**Department of Energy**

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SEP 23 2013

PPPO-02-2081085-13

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

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 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&D2/R1**

References:

1. Letter from A. Webb to R. Blumenfeld, "Conditional Approval of the 100% Remedial Design Report *In Situ* Source Treatment Using Deep Soil Mixing for the Southwest Groundwater Plume Volatile Organic Compound Source at the C-746-C Oil Landfarm (Solid Waste Management Unit 1) (DOE/LX/07-1276&D2), Paducah Gaseous Diffusion Plant, Paducah, McCracken County, Kentucky, KY8-890-008-982," dated August 23, 2013
2. Letter from J. Tufts to R. Blumenfeld, "EPA Conditional Concurrence of the 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&D2)," dated August 23, 2103

Please find enclosed the certified *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&D2/R1, (RDR) for your review and approval.

Included also in this transmittal are a redline document, Kentucky Department for Environmental Protection (KDEP) conditional response summary, U.S. Environmental Protection Agency (EPA) conditional response summary, and certification page.

This D2/R1 RDR for Solid Waste Management Unit 1 incorporates the conditions provided by EPA and KDEP on August 23, 2013. The U.S. Department of Energy (DOE) has worked closely with EPA and KDEP to clarify specific requirements for twenty-two of the fifty-five conditions during comment resolution meetings held on September 5, 2013; September 11, 2013; September13, 2013; September 19, 2013; and September 20, 2013. Following receipt of concurrence on those conditions from EPA and KDEP, conforming changes were incorporated into the D2/R1 RDR. Additionally, changes have been made to the D2/R1 RDR to address the remaining thirty-three conditions consistent with EPA's and KDEP's conditional approval. As discussed with EPA and KDEP on September 20, 2013, the changes made to the D2/R1 RDR were consistent with EPA's and KDEP's conditional approval. DOE believes these conditions have been met; however, if upon review EPA and/or KDEP determine that responses to any of the thirty-three remaining conditions are non-responsive to any of the conditions set forth by EPA and KDEP, this letter serves as DOE's written notification for invocation of dispute resolution consistent with Section XXV.A of the Paducah Federal Facility Agreement (FFA).

In the event invocation of dispute resolution should occur, the nature of the dispute shall involve resolution of the thirty-three responses to conditions which the FFA parties did not review and reach agreement upon prior to DOE's submittal of the D2/R1 RDR. The work affected by the dispute is limited to the RDR, Remedial Action Work Plan, field work, and Remedial Action Completion Report. The information that DOE is relying upon are discussions between the FFA parties during which the parties acknowledged that DOE had in good faith attempted to satisfy the regulators' thirty-three conditions and EPA and KDEP's understanding that DOE would be conditionally invoking dispute resolution in the event that EPA and/or KDEP determine that any of those conditions are not satisfied by the revised document. DOE's position is that DOE, in good faith, has attempted to satisfy the conditions to the extent the specificity of the conditions has allowed.

DOE appreciates the extra effort, time commitment, and overall level of cooperation provided by EPA and KDEP to work through resolution and finalization of the subject document. DOE looks forward to the agencies' final approval of the RDR.

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

Sincerely,

Jennifer Woodard

Jennifer Woodard
Paducah Federal Facility Manager
Portsmouth/Paducah Project Office

Enclosures:

1. Remedial Design Report clean
2. Remedial Design Report redline
3. CRS for EPA Conditions on the D2 RDR
4. CRS for Commonwealth of Kentucky Conditions on the D2 RDR
5. Certification page

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# CERTIFICATION

**Document Identification:** ***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&D2/R1**

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

LATA Environmental Services of Kentucky, LLC

9-23-13

Mark J. Duff, Paducah Project Manager

Date Signed

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

U.S. Department of Energy (DOE)

Rachel H. Blumenfeld

9-23-13

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

Date Signed

**DOE/LX/07-1276&D2/R1**
**Primary Document**

# 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

**CLEARED FOR PUBLIC RELEASE**

**DOE/LX/07-1276&D2/R1**
**Primary Document**

# 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 2013

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

**CLEARED FOR PUBLIC RELEASE**

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# FIGURES

# TABLES

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# ACRONYMS

| | |
|---|---|
| acfm | actual cubic feet per minute |
| ARAR | applicable or relevant and appropriate requirement |
| bgs | below ground surface |
| BTU | British thermal unit |
| CI | confidence interval |
| DNAPL | dense nonaqueous-phase liquid |
| DOE | U.S. Department of Energy |
| DQO | data quality objective |
| DSS | Decision Support Software |
| EPA | U.S. Environmental Protection Agency |
| E/PP | excavation/penetration permit |
| EVS-ES | Environmental Visualization Systems Expert System |
| FFA | Federal Facility Agreement |
| FFS | focused feasibility study |
| FID | flame ionization detector |
| GAC | granular activated carbon |
| GC | gas chromatograph |
| HP | horsepower |
| HU | hydrogeologic unit |
| IDW | inverse distance weighting |
| KDEP | Kentucky Department for Environmental Protection |
| KO | knock-out tank |
| LDA | large diameter auger |
| LUC | land use control |
| MACT | Maximum Achievable Control Technologies |
| MDL | method detection limit |
| MW | monitoring well |
| NAL | no action level |
| OU | operable unit |
| PAH | polycyclic aromatic hydrocarbon |
| PC | personal computer |
| PGDP | Paducah Gaseous Diffusion Plant |
| PID | photoionization detector |
| psig | per square inch gauge |
| QAPP | Quality Assurance Project Plan |
| 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 |
| RGA | Regional Gravel Aquifer |
| RI | remedial investigation |
| ROD | record of decision |
| SI | site investigation |
| SPT | standard penetration test |
| SWMU | solid waste management unit |

| | |
|---|---|
| UCRS | Upper Continental Recharge System |
| VCS | vapor conditioning system |
| VFD | variable frequency drive |
| VOC | volatile organic compound |
| WAG | waste area grouping |
| ZVI | zero-valent iron |

# EXECUTIVE SUMMARY

This Remedial Design Report (RDR) 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 area(s).

This report contains information regarding the design of the *in situ* source treatment using deep soil mixing remediation system, including discussions of the following:

- Mixing soil using large diameter augers;
- Injecting hot air and steam to volatize targeted contaminants;
- Injecting zero-valent iron as a polishing step for treating residual VOCs;
- Treating recovered vapor through a vapor conditioning/treatment system;
- Treating condensate via localized air stripping and/or granular activated carbon;
- Excavating 2 ft of surface soil, stockpiling, and respreading after the completion of mixing; and
- Collecting data and monitoring.

This D2 RDR incorporates responses to comments provided by the U.S. Environmental Protection Agency and the Commonwealth of Kentucky based on their reviews of the D1 (90%) RDR and in agreements developed in parallel discussions among the Federal Facility Agreement parties regarding optimization of the D1 design.

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# 1. INTRODUCTION

This Remedial Design Report (RDR) presents the design for the remedial action (RA) to be implemented at the Southwest Groundwater Plume source area at Paducah Gaseous Diffusion Plant (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 (RDWP) (DOE 2012b).

Remedial design information provided in this report includes the following:

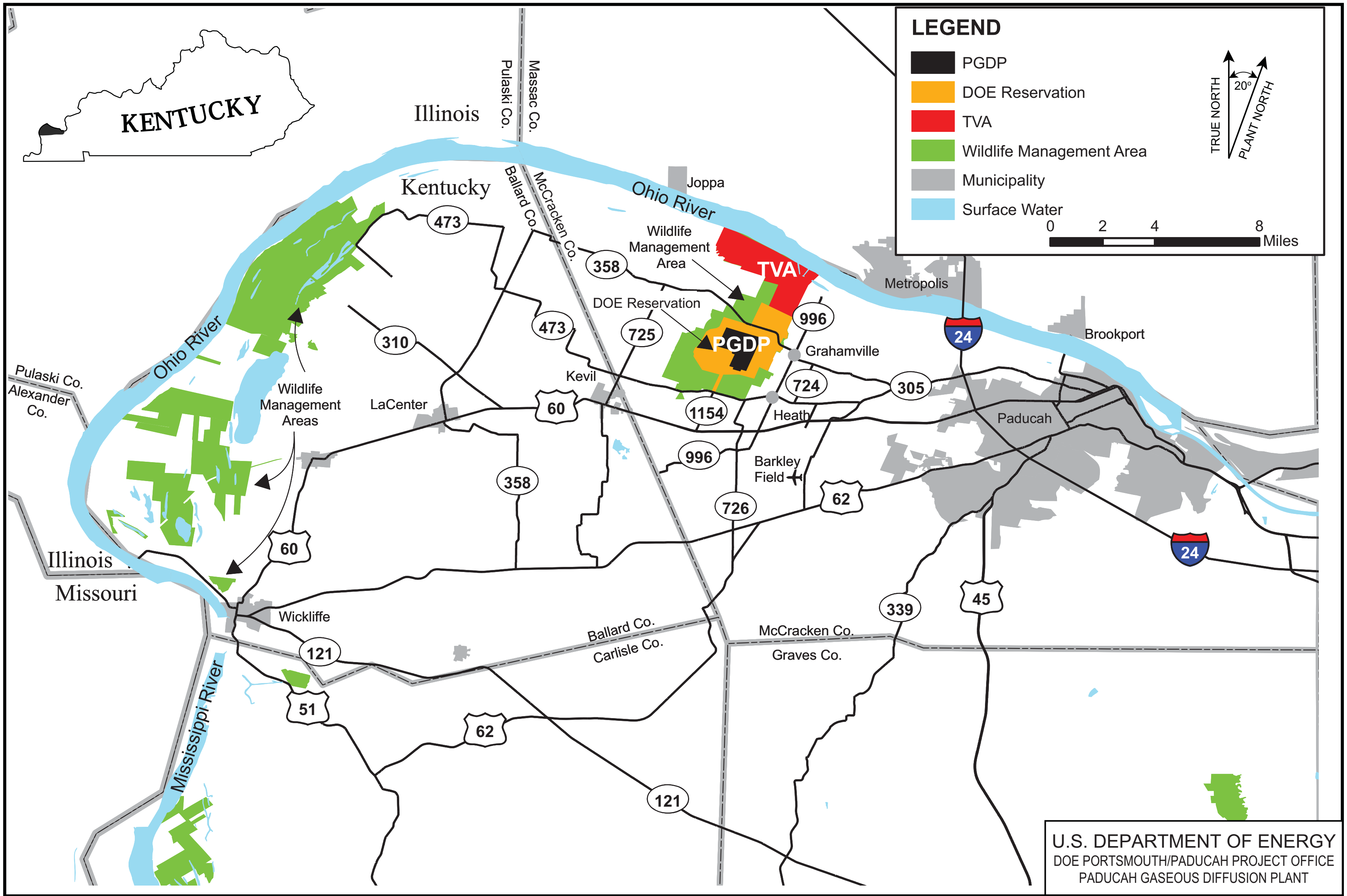
- Site description
- Technology description
- Remedial action objectives
- Design requirements
- Construction requirements

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 Cleaning Building (also known as the C-400 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. A Remedial Design Support Investigation (RDSI) was performed in 2012 consistent with the RDWP (DOE 2012b). Existing analytical data from the SWMU 1 source area is included on a CD as Appendix A.

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 and injection of zero-valent iron (ZVI). The RA also



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

Figure 1. PGDP Site Location

LATA Environmental Services of Kentucky, LLC 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. The ROD for this action does not identify a contingent remedy for implementation should the UCRS soil cleanup goals not be attained.

An RDSI is included in the RA that was completed during July, August, and September 2012. The data collected while implementing the RDSI was used to further delineate areas of TCE impacts in the Upper Continental Recharge System (UCRS) soils and in the upper RGA [hydrogeologic unit (HU4)]. The additional data was used to refine the area to be treated by the soil mixing process. Refer to Section 1.3 for more detailed information regarding the RDSI.

This RDR design report provides information regarding the remediation system, based on unit processes and activities to be included in the *in situ* source treatment. These processes and activities will include the following:

- Mixing soil using LDAs;
- Heating soil *in situ* by application of hot air/steam;
- Removing VOCs and steam from heated subsurface zones by vacuum extraction;
- Treating recovered vapor off-gas via vapor conditioning/treatment systems;
- Injecting a ZVI slurry mixture;
- Treating condensate via localized air stripping and/or granular activated carbon (GAC); and
- Collecting real-time data and monitoring contaminant concentrations in vapor phase during extraction and treatment.

This D2/R1 RDR for SWMU 1 incorporates responses to conditions provided by the U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky based on their reviews of the D2 RDR and in agreements developed in parallel discussions among the Federal Facility Agreement (FFA) parties regarding optimization of the D1 design. Design optimization discussions were held on April 10, 2013, in Atlanta, Georgia, on May 7, May 15, and May 16, 2013, and on June 16 and 17, 2013, via audio/Web-based conferencing. The following items composed the basis of discussion for optimization and describe the consensus/technical agreement reached by the parties regarding impacts to the final design.

- **Inclusion of Historical Analytical Results for TCE in Soil:** The parties reviewed available historical results for TCE in soil and determined that results from the following investigations contained analytical data that could be used to supplement the data obtained during the 2012 Remedial Design Support Investigation.

  - WAG 27 RI, 1998; and
  - SI Report for the Southwest Groundwater Plume, 2004.

  These data formed the basis of evaluation in the FFS, Proposed Plan and ROD. The parties agreed that data generated as part of the Phase II SI (DOE 1992) would not be used in developing the map of the TCE source area based on differences in investigation data quality objectives and changes in analytical technology.

- **Distribution of TCE Contamination in Soil at SWMU 1:** The TCE soil analytical data set was interpolated using C Tech Environmental Visualization Systems Expert System (EVS-ES). EVS-ES provides a number of methods for interpolating the data. The FFA parties reviewed the results of interpolating with the following methods:

  — Inverse distance weighting (IDW);
  — Nearest neighbor; and
  — Kriging.

  Ultimately, the FFA parties agreed to use Kriging as the interpolation method with Octant search for developing the vertical and horizontal extent of the TCE contamination with the use of the following agreed to approaches:

  — The TCE concentration area exceeding the TCE cleanup level of 73 µg/kg was determined using nominal (50% confidence interval) Kriging interpolation and is estimated to be approximately 13,500 $ft^2$.

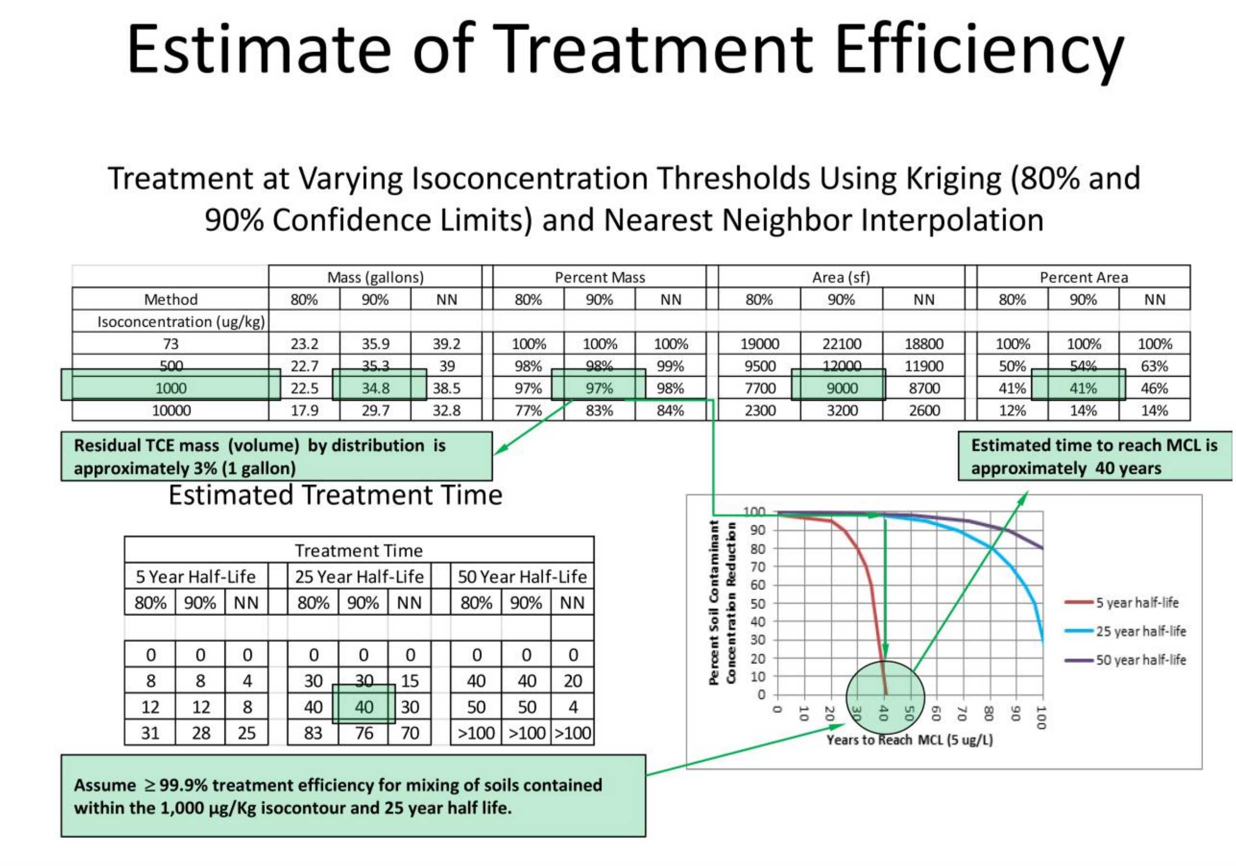
  — A 90% confidence interval of the Kriging interpolation was used to determine the location of the 1,000 µg/kg and 10,000 µg/kg TCE isoconcentration areas, which are estimated to be approximately 9,900 $ft^2$ and 3,700 $ft^2$, respectively.

  The volume of TCE estimated to be present within the area of each isoconcentration was calculated and greater than 96% of the TCE volume is located within the 90% confidence interval of the 1,000 µg/kg.

  **Treatment Efficiency—**The treatment technology employed in the final design has a demonstrated record of performance that indicates the contaminant removal rates in excess of 99% are expected, as opposed to the 91% removal rate assumed in the FFS, Proposed Plan, and ROD. The increase removal is rate is due to the combination of steam enhanced vapor stripping, combined with soil mixing and injection of ZVI. This increased efficiency has been determined from performance history at three remedial action locations, which were documented in corrective measures implementation reports (USAF 2007; USAF 2008; and USACE 2012).

