	5	4.5	0	ND	0.18	ND	0.28	ND	0.44	ND	0.2	ND	0.75
		10	9	0	ND	0.165	ND	0.255	ND	0.405	ND	0.185	ND	0.7
		15	11	0	0.98	0.98	ND	0.26	ND	0.41	ND	0.185	ND	0.7
		20	17.5	0	42	42	7.9	7.9	ND	0.405	ND	0.185	ND	0.7
		25	23	0	2.3	2.3	ND	0.24	ND	0.345	ND	0.17	ND	0.65
		30	29	0	1.7	1.7	ND	0.26	ND	0.41	ND	0.19	ND	0.7
		30D[4]	29	0	1.6		ND		ND		ND		ND	
		35	32	0	2.3	2.3	ND	0.23	ND	0.365	ND	0.165	ND	0.6
		40	39	0	45	45	1.2	1.2	ND	0.5	ND	0.24	ND	0.9
		45	44.5	0	3.2	3.2	ND	0.23	ND	0.365	ND	0.165	ND	0.6
	8/7/2012	50	49.5	115	21	21	0.92	0.92	ND	0.365	ND	0.165	ND	0.6
		55	53.5	1,712	110	110	7.9	7.9	ND	0.415	ND	0.19	ND	0.7
		60	59.0	1,373	9.2	9.2	0.83	0.83	ND	0.39	ND	0.18	ND	0.65
		65	64.1	593	5.2	5.2	0.47	0.47	ND	0.355	ND	0.165	ND	0.6
		Prelim. Borehole Average Analytical Value (0-60')				19		2		0		0		1
001-320[4]	8/7/2012	5	4.0	0	ND	0.16	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		10	6.5	43	ND	0.155	ND	0.2	ND	0.37	ND	0.17	ND	0.65
		15	14.9	1,175	160	160	8.2	8.2	ND	0.365	ND	0.175	ND	0.65
		20	17	1,074	5.9	5.9	ND	0.235	ND	0.365	ND	0.165	ND	0.65
		25	23	198	110	110	5	5	ND	0.4	ND	0.185	ND	0.7
		30	28	5,007	610	610	42	42	ND	3.3	ND	11.5	ND	10
		35	32	2,548	950	950	70	70	ND	3.35	ND	11.5	ND	10
		40	38.5	2,275	910	910	63	63	ND	3.45	ND	11.5	ND	10
		45	44	3,601	1200	1200	91	91	ND	3.45	ND	12	ND	10.5
		50	49.5	448	210	210	16	16	ND	3.2	ND	11	ND	9.5
		55	52.0	507	400	400	27	27	ND	3.4	ND	11.5	ND	10
		60	56.5	937	1.2	1.2	ND	0.3	ND	0.47	ND	0.215	ND	0.8
		Prelim. Borehole Average Analytical Value (0-60')				380		27		2		6		5

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
				Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)	**73**		**600**		**1080**		**34**		**130**	
001-321[4]	8/8/2012	5	4.0	335	1.3	1.3	ND	0.24	ND	0.38	ND	0.175	ND	0.65
		10	7.5	16	2.7	2.7	4.3	4.3	ND	0.375	ND	0.17	ND	0.65
		15	13.5	0	2.5	2.5	7	7	ND	0.355	ND	0.165	ND	0.6
		20	17.5	107	ND	0.165	ND	0.25	ND	0.395	ND	0.18	ND	0.7
		25	20.5	23	ND	0.155	ND	0.24	ND	0.375	ND	0.175	ND	0.65
		25D[4]	20.5	23	1.1		1.6		ND		ND		ND	
		30	28.5	3,315	28	28	68	68	ND	0.4	ND	0.185	5.3	5.3
		35	32	312	8.4	8.4	17	17	ND	0.365	ND	0.17	2	2
		40	38	136	ND	0.175	ND	0.27	ND	0.42	ND	0.195	ND	0.7
		45	40.5	113	8.4	8.4	13	13	ND	0.4	ND	0.185	3.8	3.8
		50	49.5	0	8	8	15	15	ND	0.38	ND	0.175	1.9	1.9
		55	54.0	0	15	15	27	27	ND	0.375	ND	0.17	4.4	4.4
		60	59.0	0	14	14	21	21	ND	0.38	ND	0.175	4.1	4.1
		Prelim. Borehole Average Analytical Value (0-60')				7		14		0		0		2
001-322[4]	8/8/2012	5	4.0	63	ND	0.175	ND	0.275	ND	0.425	ND	0.195	ND	0.75
		10	9	0	ND	0.165	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		15	10.1	13	ND	0.155	ND	0.24	ND	0.38	ND	0.175	ND	0.65
		20[7]	NA	NA										
		25	21.5	0	ND	0.17	ND	0.26	ND	0.41	ND	0.19	ND	0.7
		30	29	54	27	27	18	18	ND	0.41	1.2	1.2	ND	0.7
		35	34.9	167	5.2	5.2	3.5	3.5	ND	0.405	ND	0.185	ND	0.7
		40	35.1	261	3.9	3.9	2	2	ND	0.38	ND	0.175	ND	0.65
		45	44.5	4	86	86	42	42	ND	0.365	ND	0.165	ND	0.6
		50	48.5	51	69	69	40	40	ND	0.37	ND	0.17	ND	0.65
		55	54.9	244	44	44	29	29	ND	0.36	ND	0.165	ND	0.6
		60	57.5	129	2.7	2.7	2.6	2.6	ND	0.44	ND	0.2	ND	0.75
		Prelim. Borehole Average Analytical Value (0-60')				22		13		0		0		1

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-301	8/9/2012	5	4.0	0	ND	0.16	ND	0.245	ND	0.38	ND	0.175	ND	0.65
		10	5.1	1	ND	0.165	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		15	10.1	10	ND	0.155	ND	0.235	ND	0.37	ND	0.17	ND	0.65
		15D[4]	10.1	10	ND		ND		ND		ND		ND	
		20	17	0	ND	0.185	ND	0.285	ND	0.445	ND	0.205	ND	0.75
		25	20.5	0	ND	0.165	ND	0.25	ND	0.39	ND	0.18	ND	0.65
		30	25.1	71	6.9	6.9	4.3	4.3	ND	0.355	ND	0.165	ND	0.6
		35	31	92	15	15	12	12	ND	0.385	ND	0.175	ND	0.65
		40	35.5	33	25	25	17	17	ND	0.38	ND	0.175	ND	0.65
		45	44	189	57	57	40	40	ND	0.355	ND	0.16	ND	0.6
		50	45.1	328	83	83	58	58	ND	0.36	ND	0.165	ND	0.6
		55	50.1	510	12	12	19	19	ND	0.375	ND	0.17	ND	0.65
		60	57.5	448	27	27	19	19	ND	0.65	ND	0.295	ND	1.1
		Prelim. Borehole Average Analytical Value (0-60')				19		14		0		0		1

Table 1. Southwest Plume Preliminary RDSI Characterization Data (Continued)

Boring ID	Date of Collection	Depth (bgs)	Actual Sample Depth bgs (ft)	PID (ppb)	TCE (µg/Kg)		cis-1,2-DCE (µg/Kg)		trans-1,2-DCE (µg/Kg)		VC (µg/Kg)		1,1 DCE (µg/Kg)	
					Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]	Reported	Preliminary Average[1,2,3]
Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)					73		600		1080		34		130	
001-302	8/10/2012	5	2.0	0	ND	0.17	ND	0.26	ND	0.405	ND	0.185	ND	0.7
		10	5.5	0	ND	0.155	ND	0.235	ND	0.37	ND	0.17	ND	0.65
		15	11	45	ND	0.16	ND	0.24	ND	0.38	ND	0.175	ND	0.65
		20	18	0	ND	0.155	ND	0.24	ND	0.375	ND	0.17	ND	0.65
		25	24	0	22	22	13	13	ND	0.39	4.15	4.15	0.95	0.95
		30	28.5	1,140	25	25	9.5	9.5	ND	0.415	ND	0.19	ND	0.7
		35	31	414	280	280	72	72	ND	6.5	ND	22	ND	19
		40	36.5	35	37	37	14	14	ND	0.455	ND	0.21	3.5	3.5
		45[8]	NA	NA										
		50	47.5	578	21	21	5.3	5.3	ND	0.435	ND	0.2	ND	0.75
		55	53.0	278	200	200	39	39	ND	3.8	ND	13	ND	11.5
		57.5	55.5	493	150	150	27	27	ND	0.45	ND	0.205	2.8	2.8
		Prelim. Borehole Average Analytical Value (0-60')				67		16		1		4		4

Notes:

1 For analytical results reported as non-detect (ND), a value equal to one half of the method detection levels (MDLs) was used to calculate the preliminary average borehole soil VOC values.

