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Primary Document

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

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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

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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
U.S. Department of Energy
under contract DE-AC30-10CC40020

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Table A.2. Summary of the DQO Process for the Southwest Plume Source Areas RDSI

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: The PGDP's Southwest Plume consists of groundwater in the RGA contaminated primarily with TCE. The C-747-C Oil Landfarm (SWMU 1) and the C-720 Building Northeast and Southeast Sites (SWMUs 211-A and 211-B, respectively) are sources of contamination to the Southwest Plume. A revised FFS (DOE 2011a) was performed for the three Southwest Plume source areas. RAOs defined in the Southwest Plume FFS include: (1) Treat and/or remove principal threat waste consistent with CERCLA, the NCP. (2a) Prevent exposure to VOC contamination in the source areas that will cause an unacceptable risk to excavation workers (< 10 ft depth bgs). (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 C-720 Northeast and Southeast sites so that contaminants migrating from the treatment areas do not result in an exceedance of MCLs in underlying RGA groundwater. Soil cleanup levels, soil boring-averaged TCE UCRS soil concentrations that would meet RAO #3, calculated in the Southwest Plume Revised FFS Appendix C, are listed below: • Oil Landfarm source area: 7.3E-02 mg/kg • C-720 northeast and southeast source areas: 7.5E-02 mg/kg. Previous investigations documented in the WAG 27 RI (DOE 1999) and the SI Report (DOE 2007) did not completely define the areal and vertical extent of soil contaminated above cleanup levels in the source areas. This was identified in the Southwest Plume FFS (DOE 2011a) as a data gap to be resolved in the RDSI. The Southwest Plume Proposed Plan (DOE 2011b) identified *In Situ* Source Treatment Using Deep Soil Mixing with Interim Land Use Controls (LUCs) (Alternative 3) as the preferred alternative for the C-747-C Oil Landfarm and Final Characterization of source extent and magnitude followed by either *In Situ* Source Treatment Using Enhanced *In Situ* Bioremediation with Interim LUCs	PSQ-1: What is the areal extent of TCE and TCE degradation products present at soil boring-averaged concentrations higher than cleanup levels at the Southwest Plume source areas? PSQ-2: What are the SWMU-specific ranges of geotechnical and microbial properties that are important to the design of the remedial actions?	AA-1a: Remediation is required where the soil boring-averaged concentrations of TCE and TCE degradation products in soils of the UCRS exceed cleanup levels. AA-1b: Remediation is not required where the soil boring-averaged concentrations of TCE and TCE degradation products in soils of the UCRS do not exceed cleanup levels.	DS-1: Determine the extent of soil boring-averaged concentrations of TCE and TCE degradation products in soils of the UCRS and upper RGA in the Southwest Plume source areas that exceed cleanup levels and require remediation. DS-2: Determine where additional design-type information is required for the preferred alternatives.	1) Process knowledge of releases (DOE 2011a) 2) Previous investigation results (DOE 2011a) 3) Description of C-720 source areas in Appendix C of the GWOU FS (DOE 1999) 4) Site conceptual model (DOE 2011a) 5) Southwest Plume FFS Alternatives 2, 3, and 8 descriptions (DOE 2011a) 6) Minimum TCE cleanup levels: 7.3E-02 mg/kg for the C-747-C Oil Landfarm and 7.5E-02 mg/kg for the C-720 Northeast and Southeast Sites (DOE 2011a) 7) TCE DLs by USEC = 5E-03 mg/kg (Watson 2010). 8) Current estimates of source area dimensions shown in Southwest Plume FFS (DOE 2011a) 9) Information requirements for design of the preferred alternatives as follows: - Soil properties common to both soil mixing and *in situ* bioremediation - fraction organic carbon and grain size - Soil properties specific to soil mixing: *in situ* water content, pH, unconfined compressive strength,	*Spatial boundaries:* The vertical boundary of the study is the upper RGA as feasible (to the base of HU4 interval) at all sites. The results of soil TCE analyses will be provided to EPA and KDEP on a timely basis, and the FFA Parties will confer via teleconference regarding the need for further sampling in the RGA. TCE concentrations above cleanup levels are present at the maximum depths sampled in previous investigations. Surface and subsurface infrastructure is present in the C-720 source areas. The C-720 building bounds the north side of the southeast source area. *Schedule boundaries*: The focused investigation results must be available by the start of development of the 90% remedial design. Fieldwork and lab analysis turnaround is anticipated to require approximately 120 days. *Operational boundaries:* Field investigations and remedial design are constrained by surface and subsurface infrastructure at the C-720 Building. No significant interferences exist at the Oil Landfarm. None of the areas are posted as radiological contamination areas; however, VOCs, metals, and SVOCs are present in soils. An underground storage tank near northeast corner of C-720 may present problems both as subsurface infrastructure and source of petroleum in soils. *Administrative boundaries*: The investigation includes subcontracting for a field	DR-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.	Definitive data quality is assumed for fixed-base and field laboratory analysis. Screening level data quality is assumed for field analyses. The soil boring-averaged contaminant concentration will be derived solely from laboratory analyses from each 5-ft depth interval. The derived soil boring-averaged contaminant concentration will be used as a definitive criterion for comparison with the RG, with no consideration for false rejection rate or false acceptance rate. The sampling plan minimizes decision error by intentionally biasing the location of the sample for laboratory analysis to the location of highest field PID measurement in each 5-ft depth interval.	The selected treatment technologies are able to address the range of small, discrete areas to broad areas. There effectively is no minimum or maximum decision area. A combination of field screening instruments, field laboratory analysis, and fixed-base laboratory confirmation analysis will be used to define the outer extent of the area contaminated above the RGs. The contaminants of interest are TCE and degradation products: 1,1-dichloroethene; *cis*-1,2-dichloroethene; *trans*-1,2-dichloroethene; and vinyl chloride. The targeted depth of investigation is 60 ft bgs, which penetrates through the average depth of the base of the HU4 at SWMU 1 and at the C-720 sites. Where one or more soil boring-averaged contaminant concentrations in a soil boring exceed an RG for a site, contingency borings will be sampled, as necessary (up to the contingency allotment for each site), to bound the remediation area. At SWMU 1, successive contingency boring step outs nominally will be 75 ft. (Multiple contingency borings may extend the investigation beyond 75 ft of the SWMU boundary.) At the C-720 sites, contingency boring