  **Remedy Time Frame—**As documented in the signed ROD, leaching of residual VOCs was expected to impact RGA groundwater at levels that exceed the maximum contaminant level of 5 µg/L TCE for approximately 68 years (at 91% treatment efficiency) for soils that are ≥ 73 µg/kg TCE). It is now expected that the time period for leaching of residual VOCs will last approximately 40 years. The shorter expected period for leaching residual VOC results, in part, from assuming a 99% treatment efficiency, as opposed to the 91% treatment efficiency used in earlier calculations. Also, supporting this reduction is the increased understanding of VOC mass distribution (> 96% of the VOC mass is located within the area within the 1,000 µg/kg TCE contour), mixing of soils that are ≥ 1,000 µg/kg TCE, and the selection of targeted borings in areas outside the 1,000 µg/kg contour. Further detail concerning the determination of the reduced remedy time frame is included in Figure 2 and is referenced in DOE 2011.

  **Large Diameter Auger/Soil Mixing Area—**The FFA parties evaluated a number of approaches to determining the area to be mixed. The 90% RDR included mixing of all areas ≥ 73 µg/kg TCE. Subsequent discussions focused on conditions and evaluations described above with the intent of satisfying the goal of the ROD by reducing impacts to the RGA groundwater within the time frame identified in the ROD. Based on the available information the parties agreed to the following soil mixing configuration:



# Estimate of Treatment Efficiency

## Treatment at Varying Isoconcentration Thresholds Using Kriging (80% and 90% Confidence Limits) and Nearest Neighbor Interpolation

| | Mass (gallons) | | | Percent Mass | | | Area (sf) | | | Percent Area | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Method | 80% | 90% | NN | 80% | 90% | NN | 80% | 90% | NN | 80% | 90% | NN |
| Isoconcentration (ug/kg) | | | | | | | | | | | | |
| 73 | 23.2 | 35.9 | 39.2 | 100% | 100% | 100% | 19000 | 22100 | 18800 | 100% | 100% | 100% |
| 500 | 22.7 | 35.3 | 39 | 98% | 98% | 99% | 9500 | 12000 | 11900 | 50% | 54% | 63% |
| 1000 | 22.5 | 34.8 | 38.5 | 97% | 97% | 98% | 7700 | 9000 | 8700 | 41% | 41% | 46% |
| 10000 | 17.9 | 29.7 | 32.8 | 77% | 83% | 84% | 2300 | 3200 | 2600 | 12% | 14% | 14% |

**Residual TCE mass (volume) by distribution is approximately 3% (1 gallon)**

**Estimated time to reach MCL is approximately 40 years**

## Estimated Treatment Time

| Treatment Time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 5 Year Half-Life | | | 25 Year Half-Life | | | 50 Year Half-Life | | |
| 80% | 90% | NN | 80% | 90% | NN | 80% | 90% | NN |
| | | | | | | | | |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 8 | 4 | 30 | 30 | 15 | 40 | 40 | 20 |
| 12 | 12 | 8 | 40 | 40 | 30 | 50 | 50 | 4 |
| 31 | 28 | 25 | 83 | 76 | 70 | >100 | >100 | >100 |

**Assume ≥ 99.9% treatment efficiency for mixing of soils contained within the 1,000 µg/Kg isocontour and 25 year half life.**

Figure 2. Estimate of Treatment Efficiency

- The perimeter of the soil boring array will consist of large diameter auger borings placed on center along the 1,000 µg/kg TCE contour.

- Borings within the area defined by ≥ 1,000 µg/kg TCE and ≤ 10,000 µg/kg TCE will retain a target overlap of 10%. Boring placement may require some boring to have greater than 10% overlap and some boring to have less than 10% overlap.

- Borings within the area defined by ≥ 10,000 µg/kg TCE will retain a target overlap of 17.5%. Boring placement may require some boring to have greater than 17.5% overlap and some boring to have less than 17.5% overlap.

- Two areas will have targeted mixing borings that are placed in areas that contain apparent uncertainty based on closely spaced isoconcentration contours and associated sample density. These area are as follows:

  — Along the east side of the northern lobe in the vicinity of soil sample boring locations 001–169 and 001–303, a series of borings will be located outside the perimeter of borings that are located on center of the 1,000 µg/kg TCE contour. Approximately 4–6 borings will be located outboard of the perimeter array. These borings will not have overlap.

— Along the east-southeastern side of the source area in the vicinity of soil sample boring locations 001-308 and 001-160, a series of borings will be located outside the perimeter of borings that are located on center of the 1,000 μg/kg TCE contour. Approximately 7–9 borings will be located outboard of the perimeter array. These borings will not have overlap.

## 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: (1) loess, (2) continental deposits, and (3) McNairy Formation. The continental deposits are further divided into the subunits of upper continental deposits and lower continental deposits. Hydrogeologically, there are three major units: (1) UCRS, upper continental deposits; (2) RGA, lower continental deposits; and (3) McNairy Flow System.

The upper-most stratigraphic unit consists of fill (upper 2 ft or less in the area of the RDSI) and a layer of wind-deposited silt, 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 approximately 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 and 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 marine 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. The RGA consists of an upper thin sand unit (HU4), which is the basal unit of the Upper Continental Deposits, and a 30-ft thick sandy gravel unit (HU5), which comprises the Lower Continental Deposits beneath most of PGDP. 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. Monitoring wells (MWs) MW161 and MW162 are directly adjacent to the northern edge of SWMU 1 and are screened in the RGA from 78 to 83 ft (bgs) and the UCRS from 18 to 24 ft (bgs), respectively. Both monitoring wells were installed in 1991 and have had periodic water levels measured from 1991 to the present. MW162 (UCRS) has an average water level of 12.6 ft, while MW161 (RGA) has had an average water level over the same time period of 45.8 ft. 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. Flow direction for RGA groundwater in the area of SWMU 1 is northwest. 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 most of which are predominantly north and east of the SWMU 1 area.

## 1.2 TREATMENT SITE LOCATION

The treatment location for this RA is SWMU 1, C-747-C Oil Landfarm (Oil Landfarm), which is located near the western edge of the PGDP. The location of the SWMU 1 source area (Oil Landfarm) is shown in Figure 3 and is the focus of this RDR. SWMU 1 lies south of the C-745-A Cylinder Storage Yard. Railroads with associated drainage ditches bound SWMU 1 on the south, west, and southeast; 4th Street lies to the east and provides gravel road access to the SWMU 1 area.

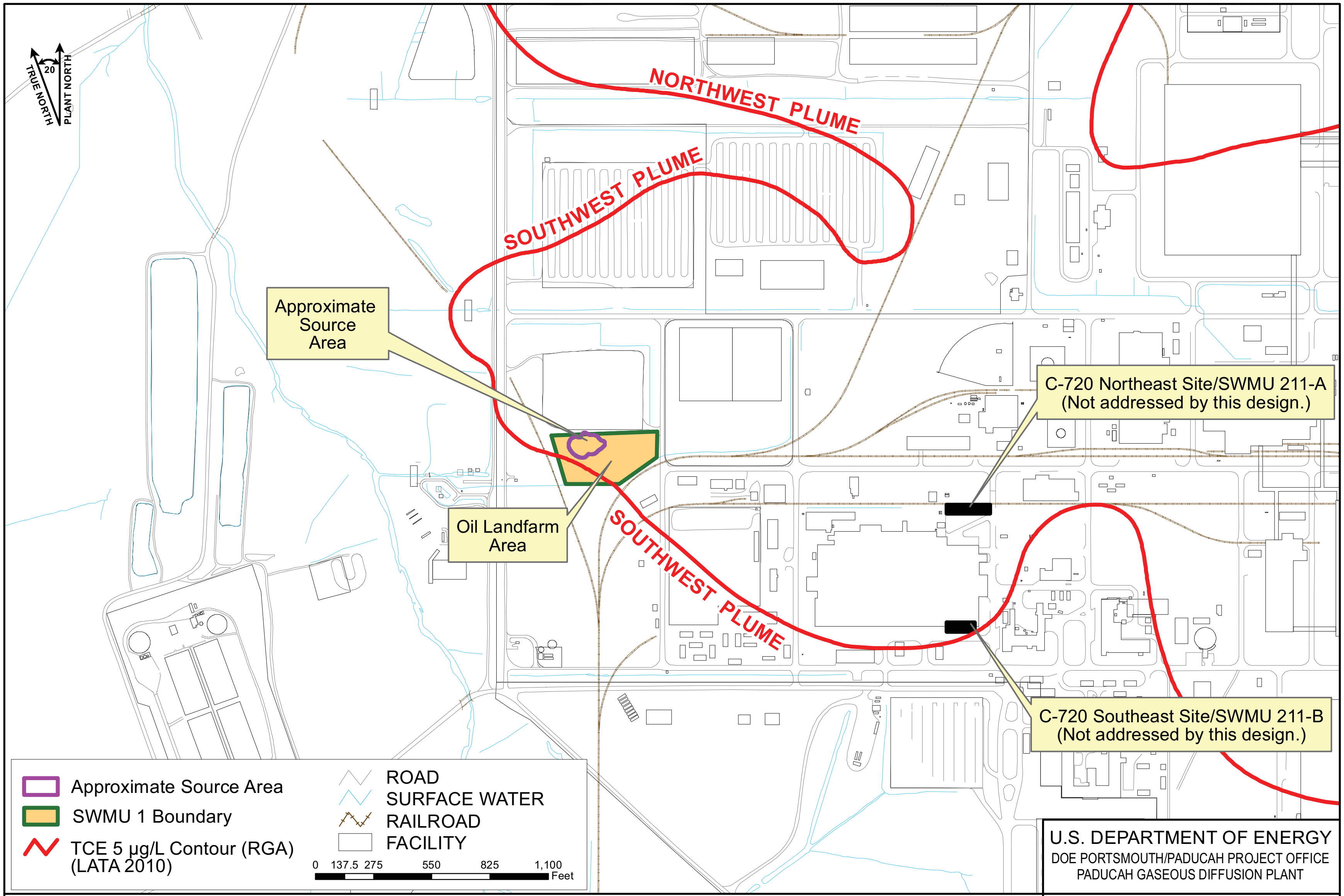
No underground utilities are located in the area to be soil mixed. Storm drains associated with the C-745-A Cylinder Storage Yard lies to the north. Buried storm drains also are located to the south away from the area to be soil mixed. Raw water and plant water lines are located on the southern edge of SWMU 1. See Figure 4. The SWMU 1 area has been investigated several times in support of remedy selection and development of this remedial design including the Phase II SI (1991); WAG 27 RI (1997); Southwest Plume SI (2004); and the RDSI (2012). The potential Southwest Plume source areas investigated in the Southwest 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.

## 1.3 REMEDIAL DESIGN SUPPORT INVESTIGATION

The RDSI was conducted in 2012 to gather supplemental data necessary for the design and implementation of the *in situ* source treatment deep soil mixing remedial action selected for SWMU 1. Furthermore, this RDSI field effort involved the collection of contaminant characterization and engineering design-related data at the C-720 SWMUs. This data will be used to support the Federal Facility Agreement parties' decision regarding selection and implementation of either enhanced *in situ* bioremediation or long-term monitoring strategies and the subsequent remedial design efforts. The design and implementation of either the enhanced *in situ* bioremediation or long-term monitoring RA 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 RDWP 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, has allowed for a more refined delineation of 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 consisted of 18 primary borings and 4 contingency borings. The contingency borings were drilled and incorporated consistent with decision rules contained in the RDSI work plan and to allow refinement of the lateral extent of the source treatment area. Results of the RDSI sampling efforts collected in support of the RDR are included in Table 1 and are based on analytical results received from the fixed-base laboratory. A total of 13 boreholes contained an average TCE result that exceeded the soil cleanup level of 73 micrograms per kilogram (µg/kg) (see Draft-Final Average column in Table 1). There were 11 boreholes that exceeded the TCE soil cleanup level in samples collected below the interval beginning at 55 ft bgs. Five boreholes had average concentrations that exceed the cleanup levels for TCE degradation compounds and 1,1-dichloroethene (DCE).

Specifically, there is one borehole that exceeded cleanup levels for *cis*-1,2-DCE, vinyl chloride, and 1,1-DCE accounting of three of the four instances. The other instance of cleanup level exceedance was for *cis*-1,2-DCE. All exceedances of the TCE breakdown products and 1,1-DCE also coincided with the



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

Figure 3. Southwest Plume Source Area Addressed by the Remedial Design

LATA Environmental Services of Kentucky, LLC

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**Legend**

- ● Soil Sampling Location
- ● Monitoring Well Location
- ▨ 90% CI TCE Concentration > 10,000 μg/kg Isopleth
- ▨ 90% CI TCE Concentration > 1,000 μg/kg Isopleth
- ▨ Nominal TCE Concentration > 73 μg/kg Isopleth
- ☐ Approximate SWMU Boundary
- ☐ WAG 23 RA Dioxin Grid
- ☐ Approximate Landfarm Plot Location (WAG27 RI)
- — Location of Excavation (WAG 27 RI, DOE 1999)
- — Electrical Line
- — Plant Water Line
- ▨ Storm Drain — Drainage Ditch

| Contour | Area (SF) | Area (SF) Exclusive |
|---|---|---|
| 73 | 13,497 | 3,569 |
| 1,000 | 9,928 | 6,272 |
| 10,000 | 3,656 | 3,656 |

Notes:
1. Results are presented in micrograms per kilogram (μg/kg).
2. Sampling depths are in feet below ground surface (ft bgs).
3. SWMU 1 Boundary and Source Area Boundary are estimated.
4. Source of 2009 Aerial: Williams Aerial & Mapping, Inc.

Path: (Titusville-01\Data\)T:\GIS\FR5082_Paducah\MXDs\SWMU1_SEPT2013\Data Labels Postings Revised Sept_2013.mxd 09 Sep 2013 JRB

**Estimated Extent of TCE Source Area**

Paducah Gaseous Diffusion Plant
Kevil, Kentucky

Geosyntec
consultants

Kennesaw
September 2013

Figure
4

## Table 1. Southwest Plume RDSI Characterization Data

DRAFT Final and Preliminary Soil Analytical Data (SWMU 1, C-747-C Oil Landfarm)