2 Final average borehole values will be calculated using the sample quantitation limit (SQL). SQLs will be provided from the contract lab as part of the final data package.

3 Decision Rule 1: If soil boring averaged concentrations of TCE and TCE degradation products in soil of the UCRS exceed cleanup levels for a given soil boring , then include the location in the treatment area. If the soil boring-averaged soil concentrations do not exceed cleanup levels, then the area need not be included in the treatment area. (Table A.2., Summary of DQO Process for the Southwest Plume Source Areas RDSI, Page A-19, Remedial Design Work Plan for Solid Waste Management Units, 1, 211-A, and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume..., (DOE/LX/07-1268&D2/R2).

4 Denotes duplicate (QA/QC) sample, duplicate samples were not used in the sample VOC averaging calculations.

5 Contingency Boring Locations

6 2 sets of analytical data reported by TA , SMO determined that reported values should be used. TCE Borehole Average changed from 66 µg/Kg to 62 µg/Kg.

7 Reportedly no 15-20 foot sample collected from 001-322.

8 Reportedly no 40-45 foot sample collected from 001-302.

also exceeded limits; therefore, exceedances of TCE breakdown products coincided with the exceedances of TCE, as would be expected.

It is anticipated that the final source area will increase in size based on initial reviews of the preliminary data. Final data from the RDSI will be available prior to completion of the 90% design RDR and will be utilized to refine the specific treatment area and implementation strategy. Collocated sampling results of historical data and RDSI preliminary data are shown in Figure 3. Note that boring locations shown on Figure 3 are based on the original design layout of the source area. Some of these boring locations were adjusted in the field where densely packed soil layers were found to be impenetrable during the time of sampling. This figure will be refined in the 90% RDR when all of the final "as-built" surveyed coordinate locations are available. Preliminary data shown should be considered "information only" because it has not yet been evaluated as part of the data verification and assessment process.

1.4 SEQUENCING WITH OTHER REMEDIES

This remedial action (RA) will be executed in coordination with the Soils Operable Unit (OU) for remediation of polychlorinated biphenyls (PCBs) and other surface soil contaminants, as appropriate. Prior to implementing the deep soil mixing RA, the top 2-ft of the source area surface soil will be removed and stockpiled on the west side of SWMU 1. The excavated soil will be covered and stored until completion of the RA; at that time, the stockpiled soil will be reused as cover material for the disturbed area. These surface soils at the source area will be addressed by the Soils OU at a later date.

2. TREATMENT TECHNOLOGY

This RA will implement *in situ* source treatment using deep soil mixing with interim LUCs. The selected RA technology involves the utilization of LDAs combined with the introduction of hot air/steam for thermal volatilization and stripping of VOCs in soil and groundwater. Granular ZVI in a guar gum solution also will be delivered to the subsurface via LDA injection as a polishing step to provide treatment of residual VOCs within the source area.

A vapor treatment system will be utilized that includes real-time monitoring for data evaluation. Real-time monitoring will assist in controlling the process parameters to maximize VOC removal and support operation of the LDA and injection systems.

A more detailed description of the treatment technology and process is included in Section 4.

3. TREATMENT SYSTEM OBJECTIVES

For the SWMU 1 site, information required to optimize soil mixing effectiveness and attain remediation goals will be obtained during the RDSI. This information will be used during the design phases of the project to determine the specific parameters of the soil mixing application, including hot air/steam generation and delivery, vapor extraction and conditioning, ZVI mixing and delivery, and vapor treatment.

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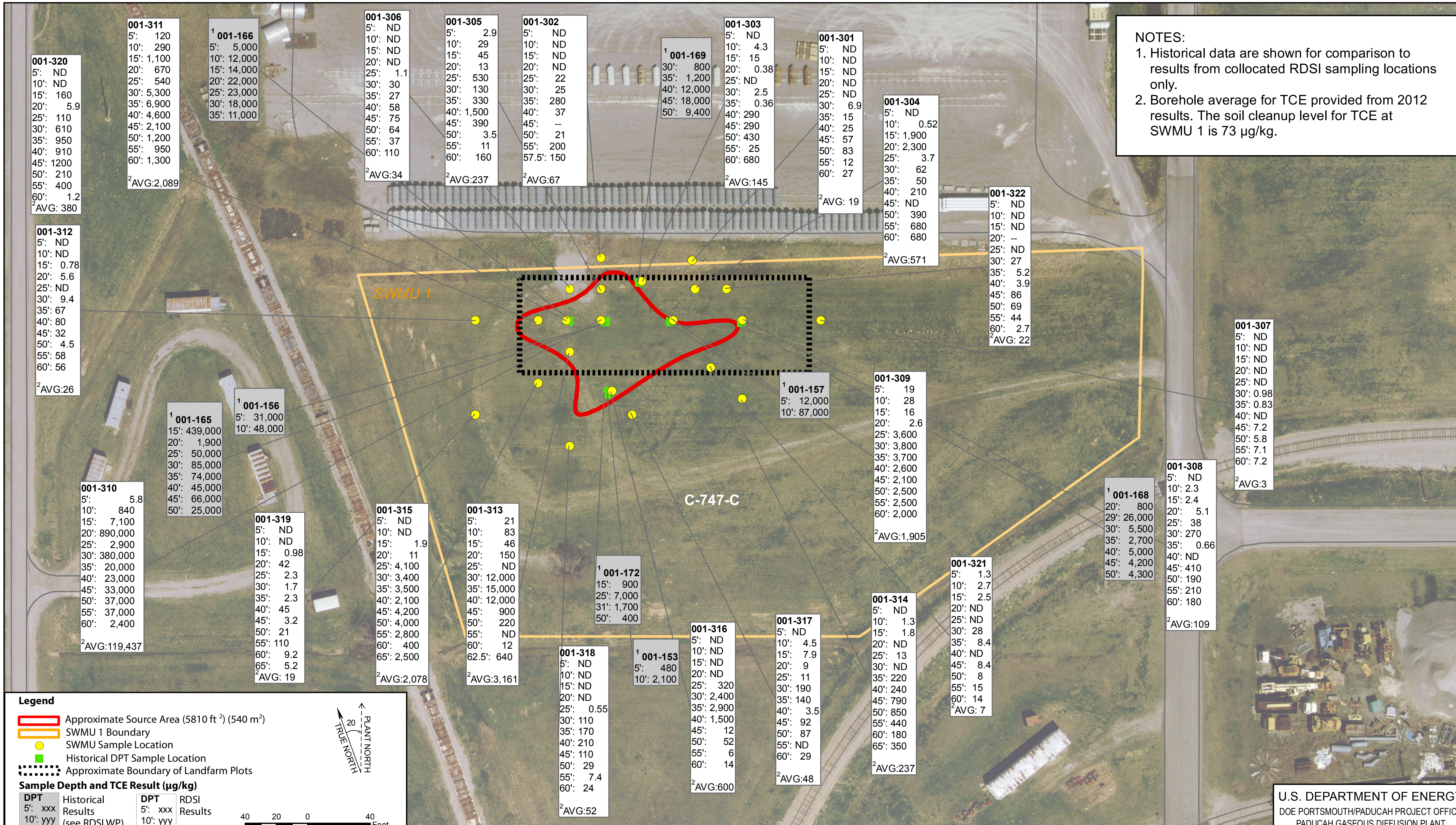

Figure 3. Preliminary RDSI and Collocated Historical Sampling Results

LATA Environmental Services of Kentucky, LLC

8/20/2012 SW Plume\LDA_SWMU1_LocationsR1data_r3.mxd

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3.1 RA OBJECTIVES

The following remedial action objectives (RAOs) are defined in the ROD for the Southwest Plume source areas (DOE 2012a).