Table A.2. Summary of the DQO Process for the Southwest Plume Source Areas RDSI (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					
(Alternative 8) or Long-term Monitoring with Interim LUCs (Alternative 2) as the preferred alternatives for the C-720 Northeast and Southeast Sites. The RDSI will be performed at the Oil Landfarm and Building C-720 to better determine the lateral and vertical extent and distribution of VOCs and source material. The investigation will determine soil and groundwater parameters including geochemical parameters at each of the SWMUs. The extent and distribution of VOCs in the UCRS and upper RGA will impact the design of each remedial alternative. Results from the RDSI will guide decisions regarding the spacing, locations, and depths of augered areas at SWMU 1, and be utilized to design *in situ* bioremediation at SWMU 211 if this alternative is selected.				compressibility, and index properties - Soil properties specific to *in situ* bioremediation: permeability - Groundwater properties needed to assess *in situ* bioremediation: alkalinity, total and dissolved metals, ferrous iron, major anions, dissolved gasses, and microbial population.	laboratory to provide near real time analysis of VOCs in soil and groundwater. Establishment of a field laboratory facility will require development of additional work control.			step outs must be consistent with the sampling grid except where prevented by the presence of utilities or other obstructions. Parameters as established in quality assurance project plan for precision, accuracy, representativeness, completeness, and comparability. A combination of field measurements and fixed-base laboratory analysis will be used to quantify key design criteria for the preferred alternatives.

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act; DL = detection limit; EPA = U.S. Environmental Protection Agency; FFS = focused feasibility study; FS = feasibility study; GWOU = Groundwater Operable Unit; MCL = maximum contaminant level; NCP = National Contingency Plan; OU = operable unit; PGDP = Paducah Gaseous Diffusion Plant; RAO = remedial action objective; RDSI = Remedial Design Support Investigation; RG = remediation goal; RGA = Regional Gravel Aquifer; SVOC = semivolatile organic compound; SWMU = solid waste management unit; TCE = trichloroethene; UCRS = Upper Continental Recharge System; USEC = United States Enrichment Corporation; VOC = volatile organic compound

A.5. TECHNICAL APPROACH FOR THE RDSI

The primary focus of this field investigation is the collection of soil samples for VOCs analysis for each 5 ft depth interval (e.g., 0-5 ft, 5-10 ft, 10-15 ft) to 60 ft depth (approximate depth of the upper RGA) in each of three investigation areas. Field measurements of VOCs in soils at 0.5 ft depth intervals [using a field photoionization detector (PID)] will be used to target sample collection for the laboratory analytical results. The average contaminant level in each soil boring will be compared to the site-specific remediation goals (RGs). The extent of soil boring average soil contamination that exceeds the RGs will define the remediation area.

Additional soil and groundwater sampling and field measurement and testing are being performed to support the remedial design.

Should VOC concentrations in the lower portion of the UCRS and upper RGA (HU4) indicate that source-based VOC mass may be present in the lower RGA (HU5, gravel zone), the FFA parties will convene and identify a path forward in regard to additional characterization requirements.

A.5.1 HEALTH AND SAFETY

A project-specific health and safety plan (HASP) will be developed for this RDSI and approved by the DOE prime contractor prior to field implementation. The HASP will establish the specific applicable standards and practices to be used during execution of the RDSI characterization plan to protect the safety and health of workers, the public, and the environment. It will incorporate directly, or by reference, applicable federal and state standards, consensus standards, and contract requirements. The HASP will be implemented in accordance with 29 *CFR* § 1926.65, *Hazardous Waste Operations and Emergency Response*. Additional specific health and safety requirements will be incorporated into the Activity Hazard Assessment (AHA) for the various field activities that comprise the RDSI.

The HASP will evolve as "lessons learned" are incorporated to continuously improve the work processes, while maintaining focus on the functions and guiding principles of the Integrated Safety Management System and the zero-accident performance philosophy.

A.5.2 SURFACE GEOPHYSICAL SURVEY

Underground utilities are present in the investigation area, and avoiding penetration of these utilities during intrusive sampling activities is a primary concern; therefore, an extensive excavation/penetration permit process, including a geophysical survey, will be conducted in each sampling area prior to intrusive sampling. This geophysical survey will verify that sample locations are free of interfering utilities. Locations of known utilities will be checked against the sampling location. The geophysical survey will assist in identifying any previously unknown utilities that may exist. This survey will be used in conjunction with utility drawings and field measurements to help locate these utilities before invasive drilling activities begin.

Sampling locations may require relocation based upon results of the geophysical survey to avoid penetrating any utilities.

A.5.3 SAMPLING STRATEGY

Soil will be the primary media for characterization of the extent of TCE. To provide timely access to the TCE characterization data, the investigation will use a subcontractor mobile field laboratory for VOC analyses, following protocols to provide quality assured data[1], or quick-turnaround analyses from a fixed-base laboratory under the DOE Consolidated Audit Program (DOECAP). The sampling strategy design, detailed in Attachment A1, is based upon site background information, the cleanup levels, DQOs, and geospatial analysis of historical data. Proposed RDSI sampling locations are listed in Attachment A1. Should the defined number of contingency borings be inadequate to define the extent of contamination exceeding the cleanup goal, DOE will confer with EPA and KDEP to identify the need for and placement of additional borings prior to demobilization. The sampling strategy to meet the RDSI objectives is described in the following subsections.

A.5.3.1 C-720 Building Source Areas

The initial site characterization will consist of field screening and sampling of soil borings that are located on a rectangular grid of 30 ft by 30 ft (or smaller interval). Where previous soil borings with detections of TCE above the cleanup level are adjacent to the sampling grids, the sampling grids have been extended beyond the boundaries of each SWMU to include the area of the previous soil borings. Each soil boring will provide continuous core for field screening at 0.5 ft depth intervals, and the collection of a soil sample for laboratory analysis from each 5 ft depth interval, to the upper RGA, a depth of approximately 60 ft bgs.