| 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) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
| | | | **Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)** | | **73** | | | | | **600** | | | | | **1080** | | | | | **34** | | | | | **130** | | | | |
| 001-311 | 7/20/2012 | 5 | NA | 0 | 120 | 120 | 140 | | 140 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.44 | U | 0.22 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 8.0 | 200 | 290 | 290 | 350 | | 350 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 15 | 13.0 | 437 | 1100 | 1100 | 1300 | | 1300 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 7.8 | U | 3.9 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 20 | 15.5 | 399 | 670 | 670 | 770 | | 770 | ND | 3.9 | 8.9 | U | 4.45 | ND | 3.05 | 7 | U | 3.5 | ND | 10.5 | 24 | U | 12 | ND | 9 | 21 | U | 10.5 |
| | | 25 | 20.5 | 56 | 540 | 540 | 590 | | 590 | ND | 3.8 | 8.3 | U | 4.15 | ND | 3 | 6.5 | U | 3.25 | ND | 10 | 22 | U | 11 | ND | 9 | 19 | U | 9.5 |
| | | 30 | 27.0 | 1,717 | 5300 | 5300 | 6300 | | 6300 | 360 | 360 | 430 | | 430 | ND | 3.4 | 8.1 | U | 4.05 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 35 | 34.9 | 19,820 | 6900 | 6900 | 8300 | | 8300 | 420 | 420 | 510 | | 510 | ND | 6.5 | 7.9 | U | 39.5 | ND | 11 | 27 | U | 13.5 | ND | 9.5 | 23 | U | 11.5 |
| | | 40 | 35.1 | 2,650 | 4600 | 4600 | 5500 | | 5500 | 310 | 310 | 370 | | 370 | ND | 3.05 | 7.4 | U | 3.7 | ND | 10.5 | 25 | U | 12.5 | ND | 9 | 22 | U | 11 |
| | 7/23/2012 | 45 | 40.5 | 9,280 | 2100 | 2100 | 2400 | | 2400 | 130 | 130 | 160 | J | 160 | ND | 3.2 | 7.5 | U | 3.75 | ND | 11 | 25 | U | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45D[3] | 40.5 | 9,280 | 1000 | | 1200 | | | 78 | | 91 | J | | ND | | 7.4 | U | | ND | | 25 | U | | ND | | 22 | U | |
| | | 50 | 47.0 | 676 | 1200 | 1200 | 1400 | | 1400 | 31 | 31 | 36 | J | 36 | ND | 3.05 | 7.2 | U | 3.6 | ND | 10.5 | 25 | U | 12.5 | ND | 9 | 22 | U | 11 |
| | | 55 | 54.0 | 899 | 950 | 950 | 1100 | | 1100 | 42 | 42 | 50 | J | 50 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 60 | 57.5 | 982 | 1300 | 1300 | 1500 | | 1500 | 72 | 72 | 85 | J | 85 | ND | 3.3 | 7.8 | U | 3.9 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 2089 | | | 2471 | | 115 | | | 138 | | 3 | | | 6 | | 10 | | | 12 | | 9 | | | 10 |
| 001-310 | 7/23/2012 | 5 | 3.5 | 0 | 5.8 | 5.8 | 6.3 | J | 6.3 | ND | 0.2505 | 0.56 | U | 0.28 | ND | 0.4 | 0.87 | U | 0.435 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 10 | 9.9 | 1,556 | 840 | 840 | 1000 | | 1000 | 460 | 460 | 540 | | 540 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 15 | 12.0 | 3,408 | 7100 | 7100 | 8300 | | 8300 | 2600 | 2600 | 3000 | | 3000 | ND | 3.25 | 7.7 | U | 3.85 | 58 | 58 | 26 | U | 13 | 21 | 21 | 23 | U | 11.5 |
| | | 20 | 16.0 | 312,000 | 890000 | 890000 | 960000 | | 960000 | ND | 1300 | 2900 | U | 1450 | ND | 1050 | 2200 | U | 1100 | ND | 3500 | 7600 | U | 3800 | ND | 3050 | 6700 | U | 3350 |
| | | 25 | 20.1 | 2,415 | 2900 | 2900 | 3300 | | 3300 | 250 | 250 | 280 | | 280 | ND | 3.5 | 7.8 | U | 3.8 | ND | 12 | 27 | U | 13.5 | ND | 10.5 | 23 | U | 11.5 |
| | 7/24/2012 | 30 | 29.5 | 41,290 | 380000 | 380000 | 440000 | | 440000 | ND | 200 | 460 | U | 230 | ND | 155 | 360 | U | 180 | ND | 500 | 1200 | U | 600 | ND | 460 | 1100 | U | 550 |
| | | 35 | 31.5 | 8,271 | 20000 | 20000 | 24000 | | 24000 | 810 | 810 | 960 | J | 960 | ND | 23.5 | 32 | U | 16 | ND | 45.5 | 110 | U | 55 | ND | 40 | 94 | U | 47 |
| | | 40 | 37.0 | 29,230 | 23000 | 23000 | 28000 | | 28000 | 1300 | 1300 | 1500 | J | 1500 | ND | 33.5 | 81 | U | 40.5 | ND | 115 | 280 | U | 140 | ND | 100 | 240 | U | 120 |
| | | 45 | 44.5 | 28,180 | 33000 | 33000 | 40000 | | 40000 | 1500 | 1500 | 1800 | | 1800 | ND | 18 | 42 | U | 21 | ND | 60 | 140 | U | 70 | ND | 55 | 130 | U | 65 |
| | | 50 | 47.5 | 21,170 | 37000 | 37000 | 45000 | | 45000 | 1300 | 1300 | 1600 | | 1600 | ND | 17 | 41 | U | 20.5 | ND | 55 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 55 | 50.1 | 24,140 | 37000 | 37000 | 44000 | | 44000 | 1500 | 1500 | 1800 | | 1800 | ND | 17 | 40 | U | 20 | ND | 55 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 60 | 55.1 | 36,120 | 2400 | 2400 | 2800 | | 2800 | ND | 4.85 | 11 | U | 5.5 | ND | 3.75 | 8.6 | U | 4.3 | ND | 13 | 29 | U | 24.5 | ND | 11 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 119437 | | | 133034 | | 935 | | | 1097 | | 111 | | | 118 | | 369 | | | 406 | | 322 | | | 358 |
| 001-309 | 7/24/2012 | 5 | 4.0 | 0 | 19 | 19 | 22 | | 22 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.395 | 0.92 | U | 0.455 | ND | 0.18 | 0.42 | U | 0.21 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 10 | 7.5 | 0 | 28 | 28 | 34 | | 34 | 11 | 11 | 14 | | 14 | ND | 0.38 | 0.92 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 12.5 | 0 | 16 | 16 | 19 | | 19 | 4.9 | 4.9 | 5.9 | J | 5.9 | ND | 0.18 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15D[3] | 17.0 | 0 | 14 | | 17 | | | 4.7 | | 5.7 | J | | ND | | 0.92 | U | | ND | | 0.42 | U | | ND | | 1.6 | U | |
| | | 20 | 17.0 | 28,100 | 2.6 | 2.6 | 2.9 | J | 2.9 | 0.6 | 0.6 | 0.67 | J | 0.67 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.48 | U | 0.24 | ND | 0.8 | 1.8 | U | 0.9 |
| | | 25 | 22.5 | 2,402 | 3600 | 3600 | 4100 | | 4100 | 1700 | 1700 | 1900 | | 1900 | ND | 3.3 | 7.5 | U | 3.75 | ND | 11 | 26 | U | 13 | ND | 10 | 22 | U | 11 |
| | 7/25/2012 | 30 | 25.1 | 161 | 3800 | 3800 | 3800 | | 3800 | 1700 | 1700 | 1700 | | 1700 | ND | 3.35 | 6.7 | U | 3.35 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | 35 | 31.5 | 2,407 | 3700 | 3700 | 3700 | | 3700 | 1300 | 1300 | 1300 | | 1300 | ND | 3.25 | 6.5 | U | 3.25 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 40 | 35.1 | 1,452 | 2600 | 2600 | 2600 | | 2600 | 820 | 820 | 820 | | 820 | ND | 3.05 | 6.1 | U | 3.5 | ND | 10.5 | 21 | U | 10.5 | ND | 9 | 18 | U | 9 |
| | | 45 | 40.5 | 6,070 | 2100 | 2100 | 2100 | | 2100 | 950 | 950 | 950 | | 950 | ND | 3.15 | 6.3 | U | 3.15 | ND | 10.5 | 21 | U | 10.5 | ND | 9.5 | 19 | U | 9.5 |
| | | 50 | 45.5 | 1,670 | 2500 | 2500 | 2500 | | 2500 | 860 | 860 | 860 | | 860 | ND | 3.15 | 6.3 | U | 3.15 | ND | 11 | 22 | U | 11 | ND | 9.5 | 19 | U | 9.5 |
| | | 55 | 52.5 | 1,838 | 2500 | 2500 | 2500 | | 2500 | 440 | 440 | 440 | | 440 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 60 | 59.5 | 4,340 | 2000 | 2000 | 2000 | | 2000 | 670 | 670 | 670 | | 670 | ND | 3.4 | 6.8 | U | 3.4 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 1905 | | | 1948 | | 705 | | | 722 | | 2 | | | 2 | | 7 | | | 8 | | 7 | | | 7 |
| 001-304 | 7/26/2012 | 5 | 3.5 | 0 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.43 | 0.96 | U | 0.48 | ND | 0.195 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 9.5 | 292 | 0.52 | 0.52 | 0.61 | J | 0.61 | 30 | 30 | 35 | | 35 | ND | 0.38 | 0.89 | U | 0.445 | 3.2 | 3.2 | 3.8 | J | 3.8 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.9 | 9,209 | 1900 | 1900 | 2300 | | 2300 | 360 | 360 | 440 | | 440 | ND | 3.7 | 8.9 | U | 4.45 | ND | 12.5 | 30 | U,* | 15 | ND | 11 | 27 | U | 13.5 |
| | | 20 [10] | 15.1 | 1,508 | 2300 | 2300 | 780 | | 780 | 350 | 350 | 190 | J | 190 | ND | 0.41 | 0.92 | U | 0.46 | 9.4 | 9.4 | 11 | | 11 | 2.7 | 2.7 | 3 | J | 3 |
| | | 25 | 21.0 | 473 | 3.7 | 3.7 | 4.2 | J | 4.2 | 3 | 3 | 3.5 | J | 3.5 | ND | 0.37 | 0.84 | U | 0.42 | ND | 0.17 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 30 | 26.5 | 0 | 62 | 62 | 64 | | 64 | 53 | 53 | 58 | | 58 | ND | 0.355 | 1.1 | U | 0.55 | 3.7 | 3.7 | 4.7 | J | 4.7 | ND | 0.6 | 1.9 | U | 0.95 |
| | | 35 | 30.5 | 527 | 50 | 50 | 130 | | 130 | 44 | 44 | 110 | | 110 | ND | 0.365 | 1.1 | U | 0.55 | 2.3 | 2.3 | 7.4 | J | 7.4 | ND | 0.65 | 1.9 | U | 0.95 |
| | | 35D[3] | 30.5 | 527 | 51 | | 60 | | | 47 | | 55 | | | ND | | 0.84 | U | | 2.3 | | 2.7 | J | | ND | | 1.4 | U | |
| | | 40 | 36.5 | 22 | 210 | 210 | 240 | | 240 | 110 | 110 | 9.3 | U | 4.65 | ND | 0.36 | 7.2 | U | 3.6 | ND | 11 | 25 | U,* | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45 | 42.5 | 0 | ND | | 15 | U | 7.5 | ND | 3.95 | 9.1 | U | 0.455 | ND | 3.1 | 7.1 | U | 3.55 | ND | 10.5 | 24 | U,* | 12 | ND | 9 | 21 | U | 10.5 |
| | | 50 | 46.5 | 611 | 390 | 390 | 240 | | 240 | 170 | 170 | 190 | J | 190 | ND | 4 | 8.7 | U | 4.35 | ND | 13.5 | 30 | U,* | 15 | ND | 12 | 26 | U | 13 |
| | | 55 | 50.1 | 1,250 | 680 | 680 | 770 | | 770 | 280 | 280 | 320 | | 320 | ND | 3.4 | 7.8 | U | 3.9 | ND | 11.5 | 26 | U,* | 13 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 55.1 | 246 | 680 | 680 | 820 | | 820 | 260 | 260 | 310 | | 310 | ND | 3.7 | 8.9 | U | 4.45 | ND | 12.5 | 30 | U,* | 15 | ND | 11 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 571 | | | 446 | | 139 | | | 138 | | 2 | | | 2 | | 8 | | | 9 | | 6 | | | 7 |
| 001-312 | 7/26/2012 | 5 | 3.5 | 0 | ND | 0.205 | 0.45 | U | 0.225 | ND | 0.31 | 0.7 | U | 0.35 | ND | 0.49 | 1.1 | U | 0.55 | ND | 0.225 | 0.5 | U | 0.25 | ND | 0.85 | 1.9 | U | 0.95 |
| | | 10 | 9.5 | 0 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 12.5 | 0 | 0.78 | 0.78 | 0.94 | U | 0.47 | ND | 0.255 | 0.61 | U | 0.305 | ND | 0.4 | 0.96 | U | 0.49 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 20 | 17.0 | 0 | 5.6 | 5.6 | 6.2 | J | 6.2 | 0.79 | 0.79 | 0.88 | J | 0.88 | ND | 0.4 | 0.89 | U | 0.445 | ND | 0.185 | 0.41 | U | 0.205 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 21.5 | 0 | ND | 0.19 | 0.41 | U | 0.205 | ND | 0.29 | 0.63 | U | 0.315 | ND | 0.455 | 0.98 | U | 0.49 | ND | 0.41 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 30 | 26.5 | 0 | 9.4 | 9.4 | 11 | | 11 | 1.8 | 1.8 | 2.1 | J | 2.1 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 35 | 31.5 | 0 | 67 | 67 | 80 | | 80 | 12 | 12 | 15 | | 15 | ND | 0.38 | 0.91 | U | 0.455 | ND | 0.175 | 0.41 | U | 0.205 | 3.7 | 3.7 | 4.4 | J | 4.4 |
| | | 40 | 39.0 | 0 | 80 | 80 | 95 | | 95 | 14 | 14 | 16 | | 16 | ND | 0.395 | 0.94 | U | 0.47 | ND | 0.18 | 0.43 | U | 0.215 | 4.7 | 4.7 | 5.6 | J | 5.6 |
| | | 45 | 43.0 | 0 | 32 | 32 | 38 | | 38 | 6.4 | 6.4 | 7.6 | J | 7.6 | ND | 0.415 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 50 | 49.9 | 0 | 4.5 | 4.5 | 5.3 | J | 5.3 | 1 | 1 | 1.2 | J | 1.2 | ND | 0.36 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 55 | 54.5 | 0 | 58 | 58 | 69 | | 69 | 11 | 11 | 13 | | 13 | ND | 0.37 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | 3.2 | 3.2 | 3.8 | J | 3.8 |
| | | 60 | 55.5 | 0 | 56 | 56 | 65 | | 65 | 10 | 10 | 12 | | 12 | ND | 0.38 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | 2.7 | 2.7 | 3.1 | J | 3.1 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 26 | | | 31 | | 5 | | | 6 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 2 |

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

DRAFT Final and Preliminary Soil Analytical Data (SWMU 1, C-747-C Oil Landfarm)