(1) Treat and/or remove the principal threat waste consistent with the National Contingency Plan.

(2a) Prevent exposure to VOC contamination in the source areas that will cause an unacceptable risk to excavation workers (< 10 ft).

(2b) Prevent exposure to non-VOC contamination and residual VOC contamination through interim LUCs within the Southwest Plume source areas (i.e., SWMU 1, SWMU 211-A, and SWMU 211-B) pending remedy selection as part of the Soils OU and the Groundwater OU.

(3) Reduce VOC migration from contaminated subsurface soils in the treatment areas at the Oil Landfarm and the C-720 Northeast and Southeast Sites so that contaminants migrating from the treatment areas do not result in the exceedance of maximum contaminant levels in the underlying RGA groundwater.

3.2 OPERATIONAL PARAMETERS

The design will allow for operational parameters to be monitored during the treatment period. Operational parameters to be monitored and evaluated may include, but are not limited to, the following:

- LDA Operational Monitoring for
  - Depth penetration rate
  - Auger rotational rate
  - Torque
  - Down-hole temperature
- Temperature, flow rate, and pressure for
  - Injected steam
  - Compressed/heated air
  - Slurry mixture
- Vapor recovery flow rate, temperature, and pressure
- Extracted VOC concentrations

4. 60% TECHNICAL DESIGN

4.1 TECHNICAL JUSTIFICATION FOR SELECTION OF REMEDIAL TECHNOLOGY

The selected RA technology for the Southwest Plume VOC Oil Landfarm source area involves the utilization of *in situ* soil mixing with LDA combined with the introduction of hot air/steam for thermal volatilization and stripping of VOCs in soil and groundwater; within the target treatment zone.

Additionally, granular ZVI in a guar gum solution will be delivered to the subsurface via LDA injection as a polishing step to provide additional treatment.

Prior to selecting the proposed RA, technology permutations considered included: (1) LDA soil mixing with emulsified ZVI delivery; (2) LDA soil mixing with oxidant delivery; and (3) LDA soil mixing with ZVI and clay delivery. Based upon an evaluation of implementation approaches, the *in situ* LDA soil mixing with hot air/steam and ZVI injection offers (1) the highest anticipated level of mass reduction and potential to achieve objectives; (2) an implementation cost that falls within the range of the other technology permutations considered; and (3) demonstrated effectiveness providing treatment of high levels of VOCs. Unique to the *in situ* LDA soil mixing with hot air/steam and ZVI injection technology, the mixing process and treatment application is adapted real-time based upon the monitoring of off-gas VOC concentrations. Accordingly, the selected RA has flexibility and can be actively adapted during individual borehole mixing to spend additional time, providing enhanced treatment to specific depth intervals and/or boreholes with higher levels of VOCs, as appropriate.

4.2 CRITICAL PARAMETERS

Critical parameters for *in situ* LDA soil mixing with hot air/steam and ZVI injection are those operational parameters of the system and the physical and chemical parameters of the media being treated that have the greatest impact on the ability of the technology to meet the performance goals. These critical parameters are as follows:

Soil and Groundwater Temperature. The temperature of soil and groundwater throughout the treated volume must be raised sufficiently to achieve volatilization of the targeted contaminants. The target soil and groundwater temperature to achieve volatilization of identified VOCs in the treatment zone will be 170°F, which has been demonstrated to achieve volatilization of TCE and daughter products at other sites that have employed this remedial technology (the injected hot air/steam contacting the soil will have a temperature exceeding 200°F). A downhole thermocouple will be used to monitor subsurface temperatures, which will be retrieved on a daily basis. The temperature of gas collection will be measured in the surficial shroud in real time. It has been established, based on experience at other sites, that by adding a correction factor of 10°F to the shroud gas temperature, the resultant is representative of the downhole temperature. Accordingly, a shroud gas temperature of 160°F will be utilized as a real time indicator of adequate subsurface temperature for VOC volatilization.

Percentage of Auger Boring Overlap. The LDA borings will be established based upon an overlap spacing ranging from 0% (no overlap) to 17.5% (representing complete overlap with no interstitial space between treatment cells) overlap. A conceptual depiction of LDA boring spacing in the Oil Landfarm source area based on an assumed 10% overlap is presented in Figure 4. The overlap spacing will be varied depending on the identified concentration of TCE at the boring location as documented in the RDSI results and/or real-time VOC monitoring data within the treatment zone. The LDA boring overlap (which will be specifically set in the 90% RDR) is anticipated to consist of the following overlap scenarios:

- A 17.5% overlap in the area of the treatment zone with "high" trichloroethene (TCE) concentrations (exceeding 10,000 micrograms per kilogram [µg/kg]). The 17.5% overlap will be applied to the group of LDA borings (minimum four locations) adjoining a "high" TCE RDSI concentration.

- A 10% overlap in the area of the treatment zone with "medium" TCE concentrations (100 µg/kg to 10,000 µg/kg).