The following is the overall sampling sequence for the C-720 northeast and southeast source areas.

(1) Perform initial site visit and geophysical surveys, excavation/penetration permit program requirements, and AHA for both sites.

(2) Mobilize to the first site (northeast or southeast).

(3) Core and sample location 1 to the upper RGA, approximately 60 ft bgs.

(4) Perform field scan of continuous core at 0.5 ft depth intervals using a field PID.[2]

(5) Subsample the core in the field using En Core® samplers[3] or equivalent. Soil samples will be collected for laboratory analysis at an approximate rate of one sample per 5 ft interval (approximately 12 soil samples per soil core). The soil samples will be collected from the interval with highest field PID results.[4] Label, document, package, and preserve the soil samples as described in Section 8.

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[1] DOE will notify EPA and KDEP once a mobile field laboratory vendor is selected and provide the mobile laboratory SOPs once the SOPs have been reviewed and approved for use.

[2] The primary field PID instrument for assessing VOC trends in the soil core will be a ppb RAE PID or equivalent. The measurement range of the ppbRAE PID is 1 ppb to 10,000 ppm.

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

[4] The field crew may elect to collect additional soil samples for VOC analysis from above and below the elevated PID response interval(s) to strategically document the vertical distribution of TCE.

(6) Repeat steps 3 through 5 for each of the remaining sample locations at the site. (There are 27 defined sample locations at the C-720 Northeast Site and 13 defined sample locations at the C-720 Southeast Site.)

(7) Deliver soil samples to the mobile field laboratory for quick-turn VOC analysis. Deliver/ship soil samples to a fixed-base laboratory for other investigation analyses.

(8) Obtain and evaluate VOC quick-turn analytical results and calculate the soil boring-averaged TCE concentration for each soil boring.

(9) For the single soil boring location at each site with the highest soil boring-averaged TCE concentration, sample four additional soil borings located in the center point of the grid surrounding the target soil boring. The screening and sampling process will be focused in the vertical depth interval(s) identified in the single soil boring which indicated the highest concentrations.

(10) Deliver soil samples to the mobile field laboratory for quick-turn VOC analysis. Deliver/ship soil samples analyses to a fixed-base laboratory for other investigation.

(11) Contour the soil boring-averaged TCE concentrations to confirm delineation and/or select additional sample locations(s) and depth intervals to bound the area of soil exceeding the cleanup level. Up to 10 additional soil borings will be sampled for field screening and laboratory analysis at the C-720 Northeast area and up to 6 additional soil borings will be sampled for field screening and lab analysis at the southeast source area.

(12) Mobilize to the second site at C-720 (northeast or southeast).

(13) Repeat steps 3–11 for the second site.

(14) Demobilize from the C-720 area.

A.5.3.2 C-747-C Oil Landfarm Source Area

The sampling sequence for the C-747-C Oil Landfarm source area will be similar to that of the C-720 Building source areas. Sampling will consist of the following steps.

(1) Perform initial site visit and geophysical surveys, excavation penetration permit program requirements, and AHA.

(2) Mobilize to the first sample location.

(3) Core and sample location 1 (of 18) to the upper RGA, approximately 60 ft bgs.

(4) Perform field scan of continuous core at 0.5 ft depth intervals using a field PID (ppbRAE PID or equivalent).

(5) Subsample the core in the field using En Core® samplers or equivalent. Soil samples will be collected for laboratory analysis at an approximate rate of one sample per 5-ft interval (approximately 12 soil samples per soil core). The soil samples will be collected from the interval

with highest field PID results.[5] Label, document, package, and preserve the soil samples, as described in Section 8.

(6) Repeat steps 3 through 5 for each of the remaining sample locations at the site. (There are 18 defined sample locations.)

(7) Deliver soil samples to the mobile field laboratory for quick-turn VOC analysis. Deliver/ship soil samples analyses to a fixed-base laboratory for other investigation.

(8) Obtain and evaluate VOC quick-turn analytical results and calculate the soil boring-averaged TCE concentration for each soil boring.

(9) Contour the soil boring-averaged TCE concentrations to confirm delineation and/or select additional sample locations(s) and depth intervals to bound the area of soil exceeding the cleanup level. Up to eight additional soil borings will be sampled for field screening and laboratory analysis.

(10) Perform additional shallow DPT probing, as needed, to identify the extent of any buried concrete debris which may impact design of the deep soil mixing remedy.

(11) Demobilize from the C-747-C Oil Landfarm.

A.5.4 GEOLOGIST'S LOGS OF SELECT SOIL CORES

A geologist will develop a continuous log of the soil core, consistent with PAD-ENM-2303, *Borehole Logging*, at all locations in each of the source areas to aid in design of the preferred remedies. These detailed logs will be used to identify the lithologic sequence and HUs at each source area.

A.5.5 GEODETIC SURVEY OF ALL SAMPLING LOCATIONS

All sampling locations shall be surveyed by a registered and licensed surveyor of the Commonwealth of Kentucky. Locations shall be surveyed on the Kentucky State Plane Coordinate System and the PGDP Plane Coordinate System. Horizontal and vertical accuracy for this work must be at least plus or minus 0.1 ft and must be sufficient to support the design of the follow-on remedial action. All coordinates and elevations shall be tied to the U.S. Geological Survey National Geodetic Vertical Datum of 1929 or the North American Datum of 1983. Survey results will be reported in both hard copy and electronic files.

A.5.6 BORING ABANDONMENT

Each borehole will be plugged and abandoned as soon as practicable on the day sampling is completed. Boring abandonment will be consistent with Commonwealth of Kentucky requirements and approved site procedures.

The driller will be required to abandon all borings, created by direct push technology (DPT) and by conventional drilling method(s), if required, by placing the grout in the borehole with a tremie pipe, proceeding from the base of the open borehole to be abandoned to near ground surface. Once the DPT or

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[5] The field crew may elect to collect additional soil samples for VOC analysis from above and below the elevated PID response interval(s) to document strategically the vertical distribution of TCE.