| 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) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
| Oil Landfarm UCRS Soil Cleanup Level (µg/Kg) | | | | | 73 | | | | | 600 | | | | | 1080 | | | | | 34 | | | | | 130 | | | | |
| 001-315 | 7/27/2012 | 5 | 4.0 | 0 | ND | 0.195 | 0.42 | U | 0.21 | ND | 0.3 | 0.65 | U | 0.325 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.46 | U | 0.23 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 10 | 7.5 | 0 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.265 | 0.64 | U | 0.32 | ND | 0.415 | 1 | U | 0.5 | ND | 0.19 | 0.46 | U | 0.23 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 15 | 14.5 | 0 | 1.9 | 1.9 | 2.2 | J | 2.2 | ND | 0.255 | 0.56 | U | 0.28 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 16.5 | 0 | 11 | 11 | 12 | | 12 | 0.66 | 0.66 | 0.74 | J | 0.74 | ND | 0.35 | 0.78 | U | 0.39 | ND | 0.16 | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 20D[3] | 16.5 | 0 | 11 | | 12 | | | 0.69 | | 0.87 | J | | ND | | 0.81 | U | | | | 0.37 | U | | U | | 1.4 | U | |
| | | 25 | 23.0 | 92 | 4100 | 4100 | 5000 | | 5000 | 260 | 260 | 310 | | 310 | ND | 3.4 | 8.3 | U | 4.15 | ND | 11.5 | 28 | U | 14 | ND | 10 | 25 | U | 12.5 |
| | | 30 | 25.1 | 1,978 | 3400 | 3400 | 4100 | | 4100 | 220 | 220 | 260 | | 260 | ND | 0.325 | 7.9 | U | 3.95 | ND | 11 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 33.5 | 15,018 | 3500 | 3500 | 4300 | | 4300 | 300 | 300 | 370 | | 370 | ND | 3.5 | 8.5 | U | 4.25 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 40 | 35.5 | 9,630 | 2100 | 2100 | 2400 | | 2400 | 200 | 200 | 230 | | 230 | ND | 3.15 | 7.3 | U | 0.365 | ND | 10.5 | 25 | U | 12.5 | ND | 9.5 | 22 | U | 11 |
| | | 45 | 40.1 | 15,100 | 4200 | 4200 | 5100 | | 5100 | 370 | 370 | 440 | | 440 | ND | 3.45 | 8.3 | U | 4.15 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 45.1 | 4,920 | 4000 | 4000 | 4900 | | 4900 | 360 | 360 | 440 | | 440 | ND | 3.4 | 8.3 | U | 4.15 | ND | 11.5 | 28 | U | 14 | ND | 10 | 25 | U | 12.5 |
| | | 55 | 50.1 | 10,700 | 2800 | 2800 | 3200 | | 3200 | 250 | 250 | 290 | | 290 | ND | 4.05 | 9.4 | U | 4.95 | ND | 13.5 | 32 | U | 16 | ND | 12 | 28 | U | 14 |
| | | 60 | 59.5 | 4,708 | 400 | 400 | 4600 | | 460 | ND | 4.8 | 11 | U | 5.5 | ND | 3.75 | 8.5 | U | 4.2 | ND | 12.5 | 29 | U | 14.5 | ND | 11 | 25 | U | 12.5 |
| | | 65 | 62.5 | 3,487 | 2500 | 2500 | 2900 | | 2900 | 120 | 120 | 130 | J | 130 | ND | 4.05 | 9.2 | U | 4.6 | ND | 14 | 31 | U | 15.5 | ND | 12 | 28 | U | 14 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 2078 | | | 2490 | | 160 | | | 191 | | 2 | | | 3 | | 8 | | | 10 | | 8 | | | 9 |
| 001-318 | 7/30/2012 | 5 | 3.0 | 0 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.56 | U | 0.28 | ND | 0.47 | 0.87 | U | 0.435 | ND | 0.225 | 0.4 | U | 0.2 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 10 | 9.0 | 0 | ND | 0.195 | 0.41 | U | 0.205 | ND | 0.3 | 0.63 | U | 0.315 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 15 | 13.0 | 0 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.55 | U | 0.275 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.415 | 0.39 | U | 0.195 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 20 | 19.0 | 0 | ND | 0.195 | 0.34 | U | 0.17 | ND | 0.3 | 0.53 | U | 0.265 | ND | 0.47 | 0.82 | U | 0.41 | ND | 0.215 | 0.38 | U | 0.19 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 20D[3] | 19.0 | 0 | ND | | 0.34 | U | | ND | | 0.52 | U | | ND | | 0.81 | U | | ND | | 0.37 | U | | ND | | 1.4 | U | |
| | | 25 | 20.5 | 553 | 0.55 | 0.55 | 0.33 | U | 0.165 | 0.66 | 0.66 | 0.51 | U | 0.255 | ND | 0.47 | 0.8 | U | 0.4 | ND | 0.215 | 0.37 | U | 0.185 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 30 | 29.0 | 0 | 110 | 110 | 65 | | 65 | 67 | 67 | 47 | | 47 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.215 | 0.39 | U | 0.195 | 3.3 | 3.3 | 2.4 | J | 2.4 |
| | | 35 | 34.0 | 24 | 170 | 170 | 200 | J | 200 | 160 | 160 | 190 | J | 190 | ND | 3.4 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U,* | 14 | ND | 10 | 24 | U | 12 |
| | | 40[5] | 35.5 | 58 | 170 | 170 | 190 | J | 190 | 160 | 160 | 190 | J | 190 | ND | 3.4 | 8.4 | U | 4.2 | ND | 11.5 | 29 | U | 1.45 | ND | 10 | 25 | U | 12.5 |
| | | 45 | 41.0 | 4 | 110 | 110 | 61 | | 61 | 64 | 64 | 44 | | 44 | ND | 0.47 | 1 | U | 0.5 | 0.94 | 0.94 | 0.46 | U | 0.23 | 5.5 | 5.5 | 3.5 | J | 3.5 |
| | | 50 | 46.0 | 16 | 29 | 29 | 19 | | 19 | 8.2 | 8.2 | 5.9 | J | 5.9 | ND | 0.47 | 0.95 | U | 0.475 | ND | 0.215 | 0.43 | U | 0.215 | 2.3 | 2.3 | 1.9 | J | 1.9 |
| | | 55 | 50.5 | 0 | 7.4 | 7.4 | 6.4 | J | 6.4 | 1.8 | 1.8 | 1.6 | J | 1.6 | ND | 0.47 | 0.82 | U | 0.41 | ND | 0.215 | 0.37 | U | 0.185 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 60 | 56.5 | 0 | 24 | 24 | 22 | | 22 | 24 | 24 | 22 | | 22 | ND | 0.47 | 0.89 | U | 0.445 | ND | 0.215 | 0.41 | U | 0.205 | ND | 0.8 | 1.5 | U | 0.75 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 52 | | | 47 | | 41 | | | 42 | | 1 | | | 1 | | 2 | | | 1 | | 3 | | | 3 |
| 001-317 | 7/30/2012 | 5 | 3.7 | 0 | ND | 0.195 | 0.41 | U | 0.205 | ND | 0.3 | 0.63 | U | 0.315 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | ND | 0.8 | 1.7 | U | 0.85 |
| | | 10 | 8.5 | 0 | 4.5 | 4.5 | 4.6 | J | 4.6 | 2.3 | 2.3 | 2.3 | J | 2.3 | ND | 0.47 | 0.94 | U | 0.47 | ND | 0.215 | 0.43 | U | 0.215 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 15 | 12.0 | 0 | 7.9 | 7.9 | 7.8 | J | 7.8 | 6.2 | 6.2 | 6.1 | J | 6.1 | ND | 0.47 | 0.93 | U | 0.465 | ND | 0.215 | 0.43 | U | 0.215 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 20 | 15.5 | 0 | 9 | 9 | 7.9 | J | 7.9 | 11 | 11 | 9.7 | | 9.7 | ND | 0.47 | 0.83 | U | 0.415 | ND | 0.215 | 0.38 | U | 0.19 | ND | 0.8 | 1.4 | U | 0.7 |
| | | 25 | 21.0 | 2,176 | 11 | 11 | 6.6 | J | 6.6 | 27 | 27 | 17 | | 17 | ND | 0.47 | 0.93 | U | 0.465 | ND | 0.215 | 0.42 | U | 0.21 | ND | 0.8 | 1.6 | U | 0.8 |
| | | 30 | 29.9 | 506 | 190 | 190 | 240 | J | 240 | 350 | 350 | 420 | | 420 | ND | 0.47 | 8.2 | U | 4.1 | 10 | 10 | 28 | U | 14 | 3.4 | 3.4 | 24 | U | 12 |
| | | 35 | 30.5 | 895 | 140 | 140 | 230 | J | 230 | 250 | 250 | 440 | | 440 | ND | 0.47 | 8 | U | 4 | 7 | 7 | 27 | U | 13.5 | 2.7 | 2.7 | 24 | U | 12 |
| | | 40 | 38.5 | 2,607 | 3.5 | 3.5 | 3.4 | J | 3.4 | 2.4 | 2.4 | 2.3 | J | 2.3 | ND | 0.47 | 0.91 | U | 0.455 | ND | 0.215 | 0.42 | U | 0.21 | 2.7 | 2.7 | 1.6 | U | 0.8 |
| | | 45 | 40.5 | 450 | 92 | 92 | 150 | | 150 | 100 | 100 | 180 | | 180 | ND | 0.47 | 0.99 | U | 0.495 | ND | 0.215 | 0.45 | U | 0.225 | 4.3 | 4.3 | 8.2 | J | 4.1 |
| | | 50 | 47.0 | 4,926 | 87 | 87 | 93 | | 93 | 37 | 37 | 40 | | 40 | ND | 0.47 | 1 | U | 0.5 | ND | 0.215 | 0.46 | U | 0.23 | 5.1 | 5.1 | 5.5 | J | 5.5 |
| | | 55 | 50.1 | 328 | ND | 0.195 | 0.36 | U | 0.18 | ND | 0.3 | 0.55 | U | 0.275 | ND | 0.47 | 0.86 | U | 0.43 | ND | 0.215 | 0.4 | U | 0.2 | ND | 0.8 | 1.5 | U | 0.75 |
| | | 60 | 56.0 | 0 | 29 | 29 | 28 | | 28 | 8.1 | 8.1 | 7.8 | J | 7.8 | ND | 0.47 | 0.9 | U | 0.45 | ND | 0.215 | 0.41 | U | 0.205 | ND | 0.8 | 1.5 | U | 0.75 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 48 | | | 64 | | 66 | | | 94 | | 0 | | | 1 | | 2 | | | 2 | | 2 | | | 3 |
| 001-316 | 7/31/2012 | 5 | 4.9 | 1,196 | ND | 0.165 | 0.33 | U | 0.165 | ND | 0.255 | 0.51 | U | 0.255 | ND | 0.4 | 0.8 | U | 0.4 | ND | 0.185 | 0.37 | U | 0.185 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 10 | 6.0 | 4,003 | ND | 0.165 | 0.33 | U | 0.165 | ND | 0.25 | 0.5 | U | 0.25 | ND | 0.395 | 0.79 | U | 0.395 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 10D[3] | 6.0 | 4,003 | ND | | 0.38 | U | | ND | 0.255 | 0.58 | U | | ND | 0.4 | 0.91 | U | | ND | 0.85 | 0.42 | U | | ND | 0.7 | 1.6 | U | |
| | | 15 | 10.1 | 6,571 | ND | 0.155 | 0.33 | U | 0.165 | | | 0.51 | U | 0.255 | | | 0.8 | U | 0.4 | | | 0.37 | U | 0.185 | | | 1.4 | U | 0.7 |
| | | 20 | 17.0 | 0 | ND | 0.155 | 0.31 | U | 0.155 | 4.8 | 4.8 | 4.8 | J | 4.8 | ND | 0.37 | 0.74 | U | 0.37 | 1.3 | 1.3 | 1.3 | J | 1.3 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 25 | 23.0 | 9,091 | 320 | 320 | 320 | | 320 | 430 | 430 | 430 | | 430 | ND | 3.85 | 7.7 | U | 0.385 | ND | 13 | 26 | U | 13 | ND | 11.5 | 23 | U | 11.5 |
| | | 30 | 29.9 | 6,875 | 2400 | 2400 | 2400 | | 2400 | 1200 | 1200 | 1200 | | 1200 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11.5 | 23 | U | 11.5 | ND | 10 | 20 | U | 10 |
| | | 35 | 31.5 | 4,443 | 2900 | 2900 | 2900 | | 2900 | 1300 | 1300 | 1300 | | 1300 | ND | 3.5 | 7 | U | 3.5 | ND | 12 | 24 | U | 12 | ND | 10.5 | 21 | U | 10.5 |
| | | 40 | 35.5 | 8,915 | 1500 | 1500 | 1500 | | 1500 | 410 | 410 | 410 | | 410 | ND | 3.3 | 6.6 | U | 3.3 | ND | 11 | 22 | U | 11 | ND | 10 | 20 | U | 10 |
| | | 45 | 41.0 | 2,242 | 12 | 12 | 12 | | 12 | 3.6 | 3.6 | 3.6 | J | 3.6 | ND | 0.41 | 0.82 | U | 0.41 | ND | 0.185 | 0.37 | U | 0.185 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 50 | 46.5 | 14 | 52 | 52 | 52 | | 52 | 7.7 | 7.7 | 7.7 | J | 7.7 | ND | 0.415 | 0.83 | U | 0.415 | ND | 0.19 | 0.38 | U | 0.19 | 2.1 | 2.1 | 2.1 | J | 2.1 |
| | | 55 | 54.0 | 0 | 6 | 6 | 6 | J | 6 | 0.59 | 0.59 | 0.59 | J | 0.59 | ND | 0.39 | 0.78 | U | 0.39 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 60 | 57.0 | 0 | 14 | 14 | 14 | | 14 | 1.4 | 1.4 | 1.4 | J | 1.4 | ND | 0.415 | 0.83 | U | 0.415 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 600 | | | 600 | | 280 | | | 280 | | 1 | | | 1 | | 4 | | | 4 | | 4 | | | 4 |
| 001-314 | 7/31/2012 | 5 | 3.0 | 0 | ND | 0.175 | 0.35 | U | 0.175 | ND | 0.27 | 0.54 | U | 0.27 | ND | 0.42 | 0.84 | U | 0.42 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 10 | 7.0 | 0 | 1.3 | 1.3 | 1.3 | J | 1.3 | ND | 0.265 | 0.53 | U | 0.265 | ND | 0.41 | 0.82 | U | 0.41 | ND | 0.19 | 0.38 | U | 0.19 | ND | 0.7 | 1.4 | U | 0.7 |
| | | 15 | 14.0 | 0 | 1.8 | 1.8 | 1.8 | J | 1.8 | ND | 0.245 | 0.49 | U | 0.245 | ND | 0.38 | 0.76 | U | 0.38 | ND | 0.175 | 0.35 | U | 0.175 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 20 | 19.0 | 0 | ND | 0.18 | 0.36 | U | 0.18 | ND | 0.275 | 0.55 | U | 0.275 | ND | 0.435 | 0.87 | U | 0.435 | ND | 0.2 | 0.4 | U | 0.2 | ND | 0.75 | 1.5 | U | 0.75 |
| | | 25 | 21.5 | 0 | 13 | 13 | 13 | | 13 | 8.4 | 8.4 | 8.4 | | 8.4 | ND | 0.375 | 0.75 | U | 0.375 | ND | 0.17 | 0.34 | U | 0.17 | ND | 0.65 | 1.3 | U | 0.65 |
| | | 30 | 28.5 | 5,709 | ND | 0.75 | 200 | J | 200 | 81 | 81 | 110 | J | 110 | ND | 3.55 | 8.3 | U | 4.15 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 35 | 32.0 | 695 | 220 | 220 | 220 | | 220 | 120 | 120 | 120 | J | 120 | ND | 3.2 | 6.4 | U | 3.2 | ND | 11 | 22 | U | 11 | ND | 9.5 | 19 | U | 9.5 |
| | | 40 | 36.5 | 511 | 240 | 240 | 270 | | 270 | ND | 4.3 | 9.7 | U | 4.85 | ND | 3.35 | 7.6 | U | 3.8 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 45 | 44.0 | 883 | 790 | 790 | 950 | | 950 | 540 | 540 | 640 | | 640 | ND | 3.45 | 8.2 | U | 4.1 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 50 | 49.0 | 732 | 850 | 850 | 1000 | | 1000 | 570 | 570 | 700 | | 700 | ND | 3.5 | 8.4 | U | 4.2 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 55 | 50.1 | 2,451 | 440 | 440 | 510 | | 510 | 230 | 230 | 270 | | 270 | ND | 3.35 | 7.8 | U | 0.39 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 57.5 | 1,846 | 180 | 180 | 210 | J | 210 | ND | 4.4 | 10 | U | 5 | ND | 3.4 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 65 | 60.5 | 137 | 350 | 350 | 410 | | 410 | 170 | 170 | 200 | J | 200 | ND | 3.45 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10.5 | 24 | U | 12 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 237 | | | 291 | | 133 | | | 158 | | 2 | | | 2 | | 7 | | | 8 | | 6 | | | 7 |

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

DRAFT Final and Preliminary Soil Analytical Data (SWMU 1, C-747-C Oil Landfarm)

| 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) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
| **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 | 0.36 | U | 0.18 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 8.0 | 0 | ND | 0.16 | 0.39 | U | 0.195 | ND | 0.245 | 0.6 | U | 0.3 | ND | 0.385 | 0.94 | U | 0.47 | ND | 0.175 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.75 |
| | | 10D[3] | 8.0 | 0 | ND | | 0.42 | U | | ND | | 0.64 | U | | ND | | 1 | U | | ND | | 0.46 | U | | ND | | 1.7 | U | |
| | | 15 | 12.5 | 0 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.26 | 0.63 | U | 0.315 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 20 | 18.0 | 0 | ND | 0.16 | 0.37 | U | 0.185 | ND | 0.25 | 0.57 | U | 0.285 | ND | 0.39 | 0.9 | U | 0.45 | ND | 0.18 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 23.5 | 0 | ND | 0.16 | 0.34 | U | 0.17 | ND | 0.24 | 0.53 | U | 0.265 | ND | 0.38 | 0.83 | U | 0.415 | ND | 0.175 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 30 | 26.0 | 0 | 0.98 | 0.98 | 1.2 | J | 1.2 | 1.8 | 1.8 | 2.1 | J | 2.1 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | 8.4 | 8.4 | 2.7 | J | 2.7 |
| | | 35 | 33.0 | 0 | 0.83 | 0.83 | 0.97 | J | 0.97 | 1.4 | 1.4 | 1.7 | J | 1.7 | ND | 0.395 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 40 | 37.0 | 0 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.435 | 0.95 | U | 0.475 | ND | 0.195 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 45 | 43.0 | 0 | 7.2 | 7.2 | 8.4 | J | 8.4 | 3 | 3 | 3.5 | J | 3.5 | ND | 0.37 | 0.86 | U | 0.43 | ND | 0.17 | 0.39 | U | 0.195 | 2.1 | 2.1 | 2.4 | J | 2.4 |
| | | 50 | 48.5 | 0 | 5.8 | 5.8 | 6.9 | J | 6.9 | 4.2 | 4.2 | 4.9 | J | 4.9 | ND | 0.39 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | 2.7 | 2.7 | 3.2 | J | 3.2 |
| | | 55 | 52.5 | 0 | 7.1 | 7.1 | 8.3 | J | 8.3 | 4.4 | 4.4 | 5.1 | J | 5.1 | ND | 0.38 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | 3.5 | 3.5 | 4.1 | J | 4.1 |
| | | 60 | 57.5 | 0 | 7.2 | 7.2 | 8.5 | J | 8.5 | 4.1 | 4.1 | 4.8 | J | 2.4 | ND | 0.385 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | 2.9 | 2.9 | 3.4 | J | 1.7 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 3 | | | 3 | | 2 | | | 2 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 2 |
| 001-308 | 8/1/2012 | 5 | 4.9 | 0 | ND | 0.165 | 0.41 | U | 0.205 | ND | 0.155 | 0.62 | U | 0.31 | ND | 0.4 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 10 | 9.0 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.26 | 0.63 | U | 0.315 | ND | 0.41 | 0.99 | U | 0.495 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 15 | 12.5 | 0 | 2.4 | 2.4 | 2.8 | J | 2.8 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 16.0 | 0 | 5.1 | 5.1 | 5.8 | J | 5.8 | 1 | 1 | 1.2 | J | 1.2 | ND | 0.34 | 0.78 | U | 0.39 | ND | 0.155 | 0.36 | U | 0.19 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 20D[3] | 16.0 | 0 | 2.2 | | 2.6 | J | | ND | | 0.58 | U | | ND | | 0.9 | U | | ND | | 0.41 | U | | ND | | 1.5 | U | |
| | | 25 | 23.5 | 0 | 38 | 38 | 45 | | 45 | 15 | 15 | 18 | | 18 | ND | 0.34 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 30 | 29.5 | 659 | 270 | 270 | 310 | | 310 | 66 | 66 | 76 | J | 76 | ND | 3.4 | 7.7 | U | 3.65 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 34.0 | 5,998 | 0.66 | 0.66 | 0.74 | J | 0.74 | ND | 0.245 | 0.56 | U | 0.28 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 40 | 37.0 | 1,192 | ND | 0.4 | 0.44 | U | 0.22 | ND | 0.31 | 0.68 | U | 0.34 | ND | 0.485 | 1.1 | U | 0.55 | ND | 0.22 | 0.49 | U | 0.245 | ND | 0.85 | 1.8 | U | 0.9 |
| | | 45 | 44.9 | 69 | 410 | 410 | 490 | | 490 | 120 | 120 | 150 | J | 150 | ND | 3.55 | 8.4 | U | 4.2 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 48.5 | 0 | 190 | 190 | 230 | J | 230 | 49 | 49 | 59 | J | 59 | ND | 3.35 | 8.1 | U | 4.05 | ND | 11.5 | 28 | U | 14 | ND | 10 | 24 | U | 12 |
| | | 55 | 54.9 | 150 | 210 | 210 | 250 | | 250 | 58 | 58 | 68 | J | 68 | ND | 3.2 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 60 | 58.5 | 500 | 180 | 180 | 200 | | 200 | 38 | 38 | 42 | | 42 | ND | 0.4 | 0.88 | U | 0.44 | ND | 0.18 | 0.4 | U | 0.2 | ND | 4.25 | 2.4 | J | 2.4 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 109 | | | 128 | | 29 | | | 35 | | 1 | | | 2 | | 4 | | | 5 | | 4 | | | 5 |
| 001-303 | 8/2/2012 | 5 | 4.0 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.255 | 0.62 | U | 0.31 | ND | 0.395 | 0.97 | U | 0.485 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 10 | 9.0 | 0 | 4.3 | 4.3 | 5.2 | J | 5.2 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 14.5 | 0 | 15 | 15 | 17 | | 17 | 6.5 | 6.5 | 7.5 | J | 7.5 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 20 | 19.5 | 0 | 0.38 | 0.38 | 0.43 | J | 0.43 | ND | 0.255 | 0.57 | U | 0.285 | ND | 0.4 | 0.9 | U | 0.45 | ND | 0.18 | 0.41 | U | 0.205 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 21.0 | 0 | ND | 0.16 | 0.36 | U | 0.18 | ND | 0.295 | 0.55 | U | 0.275 | ND | 0.385 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 30 | 27.5 | 0 | 2.5 | 2.5 | 3 | J | 3 | 1.3 | 1.3 | 1.6 | J | 1.6 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 35 | 34.5 | 12 | 0.36 | 0.36 | 0.41 | J | 0.41 | 0.93 | 0.93 | 1.1 | J | 1.1 | ND | 0.42 | 0.96 | U | 0.48 | ND | 0.19 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 39.9 | 281 | 290 | 290 | 340 | | 340 | 180 | 180 | 210 | J | 210 | ND | 3.45 | 8.2 | U | 4.1 | ND | 12 | 28 | U | 14 | ND | 0.7 | 25 | U | 12.5 |
| | | 45 | 43.5 | 2,016 | 290 | 290 | 340 | | 340 | 190 | 190 | 220 | J | 220 | ND | 3.45 | 8.1 | U | 4.05 | ND | 12 | 28 | U | 14 | ND | 10.5 | 24 | U | 12 |
| | | 50 | 49.5 | 530 | 430 | 430 | 510 | | 510 | 240 | 240 | 280 | | 280 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 55 | 50.1 | 5,530 | 25 | 25 | 29 | | 29 | 20 | 20 | 23 | | 23 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 58.5 | 8,551 | 680 | 680 | 19 | U | 9.5 | 320 | 320 | 11 | U | 5.5 | ND | 0.395 | 8.6 | U | 4.3 | 13 | 13 | 29 | U | 14.5 | 6.6 | 6.6 | 26 | U | 13 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 145 | | | 105 | | 80 | | | 62 | | 1 | | | 2 | | 4 | | | 5 | | 3 | | | 5 |
| 001-305 | 8/2/2012 | 5 | 4.5 | 0 | 2.9 | 2.9 | 3.6 | J | 3.6 | ND | 0.265 | 0.65 | U | 0.325 | ND | 0.425 | 1 | U | 0.5 | ND | 0.19 | 0.46 | U | 0.23 | ND | 0.7 | 1.7 | U | 0.755 |
| | | 10 | 8.5 | 0 | 29 | 29 | 35 | | 35 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.0 | 0 | 45 | 45 | 54 | | 54 | 2 | 2 | 2.4 | J | 2.4 | ND | 0.365 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 20 | 18.5 | 0 | 13 | 13 | 14 | | 14 | 5.6 | 5.6 | 6.2 | J | 6.2 | ND | 0.365 | 0.81 | U | 0.405 | ND | 0.165 | 0.37 | U | 0.185 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25 | 24.5 | 0 | 530 | 530 | 640 | | 640 | ND | 4.45 | 11 | U | 5.5 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 30 | 25.1 | 246 | 130 | 130 | 160 | J | 160 | ND | 4.6 | 11 | U | 5.5 | ND | 3.6 | 8.6 | U | 4.3 | ND | 12 | 29 | U | 14.5 | ND | 10.5 | 26 | U | 13 |
| | | 35 | 30.5 | 1,826 | 330 | 30 | 380 | | 380 | ND | 4.2 | 9.8 | U | 4.9 | ND | 3.3 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 40 | 39.9 | 870 | 1500 | 1500 | 1800 | | 1800 | ND | 4.15 | 9.7 | U | 4.85 | ND | 3.25 | 7.6 | U | 3.8 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 45 | 43.5 | 2,344 | 390 | 390 | 470 | | 470 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8.1 | U | 4.05 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 50 | 45.5 | 28,514 | 3.5 | 3.5 | 4.1 | J | 4.1 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.395 | 0.94 | U | 0.47 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 55 | 53.0 | 2,330 | 11 | 11 | 13 | | 13 | ND | 0.26 | 0.61 | U | 0.305 | ND | 0.41 | 0.95 | U | 475 | ND | 0.19 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 55.1 | 224 | 160 | 160 | 190 | | 190 | 3.5 | 3.5 | 4.1 | U | 2.05 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 237 | | | 314 | | 3 | | | 3 | | 2 | | | 41 | | 5 | | | 6 | | 5 | | | 5 |
| 001-306 | 8/3/2012 | 5 | 3.5 | 0 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.375 | 0.88 | U | 0.44 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 5D[3] | 3.5 | 0 | ND | | 0.39 | U | | ND | | 0.6 | U | | ND | | 0.94 | U | | ND | | 0.43 | U | | ND | | 1.6 | U | |
| | | 10 | 8.0 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.25 | 0.62 | U | 0.31 | ND | 0.39 | 0.96 | U | 0.48 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.65 | 1.7 | U | 0.85 |
| | | 15 | 13.5 | 0 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 17.0 | 0 | ND | 0.16 | 0.35 | U | 0.175 | ND | 0.245 | 0.55 | U | 0.275 | ND | 0.38 | 0.85 | U | 0.425 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 22.0 | 45 | 1.1 | 1.1 | 1.2 | J | 1.2 | ND | 0.23 | 0.5 | U | 0.25 | ND | 0.355 | 0.79 | U | 0.395 | ND | 0.165 | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | 30 | 25.1 | 1 | 30 | 30 | 36 | | 36 | 1.5 | 1.5 | 1.8 | J | 1.8 | ND | 0.38 | 0.91 | U | 0.455 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 35 | 32.0 | 0 | 27 | 27 | 32 | | 32 | 1.5 | 1.5 | 1.7 | J | 0.85 | ND | 0.405 | 0.96 | U | 0.48 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 39.0 | 50 | 58 | 58 | 67 | | 67 | 3.8 | 3.8 | 4.4 | J | 2.2 | ND | 0.385 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 40.5 | 0 | 75 | 75 | 86 | | 86 | 5.1 | 5.1 | 5.9 | J | 2.95 | ND | 0.365 | 0.84 | U | 0.42 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 50 | 49.5 | 0 | 64 | 64 | 74 | J | 74 | ND | 4.35 | 10 | U | 5 | ND | 3.4 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 55 | 53.0 | 1,215 | 37 | 37 | 43 | | 43 | 3.1 | 3.1 | 3.6 | J | 1.8 | ND | 0.385 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 60 | 56.0 | 39 | 110 | 110 | 130 | | 130 | 7.9 | 7.9 | 9.4 | J | 4.7 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 34 | | | 39 | | 2 | | | 2 | | 1 | | | 1 | | 1 | | | 1 | | 1 | | | 2 |