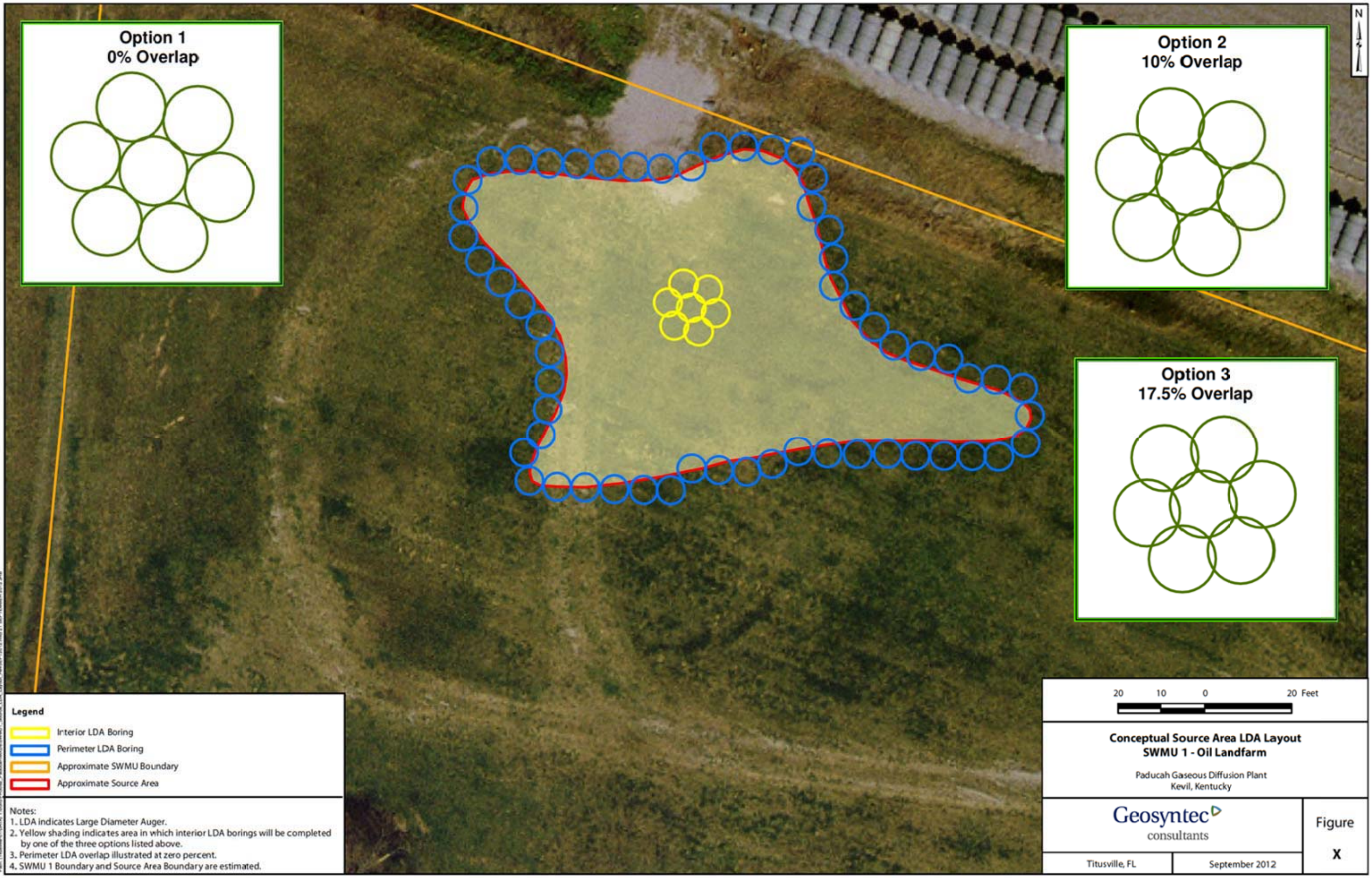

Figure 4. Conceptual Source Area LDA Layout

- A 0% overlap around the perimeter of the treatment zone, contingent upon soil TCE concentrations being "low" (not exceeding 100 µg/kg). If a perimeter location is in an area with soil TCE concentrations exceeding 100 µg/kg, the overlap (10 or 17.5%) will be adjusted based upon the maximum measured concentration.

The 90% RDR will include an updated Figure 4 that will include specific LDA boring locations and associated overlap based upon the final RDSI results, including LDA boring coordinates. Additionally, field adjustments may be made to the overlap spacing based on the real time monitoring data collected during field implementation. As described in Section 4.4.2.1 real-time PID/FID field measurements of shroud collection gases will be employed during LDA steam injection activities based on the first thermal treatment pass. Field adjustments will be made according to the following criteria.

- Results of PID/FID responses that are below the Low VOC concentration target threshold [less than 100 part per million (ppm) response] will warrant a 0% overlap of the LDA boring and four surrounding locations (unless one of the four surrounding locations indicate the need for increased overlap spacing due to PID/FID results).

- Results of PID/FID responses that are greater than the low target on the first treatment pass, but less than the low target treatment threshold on second treatment pass will warrant a 10% overlap of the LDA boring and four surrounding locations (unless one of the four surrounding locations indicate the need for increased overlap spacing due to PID/FID results).

- Results of PID/FID responses that are greater than the low target on the first and second treatment passes will warrant a 17.5% overlap (LDA boring spacing of 17.5% represents a spacing that results in 0% interstitial space between LDA borings) of the LDA boring and four surrounding locations (unless one of the four surrounding locations indicate the need for increased overlap spacing due to PID/FID results).

Soil Properties/Mixing Rate. Soil properties dictate the rate at which the LDA can penetrate the subsurface, appropriate angle of repose for the mixing blade, and considerations regarding the auger blade terminus. In consideration of the soil characteristics and consistency in the Oil Landfarm source area, which includes a hard layer identified in standard penetration test (SPT) borings in the site vicinity, it is anticipated that "rock teeth" will be required on the auger blades. For the *in situ* LDA soil mixing with hot air/steam and ZVI injection technology to be effective, no large boulders and/or large subsurface concrete structures can be present. No anomalies were identified during the RDSI.

VOC Vapor Extraction Rate. The rate of air/vapor extraction from the vadose zone must be greater than the production of contaminant vapors to prevent vaporized contaminants from escaping to the atmosphere or from condensing in the vadose zone. The vapor extraction equipment will be capable of extracting vapors at a flow rate that is twice the maximum flow rate of the hot/air steam injection equipment, and field monitoring will ensure that vapor extraction is occurring at a rate not less than 50% greater than the concurrent hot air/steam injection flow rate.

Concentration of VOCs in Extracted Vapor. The concentration of VOCs in the vapor extraction stream must be monitored in real time and balanced with the aboveground treatment system's ability to treat such concentrations. Gas samples from the process streams will be collected from the vapor extraction system for analysis by a PID/FID and/or a gas chromatograph (GC). If the PID/FID data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or dense nonaqueous-phase liquids (DNAPLs) present in the subsurface, adjustments will be made in the field to compensate by adjusting the ascent/descent rate of soil mixing, recalibration of the PID/FID equipment to a higher calibration standard to facilitate measurement, and/or introduction of additional bleed air to the system to provide for the adequate real-time monitoring of VOCs.

ZVI Dosing Concentration. A slurry mixture consisting of granular ZVI, water and guar gum (to facilitate ZVI injection into the soil) will be delivered based upon a percentage by weight application rate, with the higher weight ZVI slurry delivered to the perimeter ring of mixing locations. Field-based decisions based upon monitoring data collected during hot air/steam mixing phase will be used to adjust the ZVI dosing concentration. The amount of ZVI delivered to an LDA boring location will be established based on the observed PID/FID response value of VOCs from the first thermal treatment pass according to the following criteria:

- If a maximum PID/FID reading of 1,000 ppm or less (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 0.5% ZVI will be applied.

- If a PID/FID reading of 1,000 to 10,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.0% ZVI will be applied.

- If a PID/FID reading exceeding 10,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.5% ZVI will be applied.

The ZVI dosing concentration will be measured as a percentage by weight of the column of soil being treated.

Impact to Surrounding Structures, Utilities, and Operations. It must be possible to implement the treatment technology at the Oil Landfarm source area and to operate it with limited interference to site personnel and other facility operations. No obstructions involving utilities, metal, or concrete were identified during the RDSI.

Contaminants of Concern. The technology is designed specifically for the treatment of VOCs. Unacceptable concentrations of other contaminants previously identified within the SWMU 1 boundaries, such as PCBs, polycyclic aromatic hydrocarbons (PAHs), dioxins, radionuclides, or heavy metals in the shallow soils will not be treated by the technology and will be addressed consistent with the details discussed previously in Section 1.4, Sequencing with Other Remedies. Monitoring of the previous non-target/non-VOC contaminants of concern will be conducted in the collected vapor condensate and the off-gas discharges from the treatment system within a representative subset of the remedial monitoring protocol to establish whether additional condensate treatment measures and/or equipment decontamination procedures will be necessary.