A.6. SAMPLING AND ANALYSIS PLAN

A.6.1 SOIL SAMPLING

Table A.3 summarizes measurements and sample collection activities for this investigation. DPT will be used for soil sampling to the upper RGA for VOCs at the C-747-C Oil Landfarm and the C-720 Northeast and Southeast Sites. Soil samples will be collected using DPT equipment that advances a sampling tool by pushing, driving, or vibrating it to the desired sampling depth, consistent with PAD-ENR-0020, *Collection of Soil Samples With Direct Push Technology Sampling*. For this field characterization effort, the DPT rig will use a dual tube sampling system. A common sampler in use is the Dual Tube 22 sampler of Geoprobe®. The Dual Tube 22 sampler is a direct push system for collecting continuous core sample of unconsolidated materials from within a sealed casing of 2.25-inch probe rods. Samples are collected and retrieved within a liner that is threaded onto the leading end of a string of center rods. The center rods hold the liner in place as the outer casing is driven to fill the liner with soil. The inner rods are then retracted to retrieve the full liner. This system eliminates the generation of side slough in the sample and prevents cross-contamination. Thin-walled polyvinyl chloride (PVC) sample tubes, with a 1.375-inch outside diameter, will be used to contain and retrieve the core samples.[6]

Where the sample boring depth of 60 ft does not reach into the upper RGA, the project will continue downward collection of soil samples for VOC analysis into the RGA (HU 4 interval). The anticipated limit of the depth of sampling is the base of the HU4 sand interval of the RGA where present. The project will report sample results to EPA and KDEP weekly. DOE will confer with EPA and KDEP during the RDSI to assess the sample analyses for indications of a VOC source zone extending into the lower RGA (HU5 interval). If the assessment indicates the need for deeper characterization of the RGA, then the FFA parties will define the strategy for additional sampling.

If DPT cannot advance to the approximate targeted sampling depth or collect a representative sample because of the large size of the soil matrix relative to the diameter of the DPT sampler, a rotary sonic or hollow-stem auger boring may also be utilized.

The process for sample collection for this field investigation is summarized as follows:

(1) Cut open the liner and perform a brief radiological and field PID scan of the soil core to ensure the safety of the field samplers.

(2) Immediately cover the exposed core with clean aluminum foil once the radiological and field PID scans are completed.

(3) Measure and determine field PID scanning points to represent 0.5 ft depth increments of the soil core.[7]

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[6] PVC generally is considered an inferior material for use in collection of VOC samples. PVC is being used because it is superior material for liner durability and can be cut open with a knife for PID and radiological scanning of the soil core and for sampling. The PVC liner will be in contact only with the outside of the core (not the sampled portion for lab analysis) for the brief time between driving the soil sampler and subsampling, immediately following retrieval and field scans of the soil core.

[7] Although the soil core will be collected in 5 ft depth increments, the retrieved core may be longer or shorter than 5.0 ft depending upon swelling, compaction, or loss of the soil. Where swelling or compaction accounts for a discrepancy in the core length, the sample points will be adjusted to represent 0.5 ft depth intervals in the subsurface. Where it is apparent that soil has been lost in the sampling process, the samplers will note the lost core interval in the field logbooks and identify the sample locations to represent 0.5 ft depth intervals in the subsurface.

(4) As the field PID is available at each field PID scanning location, prepare the soil core by inserting a clean awl through the aluminum foil cover and through the soil core to expose soil for the field PID scan. Insert the field PID sample tube (equipped with a water separator) over the hole in the aluminum foil/soil core and measure the VOC level. Record each reading in a field logbook. The field PID measurements will be used to identify sections of the soil core containing high VOC levels for subsampling with an En Core® sampler.

Table A1.3. PGDP Plant Coordinates for Proposed C-747-C Oil Landfarm Source Area Sampling Locations

SWMU 1, C-747-C Oil Landfarm		
Sample Location Shown on Figure A1.1	**x**	**y**
1	-6860	-1680
2	-6880	-1680
3	-6854	-1695
4	-6780	-1700
5	-6820	-1700
6	-6880	-1700
7	-6900	-1700
8	-6790	-1720
9	-6834	-1720
10	-6880	-1720
11	-6902	-1720
12	-6960	-1720
13	-6780	-1740
14	-6810	-1750
15	-6920	-1760
16	-6873	-1765
17	-6860	-1780
18	-6900	-1800