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

DRAFT Final and Preliminary Soil Analytical Data (SWMU 1, C-747-C Oil Landfarm)

| 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) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
| **Oil Landfarm UCRS Soil Cleanup Level (µg/Kg)** | | | | | **73** | | | | | **600** | | | | | **1080** | | | | | **34** | | | | | **130** | | | | |
| 001-313 | 8/6/2012 | 5 | 3.5 | 227 | 21 | 21 | 24 | | 24 | ND | 0.28 | 0.61 | U | 0.305 | ND | 0.44 | 0.96 | U | 0.48 | ND | 0.2 | 0.44 | U | 0.22 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 7.5 | 599 | 83 | 83 | 100 | | 100 | 1.4 | 1.4 | 1.8 | J | 1.8 | ND | 0.385 | 0.94 | U | 0.47 | ND | 0.175 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 10.5 | 1,419 | 46 | 46 | 55 | | 55 | 3.1 | 3.1 | 3.7 | J | 3.7 | ND | 0.385 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.817 |
| | | 20 | 19.5 | 22,230 | 150 | 150 | 170 | | 170 | 7.3 | 7.3 | 8.1 | J | 8.1 | ND | 0.38 | 0.85 | U | 0.425 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25 | 21.5 | 54,270 | ND | 7 | 15 | U | 7.5 | ND | 4.45 | 9.1 | U | 4.55 | ND | 3.3 | 7.1 | U | 3.55 | ND | 11.5 | 24 | U | 12 | ND | 10 | 21 | U | 21 |
| | | 25D[3] | 21.5 | 54,270 | 120 | | | | | 14 | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 30 | 28.0 | 31,310 | 12000 | 12000 | 14000 | | 14000 | 950 | 950 | 1100 | | 1100 | ND | 6.5 | 16 | U | 16 | ND | 22.5 | 53 | U | 53 | ND | 19.5 | 46 | U | 23 |
| | | 35 | 33.5 | 58,714 | 15000 | 15000 | 18000 | | 18000 | 1000 | 1000 | 1200 | | 1200 | ND | 17 | 41 | U | 20.5 | ND | 60 | 140 | U | 70 | ND | 50 | 120 | U | 60 |
| | | 40 | 35.1 | 70,550 | 12000 | 12000 | 14000 | | 14000 | 770 | 770 | 900 | | 900 | ND | 7 | 16 | U | 8 | ND | 23 | 54 | U | 27 | ND | 20.5 | 48 | U | 24 |
| | | 45 | 40.1 | 17,730 | 900 | 900 | 1100 | | 1100 | ND | 4.3 | 10 | U | 5 | ND | 3.35 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 50 | 45.5 | 5,745 | 220 | 220 | 260 | | 260 | ND | 4.25 | 9.9 | U | 4.95 | ND | 3.3 | 7.8 | U | 3.9 | ND | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 55 | 52.0 | 4,187 | ND | 7.5 | 17 | U | 8.5 | ND | 4.3 | 9.8 | U | 4.9 | nd | 3.35 | 7.6 | U | 3.8 | nd | 11.5 | 26 | U | 13 | ND | 10 | 23 | U | 11.5 |
| | | 60 | 55.1 | 2,749 | 12 | 12 | 14 | | 14 | ND | 0.26 | 0.6 | U | 0.3 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 62.5 | 60.5 | 2796 | 640 | 640 | 760 | | 760 | ND | 4.25 | 10 | U | 5 | ND | 3.3 | 7.9 | U | 3.95 | ND | 11 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 3161 | | | 3731 | | 212 | | | 249 | | 4 | | | 5 | | 13 | | | 17 | | 11 | | | 14 |
| 001-319[4] | 8/6/2012 | 5 | 4.5 | 0 | ND | 0.18 | 0.4 | U | 0.2 | | | 0.62 | U | 0.31 | | | 0.97 | U | 0.495 | | | 0.44 | U | 0.22 | | | 1.7 | U | 0.85 |
| | | 10 | 9 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.255 | 0.61 | U | 0.305 | ND | 0.405 | 0.96 | U | 0.49 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 15 | 11 | 0 | 0.98 | 0.98 | 1.2 | J | 1.2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 20 | 17.5 | 0 | 42 | 42 | 48 | | 48 | 7.9 | 7.9 | 9 | J | 9 | ND | 0.405 | 0.93 | U | 0.465 | ND | 0.185 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 25 | 23 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.345 | 0.87 | U | 0.435 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 30 | 29 | 0 | 1.7 | 1.7 | 2 | J | 2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.98 | U | 0.49 | ND | 0.19 | 0.45 | U | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30D[3] | 29 | 0 | 1.6 | | | | | ND | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 35 | 32 | 0 | 2.3 | 2.3 | 2.7 | J | 2.7 | ND | 0.23 | 0.54 | U | 0.27 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 40 | 39 | 0 | 45 | 45 | 55 | | 55 | 1.5 | 1.2 | 1.5 | J | 0.75 | | | 1.3 | U | 0.65 | | | 0.58 | U | 0.29 | | | 2.2 | U | 1.1 |
| | | 45 | 44.5 | 0 | 3.2 | 3.2 | 3.9 | J | 3.9 | ND | 0.23 | 0.56 | U | 0.28 | ND | 0.365 | 0.88 | U | 0.44 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.6 | 1.5 | U | 0.75 |
| | 8/7/2012 | 50 | 49.5 | 115 | 21 | 21 | 24 | | 24 | 0.92 | 0.92 | 1.1 | J | 1.1 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 55 | 53.5 | 1,712 | 110 | 110 | 130 | | 130 | 7.9 | 7.9 | 9 | J | 9 | ND | 0.415 | 0.94 | U | 0.47 | ND | 0.19 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 60 | 59.0 | 1,373 | 9.2 | 9.2 | 10 | | 10 | 0.83 | 0.83 | 0.92 | J | 0.92 | ND | 0.39 | 0.87 | U | 0.435 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 65 | 64.1 | 593 | 5.2 | 5.2 | 5.7 | J | 5.7 | | | 0.52 | J | 0.52 | | | 0.79 | U | 0.395 | | | 0.36 | U | 0.18 | ND | 0.6 | 1.3 | U | 0.65 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 19 | | | 22 | | 2 | | | 2 | | 0 | | | 0 | | 0 | | | 0 | | 1 | | | 1 |
| 001-320[4] | 8/7/2012 | 5 | 4.0 | 0 | ND | 0.16 | 0.39 | U | 0.195 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.93 | U | 465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 10 | 6.5 | 43 | ND | 0.155 | 0.37 | U | 0.185 | ND | 0.2 | 0.58 | U | 0.29 | ND | 0.37 | 0.9 | U | 0.45 | ND | 0.17 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 14.9 | 1,175 | 160 | 160 | 180 | | 180 | 8.2 | 8.2 | 9.6 | | 9.6 | ND | 0.365 | 0.89 | U | 0.445 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 17 | 1,074 | 5.9 | 5.9 | 7 | J | 7 | ND | 0.235 | 0.55 | U | 0.275 | ND | 0.365 | 0.86 | U | 0.43 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 23 | 198 | 110 | 110 | 130 | | 130 | 5 | 5 | 6.1 | J | 6.1 | ND | 0.4 | 0.97 | U | 0.485 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30 | 28 | 5,007 | 610 | 610 | 720 | | 720 | 42 | 42 | 49 | J | 49 | ND | 3.3 | 7.8 | U | 0.39 | ND | 11.5 | 27 | U | 23.5 | ND | 10 | 23 | U | 11.5 |
| | | 35 | 32 | 2,548 | 950 | 950 | 1100 | | 1100 | 70 | 70 | 83 | J | 83 | ND | 3.35 | 7.9 | U | 3.95 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 23 | U | 11.5 |
| | | 40 | 38.5 | 2,275 | 910 | 910 | 1100 | | 1100 | 63 | 63 | 74 | J | 74 | ND | 3.45 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 45 | 44 | 3,601 | 1200 | 1200 | 1500 | | 1500 | 91 | 91 | 110 | J | 110 | ND | 3.45 | 8.4 | U | 4.2 | ND | 12 | 28 | U | 14 | ND | 10.5 | 25 | U | 12.5 |
| | | 50 | 49.5 | 448 | 210 | 210 | 250 | | 250 | 16 | 16 | 19 | J | 19 | ND | 3.2 | 7.7 | U | 3.65 | ND | 11 | 26 | U | 13 | ND | 9.5 | 23 | U | 11.5 |
| | | 55 | 52.0 | 507 | 400 | 400 | 480 | | 480 | 27 | 27 | 32 | J | 32 | ND | 3.4 | 8 | U | 4 | ND | 11.5 | 27 | U | 13.5 | ND | 10 | 24 | U | 12 |
| | | 60 | 56.5 | 937 | 1.2 | 1.2 | 1.3 | J | 1.3 | ND | 0.3 | 0.69 | U | 0.385 | ND | 0.47 | 1.1 | U | 0.55 | ND | 0.215 | 0.49 | U | 0.245 | ND | 0.8 | 1.8 | U | 0.9 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 380 | | | 456 | | 27 | | | 32 | | 2 | | | 41 | | 6 | | | 8 | | 5 | | | 6 |
| 001-321[4] | 8/8/2012 | 5 | 4.0 | 335 | 1.3 | 1.3 | 1.5 | J | 1.5 | ND | 0.24 | 0.57 | U | 0.285 | ND | 0.38 | 0.9 | U | 0.45 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 10 | 7.5 | 16 | 2.7 | 2.7 | 3.3 | J | 3.3 | 4.3 | 4.3 | 5.2 | J | 5.2 | ND | 0.375 | 0.92 | U | 0.46 | ND | 0.17 | 0.42 | U,* | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 13.5 | 0 | 2.5 | 2.5 | 3.1 | J | 3.1 | 7 | 7 | 8.5 | J | 8.5 | ND | 0.355 | 0.86 | U | 0.43 | ND | 0.165 | 0.39 | U,* | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 20 | 17.5 | 107 | ND | 0.165 | 0.36 | U | 0.18 | ND | 0.25 | 0.56 | U | 0.29 | ND | 0.395 | 0.87 | U | 0.445 | ND | 0.18 | 0.4 | U | 0.2 | ND | 0.7 | 1.5 | U | 0.75 |
| | | 25 | 20.5 | 23 | ND | 0.155 | 0.34 | U | 0.17 | ND | 0.24 | 0.52 | U | 0.26 | ND | 0.375 | 0.82 | U | 0.41 | ND | 0.175 | 0.37 | U | 0.185 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 25D[3] | 20.5 | 23 | 1.1 | | | | | 1.6 | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 30 | 28.5 | 3,315 | 28 | 28 | 35 | | 35 | 68 | 68 | 83 | | 83 | ND | 0.4 | 0.98 | U | 0.49 | ND | 0.185 | 0.45 | U,* | 0.225 | 5.3 | 5.3 | 6.5 | J | 6.5 |
| | | 35 | 32 | 312 | 8.4 | 8.4 | 9.5 | | 9.5 | 17 | 17 | 19 | | 19 | | | 0.83 | U | 0.415 | U | 0.415 | 0.38 | U,* | 0.19 | 2 | 2 | 2.2 | J | 2.2 |
| | | 40 | 38 | 136 | ND | 0.175 | 0.41 | U | 0.205 | ND | 0.27 | 0.63 | U | 0.315 | ND | 0.42 | 0.99 | U | 0.495 | ND | 0.195 | 0.45 | U,* | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 45 | 40.5 | 113 | 8.4 | 8.4 | 10 | | 10 | 13 | 13 | 15 | | 15 | ND | 0.4 | 0.95 | U | 0.475 | ND | 0.185 | 0.43 | U,* | 0.215 | 3.8 | 3.8 | 4.5 | J | 4.5 |
| | | 50 | 49.5 | 0 | 8 | 8 | 9.3 | J | 9.3 | 15 | 15 | 18 | | 18 | ND | 0.38 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | 1.9 | 1.9 | 2.3 | J | 2.3 |
| | | 55 | 54.0 | 0 | 15 | 15 | 18 | | 18 | 27 | 27 | 32 | | 32 | ND | 0.375 | 0.89 | U | 0.445 | ND | 0.17 | 0.41 | U | 0.205 | 4.4 | 4.4 | 5.2 | J | 5.2 |
| | | 60 | 59.0 | 0 | 14 | 14 | 17 | | 17 | 21 | 21 | 26 | | 26 | ND | 0.38 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U,* | 0.21 | 4.1 | 4.1 | 5 | J | 5 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 7 | | | 9 | | 14 | | | 17 | | 0 | | | 0 | | 0 | | | 0 | | 2 | | | 3 |
| 001-322[4] | 8/8/2012 | 5 | 4.0 | 63 | ND | 0.175 | 0.39 | U | 0.195 | ND | 0.275 | 0.61 | U | 0.305 | ND | 0.425 | 0.95 | U | 0.475 | ND | 0.195 | 0.43 | U,* | 0.215 | ND | 0.75 | 1.6 | U | 0.8 |
| | | 10 | 9 | 0 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.25 | 0.59 | U | 0.295 | ND | 0.39 | 0.92 | U | 0.46 | ND | 0.18 | 0.42 | u,* | 0.21 | ND | 0.65 | 1.6 | u | 0.8 |
| | | 15 | 10.1 | 13 | ND | 0.155 | 0.36 | U | 0.18 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20[6] | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 25 | 21.5 | 0 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.41 | 0.97 | U | 0.485 | ND | 0.19 | 0.45 | U,* | 0.225 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 30 | 29 | 54 | 27 | 27 | 32 | | 32 | 18 | 18 | 21 | | 21 | | | 0.96 | U | 0.48 | U | 0.48 | 1.4 | J | 1.4 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 35 | 34.9 | 167 | 5.2 | 5.2 | 5.8 | J | 5.8 | 3.5 | 3.5 | 3.9 | J | 3.9 | ND | 0.405 | 0.91 | U | 0.455 | ND | 0.185 | 0.42 | U,* | 0.21 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 40 | 35.1 | 261 | 3.9 | 3.9 | 4.5 | J | 4.5 | | | 2.3 | J | 2.3 | | | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U,* | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 44.5 | 4 | 86 | 86 | 100 | | 100 | 42 | 42 | 50 | | 50 | ND | 0.365 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U,* | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 50 | 48.5 | 51 | 69 | 69 | 80 | | 80 | 40 | 40 | 46 | | 46 | ND | 0.37 | 0.86 | U | 0.43 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 55 | 54.9 | 244 | 44 | 44 | 53 | | 53 | 29 | 29 | 34 | | 34 | ND | 0.36 | 0.85 | U | 0.425 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.6 | 1.5 | U | 0.75 |
| | | 60 | 57.5 | 129 | 2.7 | 2.7 | 3.2 | J | 3.2 | 2.6 | 2.6 | 3.1 | J | 3.1 | ND | 0.44 | 1 | U | 1 | ND | 0.2 | 0.47 | U | 0.235 | ND | 0.75 | 1.8 | U | 0.9 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 22 | | | 25 | | 14 | | | 15 | | 0 | | | 1 | | 0 | | | 0 | | 1 | | | 1 |