4.3 DESIGN REQUIREMENTS

The general input requirements for the *in situ* LDA soil mixing with hot air/steam and ZVI injection remediation design include the following:

- Site location and general site logistics, including nearby structures and site activity;
- Buried underground utilities and obstructions;
- Shape and depth of the treatment area;
- Site geology;
- Site hydrogeology, including depth to groundwater and groundwater flow rate;
- Soil chemical characteristics, including percentage of organic carbon content;

Table 2. Remediation Goals for the Oil Landfarm Source Area RA

Contaminant of Concern	RG for the Oil Landfarm, mg/kg
TCE	7.30E-02
1,1-DCE	1.30E-01
cis-1,2-DCE	6.00E-01
trans-1,2-DCE	1.08E+00
Vinyl Chloride	3.40E-02

Note: Also see ROD Tables 17 and 18 for the UCRS Soil Cleanup Levels for VOCs (DOE 2012a).

- Contaminant-specific remediation goals, defined in the FFS (DOE 2010a) and listed in Table 2;
- Compliance with applicable or relevant and appropriate requirements (ARARs)(ROD DOE 2012a);
- Absence of low-volatility co-contaminants;
- Desired remediation schedule;
- Options for wastewater disposal; and
- Selection of vapor treatment technology.

4.4 PROCESS DESCRIPTION FOR *IN SITU* LDA SOIL MIXING WITH HOT AIR/STEAM TREATMENT AND ZVI AMENDMENT

In situ LDA soil mixing with hot air/steam and ZVI treatment technology consists of the following major elements: soil mixing, hot air/steam generation and delivery, vapor extraction and conditioning, recovered-liquid storage and disposal, ZVI mixing and delivery, and vapor treatment. The treatment system includes a monitoring system for real-time data evaluation that assists in controlling the process parameters to maximize VOC removal and supports decision making for operation of the LDA and injection systems.

The mixing system will be equipped with an LDA that shears and mixes the soil as the auger is advanced below the ground surface, while concurrently injecting steam and/or hot air. This action causes thermal desorption and volatilization of the VOCs from soil particles, groundwater and interstitial spaces. The steam and hot air raises the temperature of the soil mass, increases the vapor pressure of the contaminants, volatilizes the compounds from the soil particles (through heat and air stripping), and allows them to be transported to the surface via the injected hot air/steam where they are collected in a shroud maintained under vacuum, covering the active treatment area. The shroud provides the ability to capture off-gases beyond the auger blades. The vapors are then transported from the shroud through the vapor conditioning system (VCS) to the VOC treatment system by a blower. VOC removal and treatment will then be enhanced via the placement of ZVI in the mixed soil column and aquifer material to enhance abiotic degradation of residual VOCs.

The VOC treatment system consists of a VCS and vapor treatment system. Vapor collected in the LDA shroud contains air, water, VOCs, and particulates. The VCS removes water and particulates from the vapor before being processed by the vapor treatment system. The VCS consists of a knockout tank, chiller, re-heater/heat exchanger, and particulate filter. The vapor from the VCS will then be processed in the vapor treatment system, which will consist of vapor-phase granular activated carbon (GAC) placed in series to remove VOCs. If review of the final RDSI data indicates that greater than anticipated volumes of vapor-phase GAC are required to achieve off-gas treatment, other treatment system components may be incorporated to replace or supplement the GAC units.

Real-time data monitoring is an integral part of the treatment technology because it facilitates real-time decision making to enhance the efficiency of treatment and maximize the results (i.e., additional mixing hot air/steam injection at specific locations and/or discrete depth intervals based upon real-time monitoring results).

4.4.1 Equipment Summary

The general process flow diagram for the *in situ* LDA soil mixing with hot air/steam and ZVI injection system for the Oil Landfarm source area is provided in Figure 5. General unit processes shown in Figure 5, including LDA soil mixing; hot air/steam generation and delivery; vapor extraction and conditioning; recovered-liquid storage, treatment, and disposal; ZVI mixing and delivery; and vapor treatment are expected to be part of the final design and are described generally in the following sections. A further refined technology-specific process flow diagram, providing additional process detail, will be included in the 90% RDR.

4.4.1.1 Soil mixing equipment

Major equipment and tools that are to be utilized for soil mixing will include a crane, LDA, kelly bar, and drill platform. The soil mixing rig will be comprised of a crawler-mounted lift crane, with a minimum 70-ft long hollow drill stem (kelly bar) driven by a high-torque transmission (capable of producing a range of torque of approximately 100,000 to 450,000 ft-lb of torque) and capable of achieving a design soil mix depth of 60 ft bgs (which will be 62 ft below the original land surface elevation based upon the excavation of the upper 2 ft of soil prior to implementation). Alternate heavy equipment (such as excavator-mounted soil mixing equipment) will be considered as an appropriate alternative to a crane if it is capable of meeting the afore-mentioned range of torque and achieving the required target depth. A swivel assembly attached to the end of the crane boom cables serves as the connection point for the kelly bar, allowing the bar to rotate freely while drilling. In addition, the swivel will serve as the injection point of material into the kelly bar from flexible hosing connecting the hot air/steam and ZVI delivery system to the soil mixing equipment. A multibladed rotating mixing/injection tool (auger) with a minimum diameter of 8 ft will be located at the base of the kelly bar, which is capable of injecting the hot air, steam, and ZVI slurry into the soil to volatilize and treat VOCs. The mixing tool will include an adequate number of injection ports along the blades to achieve effective distribution of hot air/steam and injected ZVI throughout the mixed soil column. In consideration of the documented soil consistency [hard (greater than 100 blows per ft) at the approximate 20 to 25 ft below grade depth interval], it is anticipated that "rock teeth" will be required on the mixing tool to facilitate penetration. A spare mixing tool of similar diameter also will be maintained on-site. The mixing rig will be capable of reaching outward from the toe of the crawler tracks two rows of overlapped column locations. The mixing rig will operate on mats that will provide stability, maintain vertically plumb mixing, and minimize contamination of drill rig tracks. The soil mixing equipment will be capable of achieving an average LDA ascent/descent rate of 1 to 3 ft per minute and an auger rotational rate of 6 to 10 revolutions per minute within the medium soil consistency range documented in the treatment zone.

4.4.1.2 Hot air/steam generation and delivery system

Hot air will be generated by drawing ambient air though air compressors capable of providing an airflow of 750 actual cubic ft per minute (acfm). A filter bank will be utilized in-line to remove entrained oil from the generated air flow. Injection pressure, temperature, and flow will be monitored and controlled during operations. Hot air will be delivered to the subsurface at flow rates ranging from 200 to 400 acfm at a maximum operating pressure of 150 pounds per square inch gauge (psig), with higher flow rates applied to higher observed VOC concentrations based upon field-based PID/FID VOC measurements.