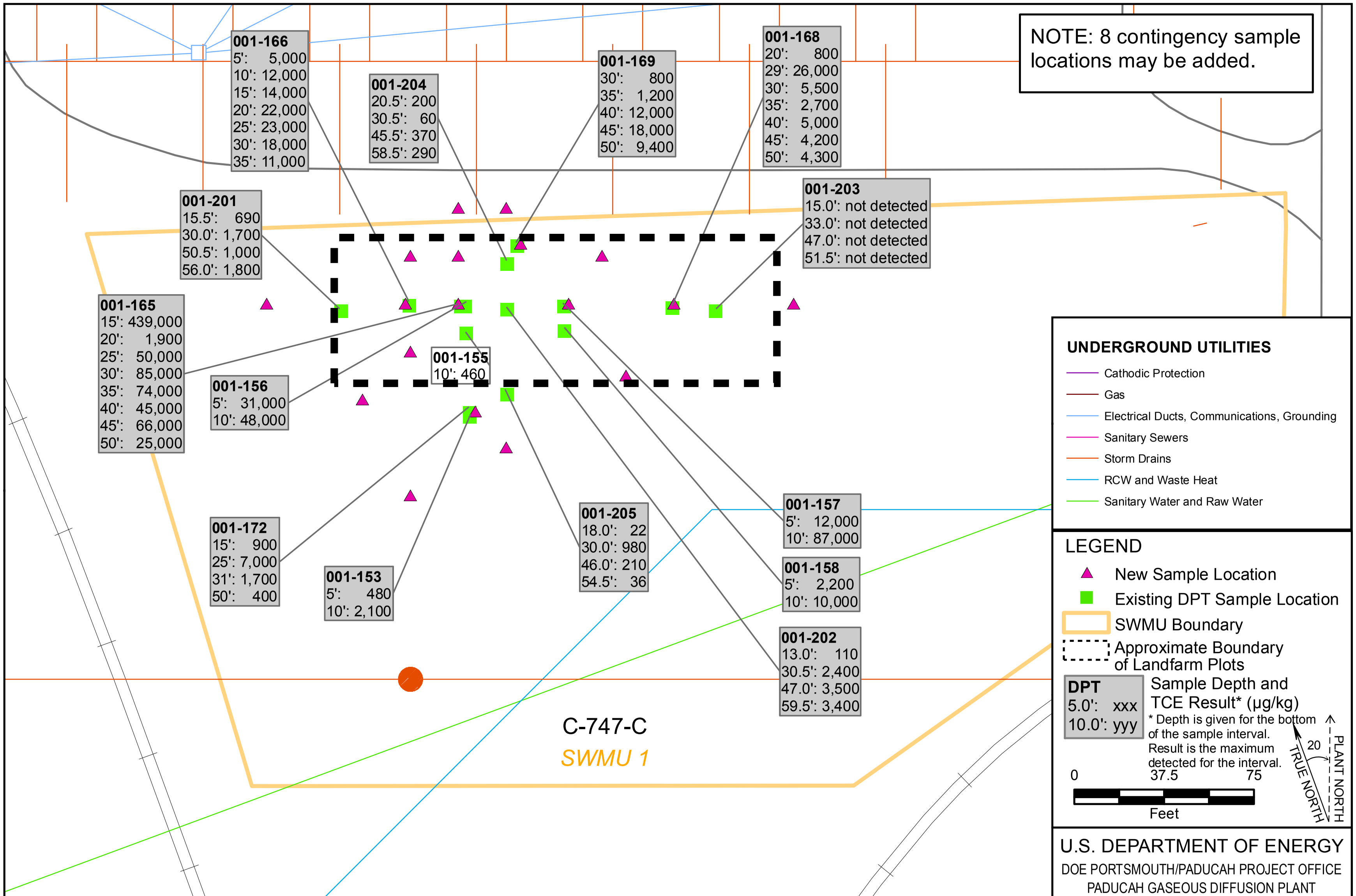

Figure A1.3. Initial Sample Locations at the C-747-C Oil Landfarm Source Area

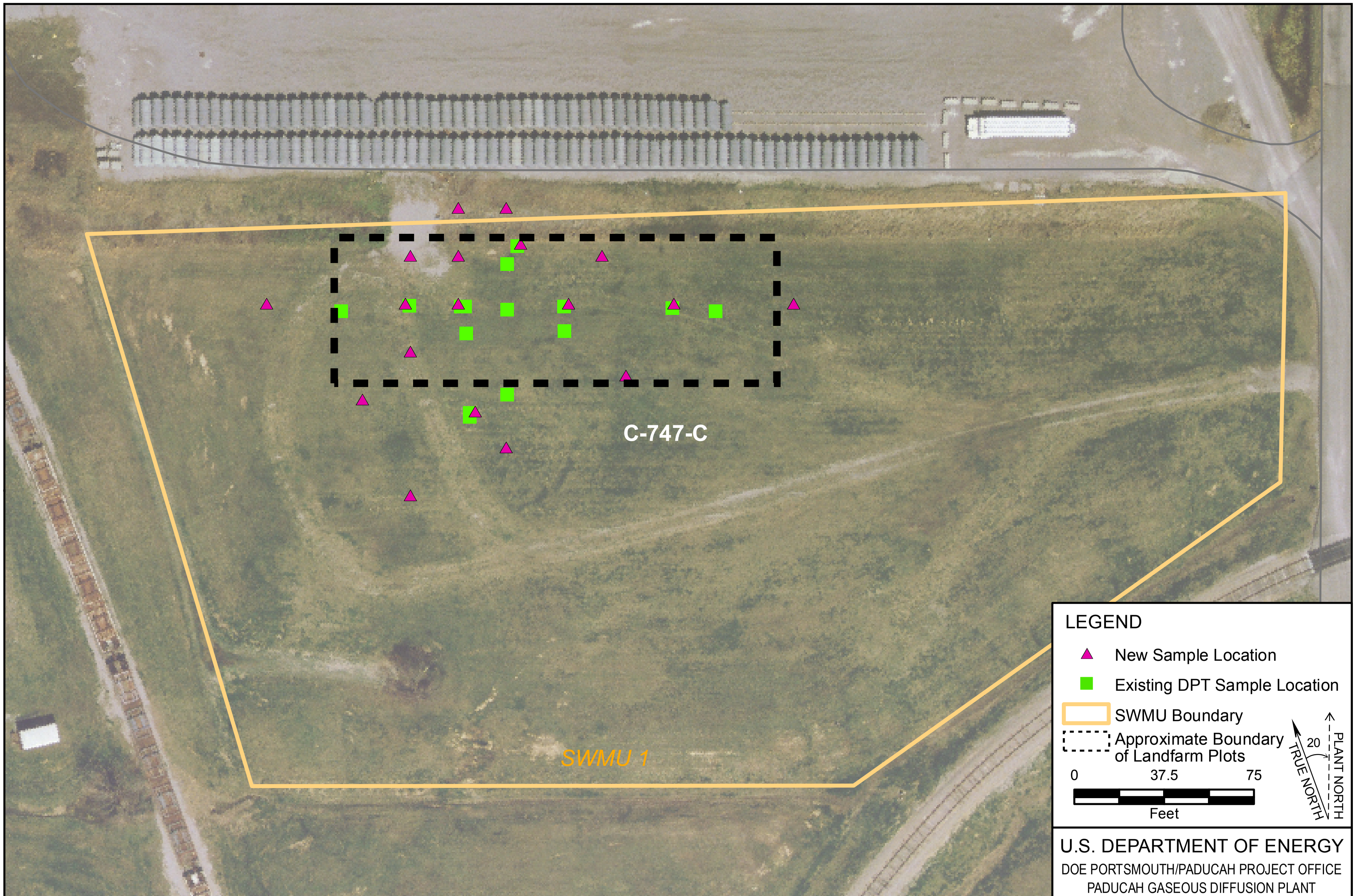

Figure A1.4. C-747-C Oil Landfarm Source Area

1/18/2012 SW Plume\SWMU1_LocationsR1aerial_r3.mxd

A1.2. APPROACH FOR CONTOURING DATA

If the sampling locations specified in Tables A1.2 and A1.3 do not bound the areas to be treated, limited additional sampling will be performed, as outlined in Section 5.3.1 (up to ten additional locations at the C-720 northeast source area, up to six additional soil borings the C-720 southeast source area, and up to eight additional locations at the C-747-C Oil Landfarm source area). Should the defined number of contingency borings be inadequate to define the extent of contamination exceeding the cleanup goal, DOE will confer with EPA and KDEP to identify the need for and placement of additional borings prior to demobilization. The soil boring-average TCE concentrations from the initial characterization soil borings at the C-720 source areas and the C-747-C Oil Landfarm source area will be contoured (using linear interpolation and extrapolation) to assess the need for additional sampling and the placement of additional sample boreholes.

Follow-on assessments to better define the area to be treated and to estimate the mass of VOCs present may be based on more robust spatial analyses consistent with the derivation of the cleanup criteria. Additional three-dimensional analysis may be performed using computer mass estimating software such as Environmental Visualization System.

NOTE: All references cited in Appendix A can be accessed in the References section of the main text of this document.

QAPP Worksheet #12-A
Measurement Performance Criteria Table[1]

Sampling will follow the standard operating procedures included in the SAP. The following table provides the measurement performance criteria.

Analyte	CAS Number	EPA Method	Soil/Sediment Accuracy % Recovery	Aqueous Accuracy % Recovery	Soil/ Sediment Precision RPD Lab/Field	Aqueous Precision RPD	Soil/ Sediment PQL (µg/Kg)	Soil/ Sediment MDL* (µg/Kg)	Water PQL (µg/L)	Water MDL* (µg/L)
Volatile Organic Compounds										
1,1-Dichloroethene	75-35-4	SW-846, 8260	50-150	80-120	< 22/<50	< 25	10	5	5	2.5
cis-1,2-Dichloroethene	156-59-2	SW-846, 8260	50-150	70-125	< 22/<50	< 25	10	5	1	0.5
trans-1,2-Dichloroethene	156-60-5	SW-846, 8260	50-150	70-125	< 22/<50	<25	10	5	1	0.5
Trichloroethene	79-01-6	SW-846, 8260	50-150	70-125	< 22/< 50	≤ 25	10	5	1	0.5
Vinyl Chloride	75-01-4	SW-846, 8260	50-150	50-145	< 22/< 50	≤ 25	10	5	2	1

[1] Additional information about quality control samples is found in Worksheet #28.

* The analytical laboratory may not be able to meet the project action limits established by contaminant transport modeling in Appendix C of *Revised Focus Feasibility Study for Solid Waste Management Units 1, 211A, and 211B Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, [Revised Focused Feasibility Study (Revised FFS), DOE 2011a]. In those cases, LATA Kentucky will have the laboratory report to the method detection limit qualifying the result as estimated. Standard practices for qualifying data will apply for any result reported below the laboratory practical quantitation limit.

QAPP Worksheet #12-B
Measurement Performance Criteria Table[1]