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

DRAFT Final and Preliminary Soil Analytical Data (SWMU 1, C-747-C Oil Landfarm)

| 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) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Preliminary Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] | Reported | Preliminary Average[1,2] | Draft Final Reported | Qual[8] | Draft Final Average[9] |
| **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 | 0.38 | U | 0.19 | ND | 0.245 | 0.59 | U | 0.295 | ND | 0.38 | 0.92 | U | 0.46 | ND | 0.175 | 0.42 | U | 0.21 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 10 | 5.1 | 1 | ND | 0.165 | 0.39 | U | 0.195 | ND | 0.25 | 0.6 | U | 0.3 | ND | 0.39 | 0.93 | U | 0.465 | ND | 0.18 | 0.43 | U | 0.215 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 15 | 10.1 | 10 | ND | 0.155 | 0.35 | U | 0.175 | ND | 0.235 | 0.54 | U | 0.27 | ND | 0.37 | 0.84 | U | 0.42 | ND | 0.17 | 0.84 | U | 0.42 | ND | 0.65 | 1.4 | U | 0.7 |
| | | 15D[3] | 10.1 | 10 | ND | | | | | ND | | | | | ND | | | | | ND | | | | | ND | | | | |
| | | 20 | 17 | 0 | ND | 0.185 | 0.41 | U | 0.205 | ND | 0.285 | 0.63 | U | 0.315 | ND | 0.445 | 0.99 | U | 0.495 | ND | 0.205 | 0.45 | U | 0.225 | ND | 0.75 | 1.7 | U | 0.85 |
| | | 25 | 20.5 | 0 | ND | 0.165 | 0.4 | U | 0.2 | ND | 0.25 | 0.61 | U | 0.305 | ND | 0.39 | 0.95 | U | 0.475 | ND | 0.18 | 0.44 | U | 0.22 | ND | 0.65 | 1.6 | U | 0.8 |
| | | 30 | 25.1 | 71 | 6.9 | 6.9 | 7.9 | J | 7.9 | 4.3 | 4.3 | 4.9 | J | 4.9 | ND | 0.355 | 0.81 | U | 0.405 | ND | 0.165 | 0.37 | U | 0.185 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 35 | 31 | 92 | 15 | 15 | 17 | | 17 | 12 | 12 | 13 | | 13 | ND | 0.385 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 40 | 35.5 | 33 | 25 | 25 | 28 | | 28 | 17 | 17 | 20 | | 20 | ND | 0.38 | 0.87 | U | 0.435 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 45 | 44 | 189 | 57 | 57 | 67 | | 67 | 40 | 40 | 47 | | 47 | ND | 0.355 | 0.82 | U | 0.41 | ND | 0.16 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 50 | 45.1 | 328 | 83 | 83 | 96 | | 96 | 58 | 58 | 67 | | 67 | ND | 0.36 | 0.83 | U | 0.415 | ND | 0.165 | 0.38 | U | 0.19 | ND | 0.6 | 1.4 | U | 0.7 |
| | | 55 | 50.1 | 510 | 12 | 12 | 13 | | 13 | 19 | 19 | 21 | | 21 | ND | 0.375 | 0.85 | U | 0.425 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 60 | 57.5 | 448 | 27 | 27 | 30 | | 30 | 19 | 19 | 21 | | 21 | ND | 0.65 | 1.4 | U | 0.7 | ND | 0.295 | 0.66 | U | 0.33 | ND | 1.1 | 2.5 | U | 1.25 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 19 | | | 22 | | 14 | | | 16 | | 0 | | | 0 | | 0 | | | 0 | | 1 | | | 1 |
| 001-302 | 8/10/2012 | 5 | 2.0 | 0 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.26 | 0.62 | U | 0.31 | ND | 0.405 | 0.97 | U | 0.485 | ND | 0.185 | 0.44 | U | 0.22 | ND | 0.7 | 1.7 | U | 0.85 |
| | | 10 | 5.5 | 0 | ND | 0.155 | 0.36 | U | 0.18 | ND | 0.235 | 0.56 | U | 0.28 | ND | 0.37 | 0.88 | U | 0.44 | ND | 0.17 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 15 | 11 | 45 | ND | 0.16 | 0.37 | U | 0.185 | ND | 0.24 | 0.56 | U | 0.28 | ND | 0.38 | 0.88 | U | 0.44 | ND | 0.175 | 0.4 | U | 0.2 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 20 | 18 | 0 | ND | 0.155 | 0.35 | U | 0.175 | ND | 0.24 | 0.54 | U | 0.27 | ND | 0.375 | 0.85 | U | 0.425 | ND | 0.17 | 0.39 | U | 0.195 | ND | 0.65 | 1.5 | U | 0.75 |
| | | 25 | 24 | 0 | 22 | 22 | 26 | | 26 | | | 15 | | 15 | | | 0.91 | U | 0.455 | | | 1.8 | J | 1.8 | | | 2.2 | J | 2.2 |
| | | 30 | 28.5 | 1,140 | 25 | 25 | 28 | | 28 | 9.5 | 9.5 | 11 | | 11 | ND | 0.415 | 0.93 | U | 0.465 | ND | 0.19 | 0.43 | U | 0.215 | ND | 0.7 | 1.6 | U | 0.8 |
| | | 35 | 31 | 414 | 280 | 280 | 310 | J | 310 | 72 | 72 | 82 | J | 82 | ND | 6.5 | 15 | U | 7.5 | ND | 22 | 50 | U | 25 | ND | 19 | 43 | U | 21.5 |
| | | 40 | 36.5 | 35 | 37 | 37 | 43 | | 43 | 14 | 14 | 16 | | 16 | ND | 0.455 | 1.1 | U | 0.55 | ND | 0.21 | 0.48 | U | 0.24 | 3.5 | 3.5 | 4.1 | J | 4.1 |
| | | 45 [7] | NA | NA | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | 50 | 47.5 | 578 | 21 | 21 | 24 | | 24 | 5.3 | 5.3 | 5.9 | J | 5.9 | ND | 0.435 | 0.97 | U | 0.485 | ND | 0.2 | 0.44 | U | 0.22 | ND | 0.75 | 1.7 | U | 0.85 |
| | | 55 | 53.0 | 278 | 200 | 200 | 230 | J | 230 | 39 | 39 | 46 | J | 46 | ND | 3.8 | 9 | U | 4.5 | ND | 13 | 31 | U | 15.5 | ND | 11.5 | 27 | U | 13.5 |
| | | 57.5 | 55.5 | 493 | 150 | 150 | 180 | | 180 | 27 | 27 | 32 | | 32 | ND | 0.45 | 1.1 | U | 0.55 | ND | 0.205 | 0.49 | U | 0.245 | 2.8 | 2.8 | 3.4 | J | 3.4 |
| | | Prelim. Borehole Average Analytical Value (0-60') | | | | 67 | | | 77 | | 17 | | | 19 | | 1 | | | 1 | | 4 | | | 4 | | 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 draft final average borehole soil VOC values which were then rounded to the nearest whole number.
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 Denotes duplicate (QA/QC) sample, duplicate samples were not used in the sample VOC averaging calculations.
4 Contingency Boring Locations
5 2 sets of analytical data reported by TA for the 35-40' interval at boring 001-318, SMO determined that reported values should be used. TCE Borehole Average changed from 66 µg/Kg to 52 µg/Kg.
6 Reportedly no 15-20 foot sample collected from 001-322.
7 Reportedly no 40-45 foot sample collected from 001-302.
8 **Qualifier Definitions:** **U** - Non-detect; **J** - Result is less than the RL but greater than or equal to the MDL and the concentration is an approximate value; **X** - Surrogate is outside control limits; **E** - Result exceeds calibration range; **F** - RPD of the MS and MSD exceeds the control limits / MS or MSD exceeds the control limits; **H** - Sample was prepped or analyzed beyond the specified holding time; ***** - RPD of the LCS and LCSD exceeds the control limits.
9 For analytical results identified with a (U) qualifier, a value equal to one half of the sample quantitation limit (SQL ) was used to calculate the Draft Final average borehole soil VOC values.
10 SMO adjusted analytical data for sample 001-304 collected at 20 ft (8-28-2012).

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exceedances of TCE, as would be expected. As such, it will not be necessary to conduct mixing and treatment of other VOC areas located outside of the overall TCE treatment area footprint.

Soil sampling results from RDSI sampling efforts at SWMU 1 are presented on Table 1. For each RDSI soil boring location (001-301 through 001-322), the depth-specific data has been presented for each detected VOC and an arithmetic average has been calculated for each detected VOC at each soil boring location. Arithmetic average concentrations have been calculated for borings in instances where the VOC was not detected above the sample-specific method detection limit (MDL). For the depth intervals within the boring that were nondetect for the VOC, one-half of the MDL was used in calculating the average borehole VOC concentration within the boring. The average values then were rounded to the nearest whole number.

In addition to the RDSI data, 49 historical soil borings were used in the development of the dataset used to support the selection of the area to be soil mixed. These historical soil borings were drilled as part of the WAG 27 and Southwest Plume SIs, performed in 1997 and 2004, respectively. The sample results from those borings are contained in Table 2. The sample results also were used to determine the area of SWMU 1 to be soil mixed and is discussed in Section 1.4, Environmental Visualization Software Evaluation-TCE Extent and Mass Estimate.

## 1.4 ENVIRONMENTAL VISUALIZATION SOFTWARE EVALUATION AND VOC MASS ESTIMATE

TCE results in soil were interpolated using the C Tech EVS-ES to estimate the mass of TCE at SWMU 1 and the horizontal and vertical extent of contamination at isoconcentration levels of 73 µg/kg, 1,000 µg/kg, and 10,000 µg/kg. The primary purpose of the TCE mass estimate is to assist in the design of the off-gas treatment system. In addition, the EVS-ES estimate of extent is used to determine the layout of the LDA borings.

EVS is similar to other Environmental Decision Support Software (DSS), such as SitePro and Spatial Analysis and Decision Assistance, and was evaluated by EPA and DOE in 1998 with five other DSS packages. EVS underwent an environmental technology verification report in March 2000 that concluded that "the main strengths of EVS-PRO are its outstanding 3-D visualization capabilities and its capability to rapidly process, analyze and visualize data" and "the demonstration showed the EVS-PRO software can be used to generate reliable and useful analyses for evaluating environmental contamination problems."

Several interpolation techniques, including IDW, nearest neighbor, and kriging were evaluated, with kriging ultimately selected as the primary interpolation technique. Kriging is a stochastic technique similar to IDW averaging in that it uses a linear combination of weights at known points to estimate the value at the grid nodes. Kriging is named after D. G. Krige, who used the kriging underlying theory to estimate ore content (Krige 1951). Kriging uses a variogram (also called a semivariogram), which is a representation of the spatial and data differences between some or all possible "pairs" of points in the measured data set. The variogram then describes the weighting factors that will be applied for the interpolation.

It is acknowledged that there are significant uncertainties associated with providing a mass estimate of dense nonaqueous-phase liquid (DNAPL) regardless of the interpolation technique; however, kriging is a useful and valid approach to estimating the extent of source area at various isoconcentration levels below the threshold of residual saturation. Kriging also provides insight about the mass distribution at differing isoconcentration levels. Uncertainty has been considered by estimating mass at different levels of

### Table 2.  Southwest Plume Historical TCE Characterization Data*

| Boring ID | Date of Collection | Depth, bgs, feet | Prefix | Concentration, µg/kg | Laboratory Qualifier† |
|---|---|---|---|---|---|
| 001-105 | 2/25/1998 | 10 | < | 700 | U |
| 001-105 | 2/25/1998 | 5 | < | 600 | U |
| 001-106 | 2/26/1998 | 10 | < | 400 | U |
| 001-106 | 2/26/1998 | 5 | < | 600 | U |
| 001-107 | 2/25/1998 | 10 | < | 500 | U |
| 001-107 | 2/25/1998 | 5 | < | 600 | U |
| 001-108 | 2/25/1998 | 10 | < | 500 | U |
| 001-108 | 2/25/1998 | 5 | < | 600 | U |
| 001-109 | 2/24/1998 | 10 | < | 500 | U |
| 001-109 | 2/24/1998 | 5 | < | 500 | U |
| 001-110 | 2/24/1998 | 10 | < | 500 | U |
| 001-110 | 2/24/1998 | 5 | < | 500 | U |
| 001-111 | 2/23/1998 | 10 | < | 500 | U |
| 001-111 | 2/23/1998 | 5 | < | 600 | U |
| 001-113 | 2/23/1998 | 10 | < | 600 | U |
| 001-113 | 2/23/1998 | 5 | < | 800 | U |
| 001-114 | 2/24/1998 | 10 | < | 500 | U |
| 001-114 | 2/24/1998 | 5 | < | 600 | U |
| 001-115 | 2/25/1998 | 10 | < | 600 | U |
| 001-115 | 2/25/1998 | 5 | < | 600 | U |
| 001-116 | 2/27/1998 | 10 |  | 100 | J |
| 001-116 | 2/27/1998 | 5 | < | 500 | U |
| 001-117 | 2/25/1998 | 10 | < | 500 | U |
| 001-117 | 2/25/1998 | 5 | < | 500 | U |
| 001-118 | 2/25/1998 | 10 | < | 600 | U |
| 001-118 | 2/25/1998 | 5 | < | 700 | U |
| 001-119 | 2/25/1998 | 10 | < | 700 | U |
| 001-119 | 2/25/1998 | 5 | < | 700 | U |
| 001-126 | 2/26/1998 | 10 | < | 600 | U |
| 001-126 | 2/26/1998 | 5 | < | 700 | U |
| 001-127 | 2/26/1998 | 10 | < | 400 | U |
| 001-127 | 2/26/1998 | 5 | < | 500 | U |
| 001-128 | 2/26/1998 | 10 | < | 400 | U |
| 001-128 | 2/26/1998 | 5 | < | 700 | U |
| 001-129 | 2/24/1998 | 10 | < | 500 | U |
| 001-129 | 2/24/1998 | 5 | < | 600 | U |
| 001-130 | 2/23/1998 | 10 | < | 500 | U |
| 001-130 | 2/23/1998 | 5 | < | 500 | U |
| 001-131 | 2/23/1998 | 10 | < | 600 | U |
| 001-131 | 2/23/1998 | 5 | < | 800 | U |
| 001-132 | 2/23/1998 | 10 | < | 270 | U |
| 001-132 | 2/23/1998 | 5 | < | 600 | U |
| 001-133 | 2/23/1998 | 10 | < | 600 | U |
| 001-133 | 2/23/1998 | 5 | < | 600 | U |

## Table 2.  Southwest Plume Historical Characterization Data* (Continued)

| Boring ID | Date of Collection | Depth, bgs, feet | Prefix | Concentration, µg/kg | Laboratory Qualifier† |
|---|---|---|---|---|---|
| 001-134 | 2/24/1998 | 10 | < | 500 | U |
| 001-134 | 2/24/1998 | 5 | < | 500 | U |
| 001-135 | 2/26/1998 | 10 | < | 400 | U |
| 001-135 | 2/26/1998 | 5 | < | 600 | U |
| 001-152 | 3/5/1998 | 10 |  | 170 | J |
| 001-152 | 3/5/1998 | 5 |  | 55 | J |
| 001-153 | 3/5/1998 | 10 |  | 2100 |  |
| 001-153 | 3/5/1998 | 5 |  | 480 |  |
| 001-154 | 3/5/1998 | 10 |  | 26 | J |
| 001-154 | 3/5/1998 | 5 |  | 60 | J |
| 001-155 | 3/6/1998 | 10 |  | 460 |  |
| 001-156 | 3/6/1998 | 10 |  | 48000 |  |
| 001-156 | 3/6/1998 | 5 |  | 31000 |  |
| 001-157 | 3/6/1998 | 10 |  | 87000 |  |
| 001-157 | 3/6/1998 | 5 |  | 12000 |  |
| 001-158 | 3/6/1998 | 10 |  | 10000 |  |
| 001-158 | 3/6/1998 | 5 |  | 2200 |  |
| 001-159 | 3/6/1998 | 10 |  | 100 | J |
| 001-160 | 3/9/1998 | 10 |  | 200 | J |
| 001-160 | 3/9/1998 | 5 |  | 100 | J |
| 001-161 | 3/6/1998 | 10 |  | 200 | J |
| 001-161 | 3/6/1998 | 5 |  | 100 | J |
| 001-162 | 3/9/1998 | 10 | < | 500 | U |
| 001-162 | 3/9/1998 | 5 | < | 600 | U |
| 001-165 | 3/16/1998 | 17 |  | 439000 |  |
| 001-165 | 3/17/1998 | 20 |  | 1900 |  |
| 001-165 | 3/17/1998 | 25 |  | 50000 |  |
| 001-165 | 3/17/1998 | 30 |  | 85000 |  |
| 001-165 | 3/17/1998 | 35 |  | 74000 |  |
| 001-165 | 3/17/1998 | 43 |  | 45000 |  |
| 001-165 | 3/17/1998 | 45 |  | 66000 |  |
| 001-165 | 3/17/1998 | 50 |  | 25000 |  |
| 001-166 | 3/18/1998 | 5 |  | 5000 |  |
| 001-166 | 3/18/1998 | 12 |  | 12000 |  |
| 001-166 | 3/18/1998 | 18 |  | 14000 |  |
| 001-166 | 3/18/1998 | 21 |  | 22000 |  |
| 001-166 | 3/18/1998 | 27 |  | 23000 |  |
| 001-166 | 3/18/1998 | 33 |  | 18000 |  |
| 001-166 | 3/18/1998 | 38 |  | 11000 |  |
| 001-166 | 3/18/1998 | 42 |  | 300 | J |
| 001-166 | 3/18/1998 | 47 | < | 800 | U |
| 001-166 | 3/18/1998 | 50 | < | 700 | U |