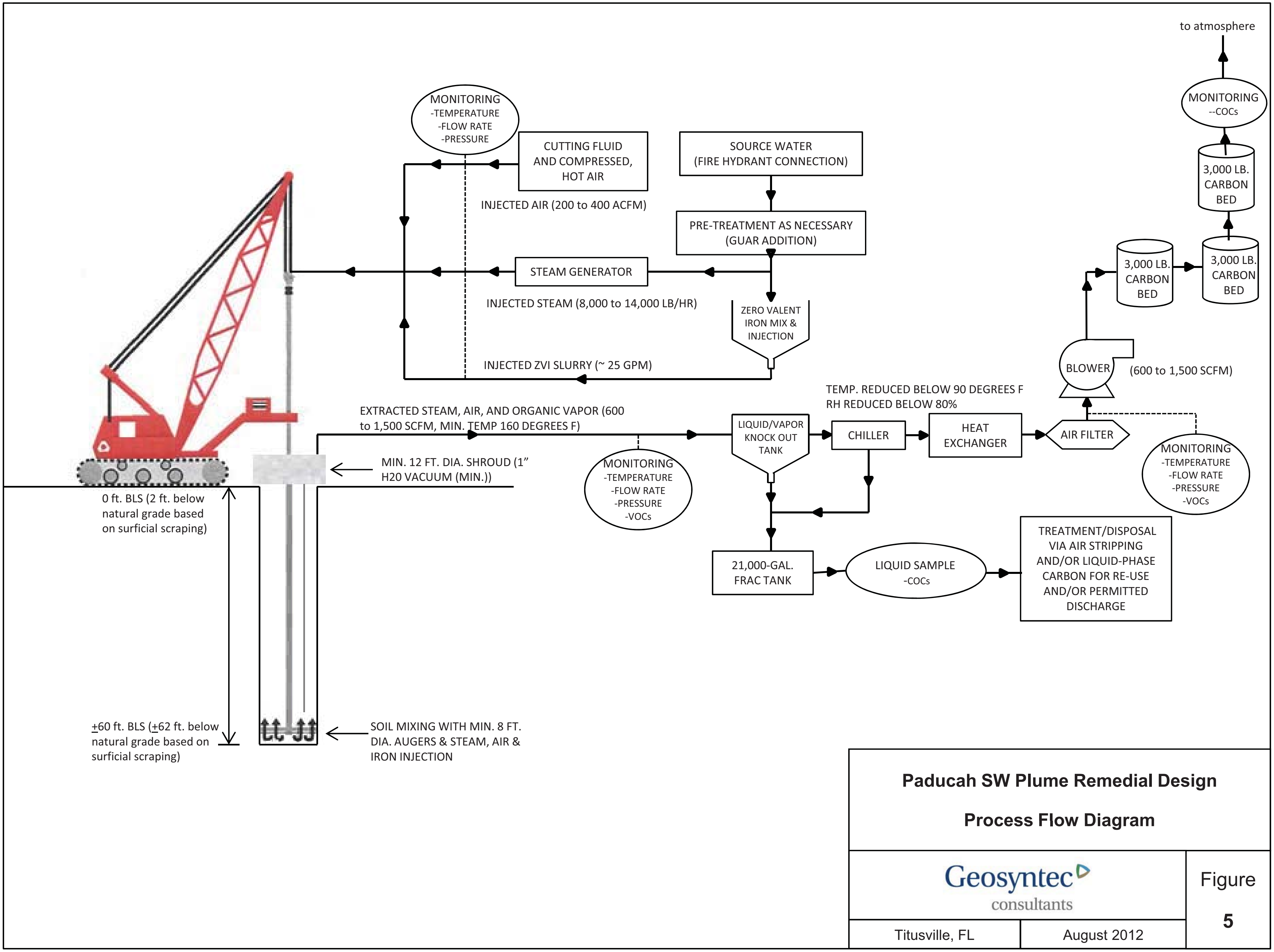

Figure 5. Process Flow Diagram

The steam generating system will be comprised of steam boilers with the capability of producing steam at a minimum temperature of 385°F from a facility-supplied water source. At the maximum operating capacity, the boilers are expected to output a minimum of 10 million British thermal units per hour (MBTU/hr). It is anticipated that a minimum of approximately 10,000 gal of water per day will be converted to steam for injection and steam will be injected at flow rates ranging from 8,000 to 14,000 pounds per hour (pph) at a maximum operating pressure of 135 psig, with higher flow rates applied to higher observed VOC concentrations based upon field-based PID/FID VOC measurements. Braided steel and rubber hose will transfer the steam from the boilers to the manifold and rubber hose will be utilized to connect the manifold to the drill stem (kelly bar). Steam injection flow rate, pressure, and temperature will be monitored and controlled during operations.

4.4.1.3 Off-gas extraction and vapor conditioning system

As the mixing blade rotates and hot air and steam are injected in the soils, VOCs will rise to the surface through the annulus created by the soil mixing process and associated pressure gradient. The contaminants will be collected within a shroud of sufficient diameter to provide capture of VOCs. The shroud will cover the ground surface around the boring location that is penetrated by the rotating kelly bar. The shroud will provide the ability to capture off-gases beyond the diameter of the drilling blades. A blower connected to the shroud will provide a vacuum on the shroud for vapor recovery and transfer to the VCS. The blower connected to the shroud will generate an anticipated air flow rate of 600 to 1,500 standard cubic feet per minute (scfm) at an approximate operating vacuum of 30 inches of water, and an applied shroud vacuum of 1 to 5 inches of water will be established prior to soil mixing and maintained throughout soil mixing activities at each boring location.

The VCS will consist of a liquid-vapor knock-out (KO)/demister tank, air filter, chiller, and reheater/heat exchanger, or equivalent. The vapor entering the shroud from the annulus is expected to be saturated with water; therefore, the vapors initially will flow through a liquid vapor KO tank to remove large dirt particles and moisture. The vapors will then flow from the KO tank into a chiller unit used to cool the gas (typically to a temperature of less than 90°F). Condensate water generated by the KO tank chiller will be transferred and stored in a 21,000-gal fractionation tank to assess constituent of concern concentrations prior to treatment at the C-612 groundwater treatment system or an on-site air stripper and/or liquid GAC prior to discharge to a surface ditch leading to a Kentucky Pollutant Discharge Elimination System outfall (in accordance with ARARs). Additionally (and prior to treatment and discharge), a representative subset of recovered condensate water will be analyzed for non-target/non-VOC contaminants of concern (such as PAHs, PCBs, radionuclides, and heavy metals) to establish whether additional treatment measures and/or equipment decontamination procedures will be necessary. Cooled vapor then will enter a reheater/heat exchanger to raise the off-gas temperature in order to reduce the off-gas relative humidity to less than 80% (thereby increasing the efficiency of the vapor-phase carbon adsorption system). Vapor then will flow through an air filter to remove fine particulates prior to entering vapor-phase GAC treatment systems. The VCS will be monitored and controlled during operations. Data that will be recorded from monitoring instruments on the VCS include pressure drop over the chiller/heat exchange unit, vapor temperature after chiller, and vapor temperature and relative humidity after the reheater.

4.4.1.4 Vapor Treatment System (Vapor-Phase Carbon Adsorption)

Conditioned vapors exiting the VCS will be treated on-site utilizing a minimum of two vapor-phase GAC adsorption vessels connected in series. The GAC vessels will provide a total holding capacity of a minimum of 9,000 lb of virgin, vapor-phase GAC and will be capable of treating an airflow range of 600 to 1,500 scfm. To monitor the GAC for breakthrough, the effluent from each GAC vessel will be monitored daily during active operations using a photo-ionization detector (PID), flame ionization detector (FID), or Draeger-Tubes®. GAC vessel change out, if required, will occur when GAC breakthrough is documented, as indicated by a spike in the measured air exhaust concentration/PID or FID response, compared to previous measurements. When an air exhaust measurement of approximately 50% of the influent measurement is detected, planning will begin for carbon replacement.

Based on a conservative estimate of total VOC contaminant mass in the SWMU 1 area of 1,000 lb, and an assumed carbon adsorptive capacity and usage rate of 20% (20 lbs TCE/100 lbs GAC) for an influent GAC relative humidity of 80%, the total mass of vapor-phase carbon to be utilized for off-gas treatment is estimated to be approximately 5,000 lb (indicating that 9,000 lb or greater of vapor-phase GAC vessels in series provides adequate capacity). For design purposes, it is assumed that 100% mass removal will be extracted in the vapor phase. If review of the final RDSI data indicates that greater than anticipated volumes of vapor-phase GAC are required to achieve off-gas treatment, other treatment system components may be incorporated to replace or supplement the GAC units.