Analyte	CAS Number	EPA Method	Aqueous Accuracy % Recovery	Aqueous Precision RPD	Water PQL (µg/L)	Water MDL (µg/L)
Metals[2]						
Aluminum	7429-90-5	EPA 200.8/ SW-846 6010/6020[3]	80-120	≤ 25	200	100
Chromium	7440-47-3	EPA 200.8/ SW-846 6010B/6020[3]	80-120	≤ 25	10	5
Iron	7439-89-6	EPA 200.8/ SW-846 6010B/6020[3]	80-120	≤ 25	200	100
Lead	7439-92-1	EPA 200.8/ SW-846 6010/6020[3]	80-120	≤ 25	1.3	0.65
Manganese	7439-96-5	EPA 200.8/ SW-846 6010B/6020[3]	80-120	≤ 25	5	2.5

[1] Additional information about quality control samples is found in Worksheet #28.
[2] Analyses for metals are total and dissolved.
[3] A post digest spike will be analyzed when the matrix spike fails.

QAPP Worksheet #17-A
Sampling Design and Rationale

Describe and provide a rationale for choosing the sampling approach (e.g., grid system, judgmental statistical approach):
The nature and extent investigation will be implemented in stages. The first stage will utilize a field laboratory, for VOC analyses only (not including 10% confirmatory analyses or field QC analyses), to provide timely characterization of VOC levels within a defined sample grid. A second stage provides a limited number of contingency borings, as necessary with analysis by field laboratory (not including 10% confirmatory analyses or field QC analyses), to define the extent of any contiguous area with TCE levels that exceed the SWMU-specific cleanup goals. (A fixed-laboratory will perform the analysis of confirmatory samples and field QC samples.) The investigation will be based primarily on sampling from soil borings completed with DPT. In each soil boring, the investigation will characterize VOC trends using field PID readings at 0.5 ft depth intervals from surface to the base of the UCRS at a depth of approximately 60 ft. At least one soil sample will be collected for field laboratory analysis from each 5-ft depth interval. An indication of VOC source material in the lower UCRS will trigger an assessment of the need for VOC source characterization in the RGA.
The investigation also will collect samples for fixed laboratory analysis to support design of the remedial action at SWMU 1 and selection and design of the remedial action at SWMUs 211A&B. The additional sampling consists of geotechnical analysis to assess deep soil mixing at SWMU 1 and groundwater chemistry analyses, microbial population analyses, and geotechnical analyses to assess enhanced *in situ* bioremediation at SWMUs 211A&B. Nested wells will be completed at each of the investigation areas to assess groundwater levels and vertical gradients.
Describe the sampling design and rationale in terms of which matrices will be sampled:
Soil borings will be sampled at predetermined locations to compare TCE levels with SWMU-specific cleanup levels. Additional contingency soil borings, placed based on results of the predetermined locations, may be used, as necessary, to define the extent of TCE levels exceeding the cleanup levels.
Soil samples will also be collected to measure geotechnical properties at each of the SWMUs.
Limited groundwater sampling will be performed from wells at each site to assess general groundwater quality and VOC levels. Additional groundwater sampling will be performed as grab samples from wells installed during this investigation to assess groundwater parameters that relate to enhanced *in situ* bioremediation and long term attenuation.