## Table 2. Southwest Plume Historical Characterization Data* (Continued)

| Boring ID | Date of Collection | Depth, bgs, feet | Prefix | Concentration, µg/kg | Laboratory Qualifier[†] |
|---|---|---|---|---|---|
| 001-168 | 3/21/1998 | 5 | < | 900 | U |
| 001-168 | 3/21/1998 | 13 | | 170 | J |
| 001-168 | 3/21/1998 | 18 | | 40 | J |
| 001-168 | 3/21/1998 | 23 | | 800 | |
| 001-168 | 3/21/1998 | 25 | | 26000 | |
| 001-168 | 3/21/1998 | 29 | | 26000 | |
| 001-168 | 3/21/1998 | 33 | | 5500 | |
| 001-168 | 3/21/1998 | 38 | | 2700 | |
| 001-168 | 3/21/1998 | 43 | | 5000 | |
| 001-168 | 3/21/1998 | 47 | | 4200 | |
| 001-168 | 3/21/1998 | 50 | | 4300 | |
| 001-169 | 3/23/1998 | 18 | < | 900 | U |
| 001-169 | 3/23/1998 | 23 | | 42 | J |
| 001-169 | 3/23/1998 | 28 | | 100 | J |
| 001-169 | 3/23/1998 | 33 | | 800 | |
| 001-169 | 3/23/1998 | 36 | | 1200 | |
| 001-169 | 3/23/1998 | 38 | | 700 | J |
| 001-169 | 3/23/1998 | 42 | | 12000 | |
| 001-169 | 3/23/1998 | 45 | | 18000 | |
| 001-169 | 3/24/1998 | 50 | | 9400 | |
| 001-171 | 4/2/1998 | 5 | < | 900 | U |
| 001-171 | 4/2/1998 | 10 | < | 900 | U |
| 001-171 | 4/2/1998 | 18 | < | 800 | U |
| 001-171 | 4/2/1998 | 20 | < | 1400 | U |
| 001-171 | 4/2/1998 | 25 | < | 900 | U |
| 001-171 | 4/2/1998 | 30 | < | 900 | U |
| 001-171 | 1/1/1998 | 35 | < | 1100 | U |
| 001-171 | 4/2/1998 | 40 | < | 1400 | U |
| 001-171 | 4/2/1998 | 45 | < | 900 | U |
| 001-171 | 4/2/1998 | 50 | < | 1300 | U |
| 001-172 | 4/3/1998 | 15 | | 900 | J |
| 001-172 | 4/3/1998 | 20 | < | 900 | U |
| 001-172 | 4/3/1998 | 25 | | 7000 | |
| 001-172 | 4/4/1998 | 31 | | 1700 | |
| 001-172 | 4/4/1998 | 35 | < | 1100 | U |
| 001-172 | 4/4/1998 | 40 | < | 900 | U |
| 001-172 | 4/4/1998 | 45 | < | 900 | U |
| 001-172 | 4/4/1998 | 50 | | 400 | J |
| 001-173 | 4/6/1998 | 5 | < | 900 | U |
| 001-173 | 4/6/1998 | 13 | < | 900 | U |
| 001-173 | 4/6/1998 | 18 | < | 900 | U |
| 001-173 | 4/6/1998 | 25 | | 15 | J |
| 001-173 | 4/6/1998 | 30 | < | 1400 | U |
| 001-173 | 4/6/1998 | 35 | < | 1100 | U |
| 001-173 | 4/6/1998 | 43 | < | 1100 | U |
| 001-173 | 4/6/1998 | 45 | | 8 | J |
| 001-173 | 4/6/1998 | 50 | < | 1000 | U |

## Table 2. Southwest Plume Historical Characterization Data* (Continued)

| Boring ID | Date of Collection | Depth, bgs, feet | Prefix | Concentration, µg/kg | Laboratory Qualifier† |
|---|---|---|---|---|---|
| 001-174 | 4/8/1998 | 15 | < | 900 | U |
| 001-174 | 4/8/1998 | 20 | < | 800 | U |
| 001-174 | 4/8/1998 | 28 | < | 1100 | U |
| 001-174 | 4/8/1998 | 30 |  | 200 | J |
| 001-174 | 4/8/1998 | 38 | < | 1000 | U |
| 001-174 | 4/8/1998 | 43 | < | 900 | U |
| 001-174 | 4/8/1998 | 45 | < | 1000 | U |
| 001-174 | 4/8/1998 | 50 | < | 800 | U |
| 001-179 | 4/23/1998 | 15 | < | 800 | U |
| 001-179 | 4/23/1998 | 20 | < | 1100 | U |
| 001-179 | 4/23/1998 | 25 | < | 800 | U |
| 001-179 | 4/23/1998 | 30 | < | 800 | U |
| 001-179 | 4/23/1998 | 35 | < | 1000 | U |
| 001-179 | 4/23/1998 | 40 | < | 1000 | U |
| 001-179 | 4/23/1998 | 45 | < | 900 | U |
| 001-179 | 4/23/1998 | 50 | < | 900 | U |
| 001-201 | 5/26/2004 | 15.5 |  | 690 |  |
| 001-201 | 5/27/2004 | 30 |  | 1700 | EXY |
| 001-201 | 5/27/2004 | 50.5 |  | 1000 | EXY |
| 001-201 | 5/27/2004 | 56 |  | 210 |  |
| 001-202 | 6/9/2004 | 0 |  | 780 |  |
| 001-202 | 6/9/2004 | 13 |  | 110 |  |
| 001-202 | 6/9/2004 | 30.5 |  | 2400 | E |
| 001-202 | 6/9/2004 | 47 |  | 3500 |  |
| 001-202 | 6/9/2004 | 59.5 |  | 3400 |  |
| 001-203 | 5/27/2004 | 15 | < | 2 | U |
| 001-203 | 5/28/2004 | 33 | < | 2 | U |
| 001-203 | 5/28/2004 | 47 | < | 2 | U |
| 001-203 | 5/28/2004 | 51.5 | < | 2 | U |
| 001-204 | 6/10/2004 | 20.5 |  | 200 |  |
| 001-204 | 6/10/2004 | 30.5 |  | 60 |  |
| 001-204 | 6/11/2004 | 45.5 |  | 370 |  |
| 001-204 | 6/11/2004 | 58.5 |  | 290 |  |
| 001-205 | 6/2/2004 | 18 |  | 22 |  |
| 001-205 | 6/2/2004 | 30 |  | 860 |  |
| 001-205 | 6/2/2004 | 46 |  | 210 |  |
| 001-205 | 6/2/2004 | 54.5 |  | 3.2 |  |

## Table 2.  Southwest Plume Historical Characterization Data* (Continued)

| Boring ID | Date of Collection | Depth, bgs, feet | Prefix | Concentration, µg/kg | Laboratory Qualifier[†] |
|---|---|---|---|---|---|

*Historical soil data in this table were collected as part of the WAG 27 RI and the Southwest Plume SI.  001-1xx is WAG 27 RI data and 001-2xx is SW Plume SI data.

Note:  Phase I and Phase II soil data were not used in producing the soil mixing treatment area.  The data, however, are included electronically in Appendix A.

[†] **Organic Laboratory Data Qualifiers:**

| | |
|---|---|
| **A** | Tentatively identified compound (TIC) is suspected aldol-condensation product. |
| **B** | Compound found in blank as well as sample. |
| **C** | Compound presence confirmed by GC/MS (GS/MS flag). |
| **D** | Compounds identified in an analysis at a secondary dilution filter. |
| **E** | Result exceeds calibratin range (GS/MS flag). |
| **J** | Indicates an estimated value. |
| **N** | Presumption evidence of a compound GS/MS flag. |
| **P** | Difference between results from two GC columns unacceptable. |
| **U** | Compound analyzed for but not detected at or below the lowest concentration reported. |
| **X** | Other specific flags and footnotes may be required to properly define the results. |
| **Y** | MS, MSD recovery and/or RPD failed acceptance criteria |
| **Z** | (Reserved by CLP for a laboratory-defined organic date qualifier.) |

Note:  Blank cell in Qualifier column means data point has no qualifier.

**Prefix Labels**

| | |
|---|---|
| < | Less than |

Note:  Blank cell in Prefix column means data point requires no prefix.

statistical confidence. By kriging data at every node of the model, an average value along with a standard deviation is calculated, thus providing a range of estimated TCE concentrations and ultimately mass. A level of significance of 0.1 [i.e., 90% confidence interval (CI)] was used in modeling the geometry and mass of TCE above 1,000 and 10,000 µg/kg to address uncertainty in the estimates. A nominal interpolation of the data corresponding to a 50% CI also was performed to serve as a basis for comparison and to provide a lower bound estimate of mass.

A one-layer geologic model was built focusing on the top 65 ft of soil for modeling soil analyte distribution. Chemical results collected during evaluation of the UCRS (1998 and 2004) and RDSI (2012) sampling of SWMU 1 soils completed within and immediately surrounding the defined SWMU 1 source area are shown in Figure 4.

Due to elevated detection limits at select locations (typically within the range of 500 to 900 µg/kg compared to the SWMU 1 treatment standard for TCE of 73 µg/kg), data from the historic 1998 and 2004 UCRS investigations were analyzed in EVS using 1 µg/kg for the detection limit for nondetect results. This detection limit is consistent with the typical detection limits observed in the RDSI data.

Due to duplicate sampling results in the historical datasets (i.e., multiple TCE analytical results for a given sampling location and depth interval), a set of decision rules was developed to select the most appropriate result to use in the modeling. The following were the rules followed in selecting a value when duplicate results were available:

- For two detects, take the highest value.
- For two detects with qualifiers, take the value that has the lowest number of qualifiers.
- If both values are nondetect, use the data point with the lowest detection limit.
- If one data point is detect and the other is estimated, take the detected value.
- If one data point is nondetect and the other is estimated, take the estimated value.

With few exceptions, the EVS-ES modeling was performed using the typical software defaults. The model parameters are documented in a calculation package included as Appendix B. The horizontal/vertical anisotropy ratio parameter, which allows the model to take into consideration expected differences in fluid flow through the soil matrix, was set to 1 versus the default of 10. This value was set at 1 to best represent the anticipated distribution of chemicals, as well as resulting in more conservative estimates of chemical mass. The Octant Search method was used to determine which sample points are selected for inclusion in the kriging matrix. This method refines the data points used in the local kriging matrix and results in better performance with clustered data. An Octant is any of the eight parts into which three mutually perpendicular planes divide space. Using EVS Octant search, searching is performed for each of the eight Octants surrounding the point to be kriged. The octant search algorithm is performed for every interpolated node of the model. Within each octant, a maximum number of points (up to one-fourth of the total points) is selected. Then, points are taken sequentially from each octant to the maximum number of total points or until all octant points have been used. Preference is given to points that are proximal to the interpolation point. Theoretically, there could be small extents such that some analytical data never would be used in the interpolation, but that would occur only in locations with clustered data over a small extent. Given the data distribution, for all intents and purposes, all the available analytical data were used in the interpolation. The model used a soil density of 1.5 gram per $cm^3$ and a chemical density of 1.46 gram per $cm^3$. The model's mass calculations then were reviewed and compared to hand calculations of the mass. A compact disc, which includes the EVS-ES output files, is included as Appendix B.

The estimated mass of TCE at SWMU 1 in UCRS soils, as documented in the signed ROD, is 49 gal (187 liters). Mass estimates were calculated using nominal (50% CI) kriging, kriging using the 90% CI, IDW, and nearest neighbor. The results of the EVS-ES modeling using the historical results and the RDSI soil results are presented in Table 3.

From a mass distribution perspective, both the 90% CI kriging and nearest neighbor interpolation indicate that 96% of the estimated mass is located within the greater than 1,000 µg/kg isocontour area. The EVS estimated weight calculated is lower than the weight estimated in the SI.

The horizontal extent of the 73 µg/kg isocontour using nominal kriging interpolation is estimated to be approximately 13,500 $ft^2$. The 1,000 µg/kg and 10,000 µg/kg isocontours using the 90% CI kriging interpolation are estimated to be approximately 9,900 $ft^2$ and 3,700 $ft^2$, respectively. The isocontours are shown on Figure 4.

**Table 3. Mass Estimates**

| | **Nominal (50% CI) Kriging** | **90% CI Kriging** | **IDW** | **Nearest Neighbor** |
|---|---|---|---|---|
| **Isoconcentration Level µg/kg** | **Mass of TCE* (gal)** | | | |
| 73 | 8.9 | 29.3 | 1.4 | 24.8 |
| 1,000 | 8.0 | 28.1 | 0.5 | 23.7 |
| 10,000 | 4.2 | 19.8 | 0.1 | 18.0 |

## 1.5 SEQUENCING WITH OTHER REMEDIES

This RA will be executed in coordination with the Soils Operable Unit (OU) remediation of surface (< 1 ft) and subsurface soil (> 1 ft and < 10 ft) contaminants, as appropriate. The Soils OU remediation currently is planned for implementation following the SWMU 1 groundwater VOC contaminant source RA. A review of contaminants that exceed the no action level (NAL), as contained in Soils OU RI, DOE/LX/07-0258&D2 (DOE 2012c) was performed. The evaluation contained in the remedial investigation report separated the soils into surface and subsurface. Surface soils are located < 1 ft in depth; subsurface soils are located > 1 ft in depth and less than 10 ft in depth.

The surface soils in the area to be mixed contain polychlorinated biphenyls (PCBs) and metals above the Industrial NAL (DOE 2012c). The expected maximum PCB and metal contaminant concentrations in the soil mixing area are as follows:

| | |
|---|---|
| - PCBs | 3.4 mg/kg |
| - Arsenic | 6.3 mg/kg |
| - Beryllium | 0.7 mg/kg |
| - Cadmium | 6.4 mg/kg |
| - Cobalt | 13.7 mg/kg |
| - Vanadium | 24 mg/kg |

Information concerning the nature and extent of contamination in the subsurface soils and surface soils in SWMU 1 is located in the *Soils Operable Unit Remedial Investigation Report at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0358&D2/R1 (DOE 2012c). In summary, this information states that no VOCs, radioactive compounds, or semivolatile organic compounds exceeded the NAL in the surface soils in the area to be soil mixed. For subsurface soils in SWMU 1, VOCs, PCBs, and metals exceed NALs in the planned soil mixing zone. No radionuclide or semivolatiles exceed NALs in the planned soil mixing zone. During test pit excavation operations performed as part of the WAG 27 RI at SWMU 1, a whitish granular material was identified (DOE 1999). Subsequent evaluation identified the material as alumina pellet material used to trap low concentrations of uranium. DOE has checked with a deep soil mixing subcontractor to determine whether the soil mixing is likely to result in significant horizontal or vertical dispersal/spread of potential contamination from the alumina pellets during execution of the project. The subcontractor indicated that the soil mixing process is not envisioned to result in significant spreading of any alumina pellets outside the diameter of individual mixing boring footprints and no more than 1 to 2 ft vertically. However, the D2 Remedial Action Work Plan (RAWP) will address what will be done, if anything, with any remaining alumina material after the removal of the upper 2 ft of soil prior to soil mixing.

To protect the aboveground treatment system from potential PCB contamination and to facilitate greater depths in soil mixing, prior to implementing the deep soil mixing RA, the top 2 ft of the treatment/source area soil to be mixed, as defined in Figure 5, will be removed, stockpiled adjacent to the mixing area on a synthetic liner and covered with a liner to prevent erosion, and respread in the excavation after soil mixing action is complete.

The excavation of surface soil supports the soil mixing in the following ways:

1. PCBs contacting the mixing equipment or passing through the vapor of liquid treatment system could contaminate the equipment and prevent the release of the equipment.

2. The presence of the metals could result in their being solubilized and passing through the treatment equipment and resulting in excess metals in the treatment effluent.

3. The soil mixing equipment with the 8-ft augering system, combined and our soil conditions, is limited to a depth of 60 ft, and the excavation will assist in attaining mixing to the bottom of HU4 (see Section 2).

During excavation of the top 2 ft of soil, the exposed area to be soil mixed will be inspected visually and will be probed with hand tools to determine if engineered layers of gravel are present near the surface that could inhibit effective vacuum extraction through the soil mixing hood. If the presence of such engineered gravels is detected, the graveled areas will be excavated and stockpiled, with the upper 2 ft for spreading after the soil mixing operations have been completed.