4.4.1.5 ZVI Mixing and Delivery System

A slurry mixture consisting of granular ZVI, water, and guar gum (to facilitate ZVI injection into the soil) will be prepared on-site and delivered on the final pass of the LDA at each boring location. Based upon a review of LDA soil mixing with hot air/steam and ZVI injection applications at Cape Canaveral Air Force Station, Florida, and Offutt Air Force Base, Nebraska, it is anticipated that granular ZVI particle size will range from approximately 50 micron to 300 micron in diameter. To create this slurry mixture, ZVI will be suspended in the slurry at a rate of approximately 5 to 7 lbs of ZVI per gal of water, and guar gum will be mixed at a rate of approximately 60 to 80 lb per 1,000 gal of water. The actual quantity of guar gum and water may be adjusted (within the range provided), during field preparation to create a site-specific mixture, which adequately suspends the ZVI and achieves the optimal pumping viscosity. ZVI preparation and delivery equipment will consist of mixing tanks of a minimum of 500 gal each, a high-shear slurry mixer, a progressive cavity pump and a high viscosity flow meter. It is anticipated that up to approximately 2,000 gal of water per day will be utilized in the preparation of the ZVI/guar slurry.

4.4.1.6 Real-time data collection and monitoring system

The effective application of the *in situ* LDA soil mixing with hot air/steam and ZVI injection system involves real-time data collection and monitoring to allow for field-based decision processes regarding the following:

- Depth penetration rate, auger rotational rate, torque, and down-hole temperature of LDA soil mixing;
- Injection temperature, pressure and flow rate of hot air and steam;
- Temperature, pressure, flow rate, relative humidity and VOC concentrations in the vapor extraction and conditioning systems;
- Injection temperature, pressure and flow rate of the ZVI slurry injection system; and
- VOC concentration of the vapor-phase treatment system effluent.

Operational parameters of the previously mentioned monitoring protocol are discussed throughout applicable portions of Section 4. Gas samples from the process streams will be collected from the vapor extraction system for analysis by a PID/FID and/or a GC. GCs will be used to detect, speciate, and quantify target analytes from the treatment process off-gas. PIDs/FIDs will be used to continuously monitor the vapors produced by the treatment process. If the PID/FID data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or DNAPLs present in the subsurface, adjustments will be made in the field to compensate by adjusting the ascent/descent rate of soil mixing, recalibration of the PID/FID equipment to a higher calibration standard to facilitate measurement, and/or introduction of additional bleed air to the system to provide for the adequate real-time monitoring of VOCs. Data from the PIDs/FIDs and GCs will be utilized to evaluate VOC trends in depth, concentration, and location of contamination mass requiring focused treatment (i.e., additional mixing time, higher application of ZVI slurry mixture within a specific interval, etc.).

4.4.2 Implementation Sequence

The LDA borings will be established based upon an overlap spacing ranging from 0% to 17.5% (representing complete overlap with no interstitial space) overlap. A depiction of LDA boring spacing in the Oil Landfarm source area based on a 10% overlap is presented in Figure 4. The protocol for establishing overlap spacing is discussed in greater detail in Section 4.2 [generally, reduced overlap spacing will be employed around the periphery of the treatment cell (concurrent with lower VOC concentrations), and increased overlap spacing (concurrent with higher VOC concentrations) will be employed internal to the treatment cell]. The sequencing of soil mixing and treatment locations will be conducted such that the perimeter cells are treated first and subsequent locations will move inward in concentric circles, generally targeting lower concentration areas prior to targeting higher concentration areas and creating a perimeter ZVI slurry enhanced ring, which would provide treatment to groundwater displaced outward during implementation.

4.4.2.1 Description of soil mixing and hot air/steam delivery procedure

Soil mixing with hot air/steam delivery will be conducted at each cell location in treatment passes (a pass is considered to be one movement of auger through the entire depth of the cell in one direction, up or down). Data collected from off-gas analysis from the PIDs/FIDs and GCs during the first hot air/steam treatment pass will be monitored to aid in the real-time decision making process and to evaluate results against treatment criteria, completion criteria, and iron dosage quantities.

The hot air/steam treatment pass will be initiated when the auger is drilled from the ground surface to the starting thermal treatment depth for the zone of treatment at a typical descent rate of 1 to 3 ft per minute and 6 to 10 revolutions per minute. Additionally, if warranted based on field conditions, a drilling mud may be utilized as a cutting fluid to assist in auger advancement in the formation. The GCs continuously will process samples at a rate of approximately every 2 to 5 minutes for analysis. The PIDs/FIDs continuously will analyze and process the off-gas total VOC concentration. Once the auger reaches the target starting depth (anticipated to be 5 to 6 ft bgs), the steam valve will be opened, steam will enter the treatment column, and the auger will continue descent to the desired finishing depth, which is anticipated to be 60 ft bgs (62 ft below original land surface because the upper 2 ft will be excavated prior to LDA operations). The protocol for evaluating the number of treatment passes which will be completed at each treatment cell will be based on the peak TCE concentration in UCRS soils and in the upper RGA (HU4) evaluated by the data collection system during the first treatment pass. Once the peak off-gas VOC values are collected from the first treatment pass, the cell treatment protocol will be characterized into one of three categories, which are described as follows.

(1) Low VOC concentration target threshold (less than 100 ppm response)—Requires a minimum of one complete thermal pass; a shroud temperature of 160^{o}F maintained throughout the treatment pass; and monitoring of VOC concentrations to ensure that they are below the established low target threshold.

(2) Greater than the low target on the first treatment pass, but less than the low target treatment threshold on second treatment pass—Requires a minimum of two complete thermal passes; a shroud

temperature of 160^{o}F maintained throughout the complete final pass; and monitoring of VOC concentrations to ensure that they are below the established low target threshold.

(3) Greater than the low target on the first and second treatment passes—Requires a minimum of four complete thermal passes and a shroud temperature of 160^{o}F maintained throughout the entire complete final pass. Depth-focused passes could be implemented after the second pass; however, the final pass must have been completed from total treatment depth to top of target treatment interval, and to obtain completion criteria of an FID concentration less than 80% of the highest peak FID value obtained during the first pass, or VOC concentrations less than low target threshold, or reach a maximum hot air/steam treatment time of 240 minutes.

If residual VOCs remain following the thermal treatment protocol, they will be addressed further through the introduction of the ZVI slurry mixture, which will be concentration weighted based on PID/FID data, as described in Section 4.4.2.2. The Low VOC concentration target threshold value is based upon the field-screening PID response data from the RDSI boring locations generally corresponding to low VOC concentrations in soil (less than 70 µg/kg TCE). Alternatively, an LDA boring may be advanced at a peripheral RDSI boring location where a maximum soil concentration of 70 µg/kg TCE was measured, and the peak off-gas concentration from the test location may be used to set the low VOC concentration target threshold.

4.4.2.2 Description of ZVI Dosing

The actual quantity of guar gum and water will be adjusted during field preparation to adequately suspend the ZVI and achieve optimal pumping viscosity. The amount of ZVI injected at each location will be determined based upon LDA boring location and also by reading the maximum PID/FID and GC concentration in the treatment cell during operation. The peak VOC concentrations will be subdivided into low, medium, and high VOC concentration thresholds, and a ZVI slurry injection target concentration of 0.5%, 1.0%, or 1.5% by wt (i.e., percentage mass of ZVI to mass of soil) will be used according to the following criteria.

- Low VOC concentration threshold—If a maximum PID/FID reading of 1,000 ppm or less (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 0.5% ZVI will be applied.

- Medium VOC concentration threshold—If a PID/FID reading of 1,000 to 10,000 ppm (after subtracting the methane value) is observed on the first or thermal treatment pass, an application of 1.0% ZVI will be applied.