QAPP Worksheet #17-A (Continued)
Sampling Design and Rationale

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

  Standard Environmental Sampling:

  Volatile organic compounds (VOCs) by SW-846, 8260; metals analysis by EPA 200.8 and SW-846, 6010B/6020. **See Worksheet #12 for method detection limit.**

  Engineering & Design Sampling:

  For soils: grain size analysis by ASTM D422, *in situ* water content by ASTM D2216, pH by ASTM G51, unconfined compressive strength by ASTM D2166, compressibility by ASTM D2850, index properties by ASTM D4318, permeameter testing by ASTM D5084.

  For groundwater: alkalinity by Hach® test kit Model AL-DT, ferrous iron by Hach® test kit Model IR-18C, dissolved methane, ethane, and ethane by modified R.S. Kerr SOP-175, microbial population analysis by the quantitative polymerase chain reaction method. See Worksheet 17-B for additional details.

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

  See Worksheet #18.

- **How many samples to be taken?**

  See Worksheet #18.

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

  This is a one-time sampling event except for the monitoring wells. They will be sampled on three consecutive weeks.

QAPP Worksheet #17-B
Engineering and Design Sampling

	Media Type	Sample Location	Number of Samples	Test/Analytical Method	Project Action Limit	PQL
Geotechnical Analysis						
Grain Size Analysis	Soil	3/all HUs at each source area	27	ASTM D422[a]	N/A	N/A
Fraction Organic Carbon	Soil	3/all HUs at each source area	27	SW9060 as modified for soil samples[b]	N/A	N/A
Permeameter Testing	Soil	3/all HUs at each C-720 site	18	ASTM D5084-10[a]	N/A	N/A
In Situ Water Content	Soil	3/all HUs at SWMU 1	9	ASTM D2216-10[a]	N/A	N/A
pH	Soil	3/all HUs at SWMU 1	9	ASTM G51[a]	N/A	N/A
Unconfined Compressive Strength	Soil	3/all HUs at SWMU 1	9	ASTM D2166-06[a]	N/A	N/A
Compressibility	Soil	3/all HUs at SWMU 1	9	ASTM D2850-03a[a]	N/A	N/A
Index Properties	Soil	3/all HUs at SWMU 1	9	ASTM D4318-10[a]	N/A	N/A

[a] These tests will be performed by a fixed-base laboratory.
[b] The modification is in sample preparation and heat of combustion.

QAPP Worksheet #17-B (Continued)
Engineering and Design Sampling

	Media Type	Sample Location	Number of Samples	Test/Analytical Method	Project Action Limit	PQL
Microbial Analysis						
Microbial population	Water	nested wells at each source area	9	Quantitative Polymerase Chain Reaction Method[a]	N/A	N/A
Field Parameters						
Dissolved Oxygen	Water	wells at each source area	27	Hach® Quanta Hydrolab	0.5 mg/L	0.2 mg/L
Oxidation Reduction Potential	Water	wells at each source area	27	Hach® Quanta Hydrolab	50 mV against Ag/AgCl	20 mV
pH	Water	wells at each source area	27	Hach® Quanta Hydrolab	5 to 9 Std Units	0.02 Std Units
Specific Conductance	Water	wells at each source area	27	Hach® Quanta Hydrolab	N/A	0.001 mS/cm

[a] These tests will be performed by a fixed-base laboratory.

QAPP Worksheet #22 (Continued)
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*
Ferrous Iron Colorimeter	Accuracy check at the beginning and end of the day	Return to instrument rental for replacement	Measure with standard solution	Upon receipt, successful operation	Check daily before each use	Pass/Fail	Return to rental company for replacement	Field Team Leader	Manufacturer's specifications
Titrator (for alkalinity)	Calibrate to manufacturer's solution weekly	As needed	Measure with standard solution	Upon receipt, successful operation	Daily before each use	With range of manufacturer's standard	Service by manufacturer	Field Team Leader	Manufacturer's specifications
Alpha Scintillator	Annually or as specified by manufacturer	Annually or as needed	Daily prior to use	Upon receipt, successful operation	Daily prior to use	Pass/Fail	Return to rental company for replacement	RCT Supervisor	Manufacturer's specifications
Geiger Mueller	Annually or as specified by manufacturer	Annually or as needed	Daily prior to use	Upon receipt, successful operation	Daily prior to use	Pass/Fail	Return to rental company for replacement	RCT Supervisor	Manufacturer's specifications
Gamma Scintillator or FIDLER	Annually or as specified by manufacturer	Annually or as needed	Daily prior to use	Upon receipt, successful operation	Daily prior to use	Pass/Fail	Service by manufacturer	RCT Supervisor	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

* 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)
SW-846, 8260	Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)	Definitive	VOAs	GC/MS	TBD	TBD
EPA 200.8 and SW-846, 6010B	Inductively Coupled Plasma-Atomic Emission Spectrometry	Definitive	Metals	ICP	TBD	TBD
EPA 200.8 and SW-846, 6020	Inductively Coupled Plasma-Mass Spectrometry	Definitive	Metals	ICP-MS	TBD	TBD
EPA 300.0/SW846-9056	Determination of Inorganic Ions by Ion Chromatography	Definitive	Anions	Ion Chromatograph	TBD	TBD
Modified R.S. Kerr SOP-175	Dissolved Gas Analysis in Water Samples Using a GC Headspace Equilibration Technique	Definitive	Dissolved Gasses	GC	TBD	YES
Vendor Specific	Quantitative Polymerase Chain Reaction Method	Definitive	Microbial Population	Quantitative Polymerase Chain Reaction	TBD	TBD

* Information will be based on laboratory used. Analysis will be by the most recent revision.
TBD = to be determined

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):

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 chain-of-custody 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 work package documents and will comply with the Data Management Implementation Plan included in the RDSI Characterization Plan.