- High VOC concentration threshold—If a PID/FID reading exceeding 10,000 ppm (after subtracting the methane value) is observed on the first or thermal treatment pass, an application of 1.5% ZVI will be applied.

During the LDA ZVI slurry injection pass, the desired quantity of ZVI-guar slurry mixture for each cell will be transferred to the soil mixing auger by a pump. The slurry then will travel down the kelly bar and will be injected into the subsurface at a flow rate of approximately 25 gal per minute (gpm) through the rotating auger to distribute the iron throughout the column. Water will be used to flush the iron-guar slurry from the injection plumbing into the column during the final pass to ensure that the entire quantity of iron required is injected into the column.

5. CONSTRUCTION REQUIREMENTS

5.1 CONSTRUCTION EQUIPMENT

Construction-type equipment will be required to deliver and stage equipment on-site and to perform *in situ* LDA soil mixing with hot air/steam and ZVI soil mixing and treatment activities. These will likely include, but not be limited to, these items.

- Crawler crane or heavy equipment capable of delivering required torque and soil mixing requirements
- Flatbed truck
- Storage units (e.g., Conex boxes/Sealand containers)
- Drill turntable
- Excavator
- Loader
- High reach manlift
- 21,000-gal Frac tank(s) for KO vessel water storage
- Telescopic forklift

The mixing rig will be mobilized to the site with multiple tractor-trailer components. A crane will be required to unload the tractor-trailers and place the component parts of the mixing rig in the site staging area for rig assembly.

5.2 *IN SITU* DEEP SOIL MIXING WITH HOT AIR AND STEAM TREATMENT AND ZVI AMENDMENT SYSTEM EQUIPMENT

Following is a list of typical equipment required for the extraction and treatment systems. Required equipment for the selected *in situ* LDA soil mixing with hot air/steam and ZVI injection may be evaluated further in the 90% RDR.

- Mixer
- Liquid mixing tanks
- Liquid transfer pumps
- Hollow kelly bar (70 ft long) and swivel
- 8-ft auger
- Containment shroud
- Chiller unit
- Process knockout tank
- Heat exchanger
- Blower
- Vapor-phase carbon adsorption vessels
- Boilers/steam generators
- Power generators

5.3 ELECTRICAL REQUIREMENTS

Electrical components needed for the i*n situ* soil mixing and treatment system will require 3-phase power for the operation of air compressor, pumps and blowers, mixing equipment, instrument panels and controls, electronic instruments, and thermocouples, etc. It is anticipated that approximately 750 kilovolt amperes (kVA) will be required to operate the *in situ* LDA soil mixing with hot air/steam and ZVI injection system, which will be obtained through a facility power connection or an on-site generator. Electrical requirements for the selected treatment system will be evaluated further in the 90% RDR.

5.4 WATER REQUIREMENTS

It is anticipated that at least 12,000 gal of water will be utilized by the *in situ* soil mixing and treatment system per day of operation. Water will be utilized for the generation of steam (approximately 10,000 gal per day) and for mixing the ZVI slurry (approximately 2,000 gal per day). Water entering steam boiler units may require conditioning using water softening ion exchange units to prevent scaling of the units. The water supply source and pretreatment requirement will be further evaluated in the 90% RDR.

5.5 SITE PREPARATION

Site preparation also may include the sighting of an operations trailer, site surveying, utility locating, well abandonment, clearing and grubbing, grading, and leveling. Additional activities for site preparations will include, but are not limited to, removing the top 2-ft of surface soil to remove PCBs that may be present and stockpiling the soil in an area on the west end of SWMU 1. These contaminants will not be treated by the technology and will be addressed consistent with the approach discussed previously in Section 1.4, Sequencing with Other Remedies. Plastic sheeting or a material such as Hypalon® will be placed under and over the stockpiled soil until completion of the RA.

5.6 PERMITTING

It is anticipated that site-specific permits may be required for the implementation of the RA utilizing the selected *in situ* soil mixing and treatment system. Applicable site-specific permits may include, but are not limited to, the following:

- Excavation/penetration permits
- Lockout/tagout permits
- Hot work permits

Site permitting requirements for the selected *in situ* soil mixing and treatment system will be evaluated further in the 90% RDR.

6. SAMPLING AND MONITORING

6.1 SAMPLING AND MONITORING DURING SOIL MIXING

During operation, on-site personnel will monitor the soil mixing and treatment system activities to assess the performance and progress of the remedial action. Sampling and monitoring requirements for the selected *in situ* soil mixing with hot air/steam and ZVI injection will be evaluated further in the 90% RDR. Systems will be designed to accommodate operational sampling and real-time monitoring for parameters, such as the following:

- Subsurface temperatures;
- VOC concentrations in recovered vapor;
- VOC concentrations in the worker breathing zone;
- Shroud extraction vacuum, temperature, and flow rate;
- Hot air/steam delivery pressure, temperature and flow rate;
- ZVI injection temperature, pressure, and flow rate;
- Vapor-phase effluent discharge flow rate and VOC concentration;
- VOC concentration in condensed liquids from the vapor stream;
- PCB, PAH, radionuclide, and heavy metals concentration in a subset of condensed liquids from the vapor stream and vapor-phase effluent; and
- Heat exchanger air temperatures and relative humidity.

6.2 SAMPLING AND MONITORING POSTREMEDIAL ACTION

Following the cessation of active remedial operations with *in situ* soil mixing with hot air/steam and ZVI injection, postremedial performance monitoring and sampling will be conducted to evaluate remedial performance against the established objectives. Postremedial sampling and monitoring requirements will be evaluated further in the 90% RDR, but generally will include the following:

- Postremedial sampling of affected equipment for determining equipment decontamination needs;
- Postremedial evaluation of potential equipment waste;
- Postremedial soil and groundwater sampling for VOCs;
- Postremedial soil temperature evaluation; and
- Postremedial evaluation of soil homogeneity and ZVI distribution.

7. DATA MANAGEMENT

A project-specific data management and implementation plan will be included in the remedial action work plan (RAWP).

8. HEALTH AND SAFETY

A project-specific health and safety plan will be included in the RAWP.

9. WASTE MANAGEMENT

The sitewide Waste Management Plan (PAD-PLA-ENV-001) will be the basis for all waste management activities. Any deviations from this sitewide plan will be documented in the project-specific RAWP.

10. REFERENCES

DOE (U.S. Department of Energy) 1999. *Remedial Investigation Report for Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1777&D2, U.S. Department of Energy, Paducah, KY, June.

DOE 2000a. *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1895&D1, U.S. Department of Energy, Paducah, KY, September.

DOE 2000b. *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845/D1 (also known as Data Gaps document), U.S. Department of Energy, January.

DOE 2007. *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2/R1, U.S. Department of Energy, Paducah, KY, June.

DOE 2010a. *Focused Feasibility Study for the Southwest Groundwater Plume Volatile Organic Compound Sources (C-747-C Oil Landfarm and C-720 Northeast and Southeast Sites) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07/0186&D2/R1, U.S. Department of Energy, Paducah, KY, June.

DOE 2010b. *Remedial Design Support Investigation Characterization Plan for the C-747-C Oil Landfarm and C-720 Northeast and Southeast Sites at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Draft in Progress), U.S. Department of Energy, Paducah, KY, July.

DOE 2012a. *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0365&D2/R1, U.S. Department of Energy, Paducah, KY, March.

DOE 2012b. *Remedial Design Work Plan for Solid Waste Management Units 1, 211-A, and 211-B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1268&D2/R1, U.S. Department of Energy, Paducah, KY, April.

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APPENDIX

SWMU 1 SOURCE AREA EXISTING ANALYTICAL DATA

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APPENDIX

SWMU 1 SOURCE AREA EXISTING ANALYTICAL DATA (CD)

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