Chain-of-custody Procedures:

Chain-of-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.*

* It is understood that SOPs are contractor specific.

QAPP Worksheet #28
QC Samples Table

Matrix:	Aqueous
Analytical Group/Concentration Level:	Metals
Sampling SOP:	See Worksheet #21
Analytical Method/SOP Reference:	EPA 200.8 and SW-846, 6010/6020
Sampler's Name/Field Sampling Organization:	TBD
Analytical Organization:	TBD
No. of Sample Locations	See Section 5 and Appendix A of the characterization plan

QC Sample:	Frequency	Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Split Samples	As requested by regulatory agency	TBD	N/A	N/A	N/A	N/A	N/A
Field Blank	Minimum 5%	3	$\leq$ CRQL	Verify results; reanalyze	Laboratory should alert project	Contamination–Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Equipment Blank	Minimum 5%	3	$\leq$ CRQL	Verify results; reanalyze		Contamination–Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Prep Blank	1 per SDG[1]	TBD	See data validation procedure PAD-ENM-5107	Verify results; reanalyze	Data reviewer/Data validator	Contamination–Accuracy/bias	See data validation procedure PAD-ENM-5107

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
Post Digestion Spike	1 per SDG[1]	TBD	See data validation procedure PAD-ENM-5107	Verify results; reanalyze	Data reviewer/Data validator	Precision/ Accuracy	See data validation procedure PAD-ENM-5107
Serial Dilution Test	1 per SDG[1]	TBD	See data validation procedure PAD-ENM-5107	Verify results; reanalyze	Data reviewer/Data validator	Precision/ Accuracy	See data validation procedure PAD-ENM-5107
Internal standards, laboratory spiked blanks or spiked field samples (matrix spike samples[2])	Minimum 5%	3	See data validation procedures PAD-ENM-5105, 5107, 5103, 5102	Check calculations and instrument; reanalyze affected samples	Laboratory should alert project	Accuracy	See procedure PAD-ENM-5003, *Quality Assured Data*
Field duplicate	Minimum 5%	3	None	Data reviewer will place qualifiers on samples affected	Data reviewer/ Project manager	Homogeneity/ Precision	RPD < 25%
Laboratory duplicate	Per laboratory procedure	TBD	See data validation procedures PAD-ENM-5105, 5107, 5103, 5102	Verify results re-prepare and reanalyze	Laboratory analyst	Precision	See procedure PAD-ENM-5003, *Quality Assured Data*

[1] 1 per Sample Delivery Group (SDG) or 1 per 20 samples, whichever is most frequent.
[2] Both matrix spike samples and matrix spike duplicate samples are analyzed at a minimum frequency of 5%.

QAPP Worksheet #28 (Continued)
QC Samples Table

Matrix:	Aqueous/Soils
Analytical Group/Concentration Level:	VOCs
Sampling SOP:	See Worksheet #21
Analytical Method/SOP Reference:	8260
Sampler's Name/Field Sampling Organization:	TBD
Analytical Organization:	TBD
No. of Sample Locations	See Section 5 and Appendix A of the characterization plan

QC Sample:	Frequency	Number	Method/SOP QC Acceptance Limits	Corrective Action	Person(s) Responsible for Corrective Action	Data Quality Indicator (DQI)	Measurement Performance Criteria
Split Samples	As requested by regulatory agency	TBD	N/A	N/A	N/A	N/A	N/A
Field Blank	Minimum 5%	57	≤ CRQL	Verify results; reanalyze	Laboratory should alert project	Contamination–Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Trip Blank	1 per cooler containing VOC samples	~186	≤ CRQL	Verify results; reanalyze		Contamination–Accuracy/bias	See procedure PAD-ENM-5003, *Quality Assured Data*
Equipment Blank	Minimum 5%	57	≤ CRQL	Verify results; reanalyze		Contamination–Accuracy/bias	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
Method Blank	1 per SDG[1]	TBD	See data validation procedure PAD-ENM-5105	Verify results; reanalyze	Data reviewer/Data validator	Contamination–Accuracy/bias	See data validation procedure PAD-ENM-5105
Surrogate Samples	All samples[2]	Total number of samples	See data validation procedure PAD-ENM-5105	Verify results; reanalyze	Data reviewer/Data validator	Accuracy	See data validation procedure PAD-ENM-5105
Internal standards, laboratory spiked blanks or spiked field samples (matrix spike samples[3])	Minimum 5%	57	See data validation procedures PAD-ENM-5105, 5107, 5103, 5102	Check calculations and instrument; reanalyze affected samples	Laboratory should alert project	Accuracy	See procedure PAD-ENM-5003, *Quality Assured Data*
Field duplicate	Minimum 5%	57	None	Data reviewer will place qualifiers on samples affected	Data reviewer/ Project manager	Homogeneity/ Precision	RPD ≤ 50% soils, RPD < 25% aqueous
Laboratory duplicate	Per laboratory procedure	TBD	See data validation procedures PAD-ENM-5105, 5107, 5103, 5102	Verify results re-prepare and reanalyze	Laboratory analyst	Precision	See procedure PAD-ENM-5003, *Quality Assured Data*

[1] 1 per Sample Delivery Group (SDG) or 1 per 20 samples, whichever is most frequent.
[2] Surrogate standards are added to all analytical samples, blanks and QC samples.
[3] Both matrix spike samples and matrix spike duplicate samples are analyzed at a minimum frequency of 5%.

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 and associated completed sampling forms; sample chains-of-custody	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	None

* It is understood that SOPs are contractor specific.