Following completion of the mixing process, the excavated area will be backfilled with the excavated surface and subsurface soils (0 ft to 2 ft) to bring the ground surface back to grade with the surrounding unmixed area. Because soils in the mixing area will be disturbed, the surface soils in that area will require recharacterization for use in the Surface Soils OU. DOE will recharacterize those soils (0 ft to 2 ft) as part of the Soils OU at the appropriate time in the future prior to selecting an appropriate remedial measure. To provide for continuity among the OUs, DOE will insert a footnote in Appendix 5 of the FY 2014 Site Management Plan stating that the D1 Feasibility for Soils OU Remedial Action 1 will evaluate VOC soil contamination at SWMU 1 that did not undergo active treatment (i.e., deep soil mixing). The surface soils located outside of the area to be soil mixed will be addressed, as appropriate, by the Soils OU at a later date. The replacement of the excavated soils is not expected to contaminate the subsurface UCRS soil at depth because the subsurface soils will be loaded with a minimum of 0.5% ZVI to provide for treatment of residual VOCs including those potentially migrating from the surface. PCBs in the replaced soil are not expected to become mobile after replacement because PCBs have a tendency to bind with soil. Until the completion of the Soils OU actions (0 ft to 10 ft), the interim LUCs to be instituted following completion

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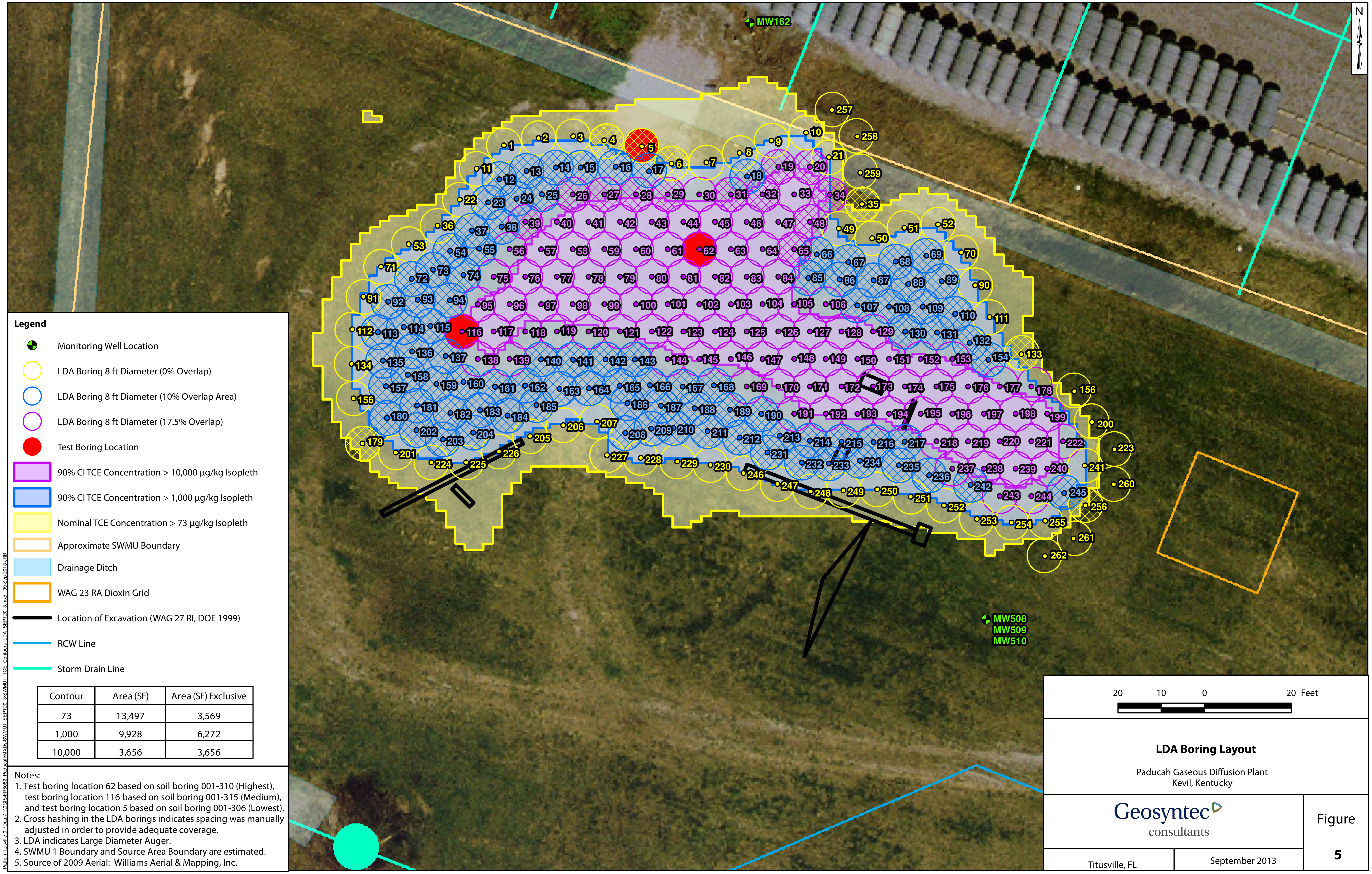

**Legend**

| | |
|---|---|
| ● | Monitoring Well Location |
| ○ | LDA Boring 8 ft Diameter (0% Overlap) |
| ○ | LDA Boring 8 ft Diameter (10% Overlap Area) |
| ○ | LDA Boring 8 ft Diameter (17.5% Overlap) |
| ● | Test Boring Location |
| ▨ | 90% CI TCE Concentration > 10,000 µg/kg Isopleth |
| ▨ | 90% CI TCE Concentration > 1,000 µg/kg Isopleth |
| ▨ | Nominal TCE Concentration > 73 µg/kg Isopleth |
| ☐ | Approximate SWMU Boundary |
| ▨ | Drainage Ditch |
| ☐ | WAG 23 RA Dioxin Grid |
| — | Location of Excavation (WAG 27 RI, DOE 1999) |
| — | RCW Line |
| — | Storm Drain Line |

| Contour | Area (SF) | Area (SF) Exclusive |
|---|---|---|
| 73 | 13,497 | 3,569 |
| 1,000 | 9,928 | 6,272 |
| 10,000 | 3,656 | 3,656 |

Notes:
1. Test boring location 62 based on soil boring 001-310 (Highest), test boring location 116 based on soil boring 001-315 (Medium), and test boring location 5 based on soil boring 001-306 (Lowest).
2. Cross hashing in the LDA borings indicates spacing was manually adjusted in order to provide adequate coverage.
3. LDA indicates Large Diameter Auger.
4. SWMU 1 Boundary and Source Area Boundary are estimated.
5. Source of 2009 Aerial: Williams Aerial & Mapping, Inc.

Path: (Titusville-01\Data)\T:\0GIS\FR5082 Paducah\MXDs\SWMU1 SEPT2013\SWMU1 TCE Contours LDA SEPT2013.mxd 09 Sep 2013 JRB

**LDA Boring Layout**

Paducah Gaseous Diffusion Plant
Kevil, Kentucky

Geosyntec consultants

Figure
5

Titusville, FL
September 2013

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of SWMU treatment by the Groundwater Operable Unit will serve to insure protectiveness of the worker until such time as the Soils OU can address remaining contaminants present in the 0-10 ft zone throughout the SWMU.

Historical photographic documentation analysis performed by the FFA parties of SWMU 1 and information gathered from interviews of past workers at the SWMU 1 Landfarm have identified that activities (captured as images/shadows on air photographs) occurred at SWMU 1 east of the area planned for soil mixing operations. These activities, although unidentified, are not expected to have been actual landfarming of contaminated oil. Information collected to date, including WAG 27 RI test pit descriptions, place the two oil landfarm plots in the western one-half of the SWMU 1 area. These activities, however, result in a level of uncertainty in landfarming plot location that cannot be addressed with the available current soil contaminant analytical data. To address this uncertainty, additional investigation activities will be performed in the southern and eastern areas of SWMU 1. The investigation will include the drilling of soil borings to a minimum depth of 50 ft and the collecting of soil samples for analysis of VOCs. This additional investigation will be coordinated with and performed as part of the Soils Operable Unit RI 2, which will be performed 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 in the UCRS and upper RGA (hydrogeologically) soils to a depth of 62 ft bgs (takes into consideration the removal of the top 2 ft of soil prior to LDA implementation). To confirm the treatment of the UCRS and upper RGA (HU4) soils, the mapped source treatment area was placed over a kriging-based evaluation of the HU4/HU5 interface (Figure 6). This information, which is based upon the RDSI soil borings, documents that the HU4/HU5 interface is a maximum of 62 ft bgs within the treatment area. Accordingly, the proposed treatment depth of 62 ft bgs matches or exceeds the HU4/HU5 interface within the treatment area.

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 and provides a real-time indication of the level of contamination in specific zones being treated. Real-time monitoring will assist in controlling the process parameters to maximize VOC removal, control of operating treatment equipment, and support operation of the LDA and injection systems.

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

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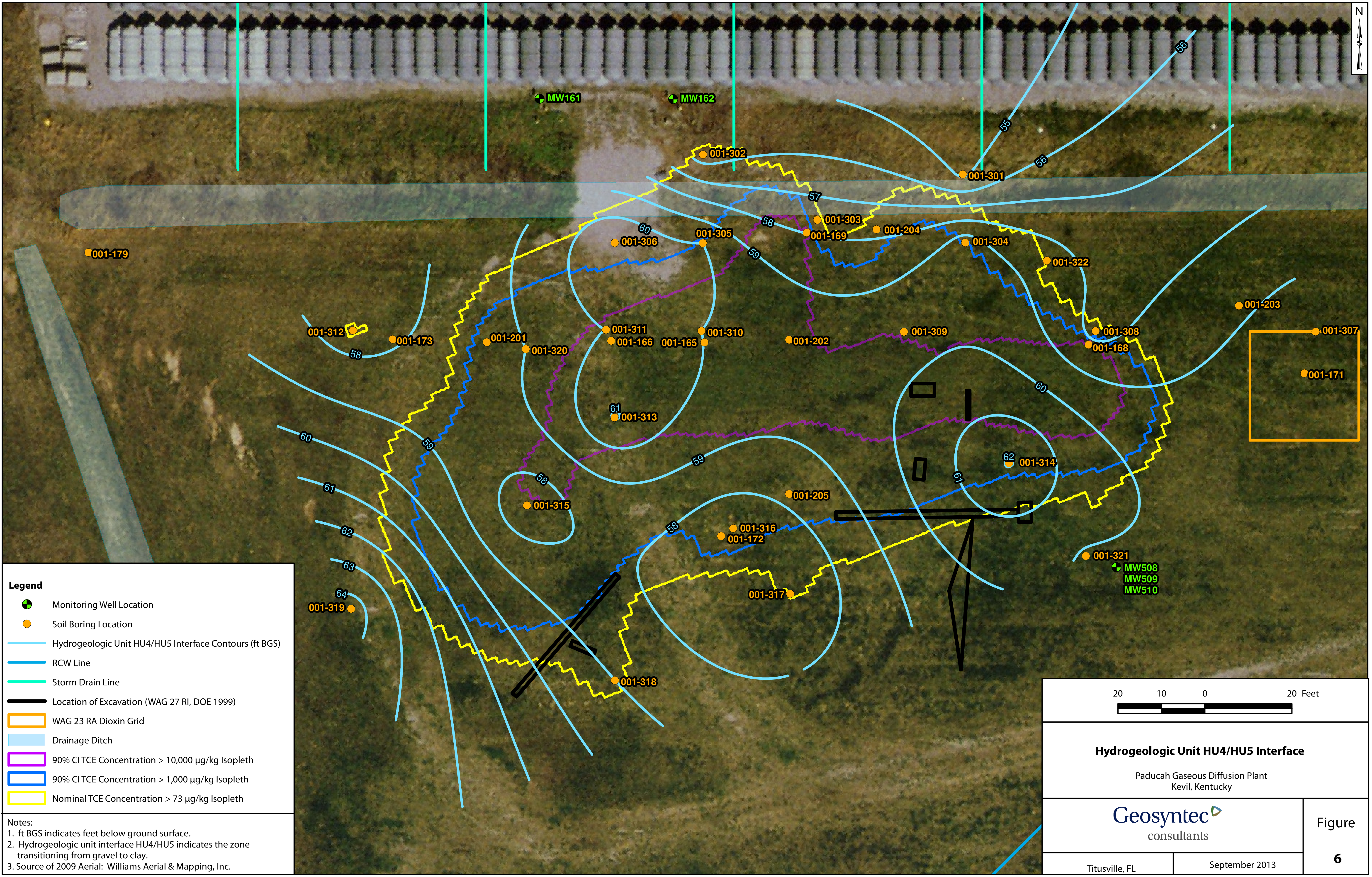

**Legend**

- ● Monitoring Well Location
- ● Soil Boring Location
- Hydrogeologic Unit HU4/HU5 Interface Contours (ft BGS)
- RCW Line
- Storm Drain Line
- Location of Excavation (WAG 27 RI, DOE 1999)
- ☐ WAG 23 RA Dioxin Grid
- ▭ Drainage Ditch
- ☐ 90% CI TCE Concentration > 10,000 µg/kg Isopleth
- ☐ 90% CI TCE Concentration > 1,000 µg/kg Isopleth
- ☐ Nominal TCE Concentration > 73 µg/kg Isopleth

Notes:
1. ft BGS indicates feet below ground surface.
2. Hydrogeologic unit interface HU4/HU5 indicates the zone transitioning from gravel to clay.
3. Source of 2009 Aerial: Williams Aerial & Mapping, Inc.

Path: (Titusville-01\Data)T:\0GIS\FR5082_Paducah\MXDs\SWMU1_SEPT2013\GW_Elev_Contours_HU4HU5zone_SEPT2013.mxd 09 Sep 2013 JRB

**Hydrogeologic Unit HU4/HU5 Interface**

Paducah Gaseous Diffusion Plant
Kevil, Kentucky

Geosyntec
consultants

Titusville, FL

September 2013

Figure
6

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# 3. TREATMENT SYSTEM OBJECTIVES

As discussed in Section 2, design information, including contaminant levels, areas of soil VOC impacts and mass present in the treatment zone, was obtained during the RDSI. The RDSI information regarding the distribution of VOCs in the treatment zone is used in this design to optimize the LDA treatment area layout and auger boring overlap to provide effective VOC treatment and achieve project objectives. The following subsections provide discussions on the remedial action objectives and the key operational parameters of the mixing process to attain the objectives.

## 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; and

(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 will include the following:

- LDA Operational Monitoring for
  - Depth penetration rate
  - Auger rotational rate
  - Applied torque
  - Down-hole temperature

- Temperature, flow rate, and injection pressure for
  - Injected steam
  - Compressed/heated air
  - ZVI slurry mixture

- Vapor recovery flow rate, temperature, and vacuum pressure
- Extracted VOC concentrations
- Treated vapor phase VOC concentrations

# 4. 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 a projected 262 boring locations 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. Due to the significant operational flexibility provided by this technology, the actual number of LDA borings completed may change based on remedial team discussion (to include representatives from EPA, KDEP, DOE, and DOE design team representatives) that may occur during remedial implementation based on analysis of real-time field-collected data from the remedial equipment.

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 for 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 (discussed in Sections 4.2 and 4.4.2.2). 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 (discussed in Section 4.4.2.1).

## 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 [e.g., Launch Complex 15, Ordnance Support Facility 1381 (USAF 2008), Security Police Confidence Course located at Cape Canaveral Air Force Station (USAF 2007); and Offutt Air Force Base, Nebraska (USACE 2012)] that have employed this remedial technology (the injected hot air/steam contacting the soil will have a temperature exceeding 200°F). A downhole thermocouple data logger, physically mounted to the LDA auger blade, will be used to monitor subsurface temperatures at the end of mixing operations for any given time period. The data logger will be retrieved from the LDA auger blade to download and view the data. 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 (identified above) that, by adding a correction factor of 10°F to the shroud gas temperature, the resultant is representative of the downhole temperature. These studies were performed through installation of thermocouples posttreatment (at least 5 days) that indicated that subsurface temperatures typically were measured at approximately 10°F greater than the measured shroud temperature during mixing. It is noted that some cooling may have occurred during the lag time between treatment and posttreatment measurements; therefore, this correction factor is assumed to be conservative. Though it is noted that the downhole thermocouple may be slightly biased by the friction of auger rotation, this data measurement is offered to provide a singular line of evidence regarding downhole temperatures achieved through thermal treatment. 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 three overlap spacing scenarios with slight variation in the three scenarios as needed to place circular soil mixing columns within the irregular geometric area. The fixed overlap scenarios are 0% (no overlap); 10% (some overlap for reduction of interstitial space between treatment cells/borings); or 17.5% (representing complete overlap with no interstitial space between treatment cells/borings). The overlap spacing is varied based upon on the average concentration of TCE in the RDSI soil borings. The LDA boring overlap consists of the following overlap scenarios:

- A 17.5% overlap will be provided in the area within the greater than 10,000 µg/kg average TCE isoconcentration contour.

- A 10% overlap will be provided in the area within the greater than 1,000 µg/kg and less than 10,000 µg/kg average TCE isoconcentration contours.

- A 0% overlap (or greater to account for auger boring layout spacing) will be provided in the area within the greater than 73 µg/kg and less than 1,000 µg/kg average TCE isoconcentration contours.

Due to transition issues among the three overlap scenarios and to resolve interference between borings in geometric placement, the overlap in some cases has been increased or decreased slightly. This slight modification in overlap allows the optimized placement of the soil mixing borings. The soil mixing borings which the slight modification incorporated are shown with cross-hatching in Figure 5. The slight modification in overlap is not expected to result in decreased effectiveness of the remedial action because, the LDA boring overlap scenario exceeds what has been used previously at other locations. The successful LDA technology implementation at the Security Police Confidence Course (Facility 18003) at Cape Canaveral Air Force Station, which used a 6% overlap throughout (USAF 2007); and the Ordnance Support Facility at Cape Canaveral Air Force Station, which used a 0% overlap throughout (USAF 2008). The referenced sites are located in a fully-saturated sand aquifer, which reflects a heating environment that is more difficult to steam volatilize VOCs than the soils present at SWMU 1. Additionally, the Offutt Air Force Base LDA soil mixing project was performed in a lithology-type (silty clay) similar to SWMU 1 and also achieved project objectives (USACE 2012). Figure 5 presents the LDA boring layout and up to 262 proposed boring locations. Boring locations will be surveyed by a professional, licensed land surveyor prior to implementation of soil mixing. As previously noted, due to the significant operational flexibility provided by this technology, the actual number of LDA borings completed may change based on remedial team discussion (to include representatives from EPA, Kentucky Department for Environmental Protection (KDEP), DOE, and DOE design team representatives); these may occur during remedial implementation based on analysis of real-time field-collected data from the remedial equipment. Criteria anticipated to possibly change the number of borings and/or the boring locations will include individual boring vapor response and/or mass of VOCs removed relative to adjacent locations. The FFA parties will be consulted if a reduction in boring overlap is required.

**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. Previously, two anomalies were found through geophysical techniques and these were excavated. One was a large concrete pipe that did not appear to be associated with the former operations of the SWMU. The second anomaly was not identified, but was believed to have been a result of the presence of small metal objects such as drum lids, bungs, metal shavings, etc. Appendix C includes SPT blow count data and geotechnical data for soils anticipated to be encountered during LDA soil mixing for determination of penetration rate, angle of repose for the mixing blade/auger blade, and blade type selection by equipment vendors.

**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. If field observations indicate that the measured vapor extraction rate is not at least 50% greater than the concurrent hot air/steam injection flow rate, then either the injection flow rate will be reduced and/or RAs will be ceased temporarily until the vapor extraction rate has been modified to achieve the design criteria. LDA soil mixing, thermal treatment, VCS, vapor treatment, and ZVI injection equipment will be operator-controlled by a workman experienced in the operation of this equipment (similar to previous applications of the technology). Due to the complexity of the equipment and because equipment operators maintain shutdown procedures specific to their equipment, it typically is inappropriate for alarm conditions to cause automatic shutdown of this remedial equipment. Alarm conditions are provided to alert the experienced operator of such conditions so that they can react accordingly. For example, a loss of vacuum in the collection shroud would result in a notification to the operator, which would trigger the operator to cease treatment operations until the alarm condition can be corrected. Additionally, workers will monitor the air in the worker breathing zone with an Organic Vapor Analyzer fitted with a flame ionization detector (FID)/photoionization detector (PID) (PID lamp 10.6 eV), after methane subtraction, to evaluate a condition where VOCs may escape the shroud pursuant to a project-specific health and safety plan (Section 8).

**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 (after subtracting a methane value) and/or a gas chromatograph (GC). Regarding the subtraction of the methane value, the technique of flame ionization detection relies on the ionization of molecules during high temperature combustion in the reaction zone of the FID-flame to determine the total volatile organic concentration within a continuous gaseous sample (includes both methane and VOCs). The methane content of the continuous sample may be determined by directing the sample through a bed of activated carbon to remove VOCs (methane is not removed by the carbon) and then into the FID. The methane concentration then may be subtracted from the total volatile organic concentration to obtain the difference, which represents the VOC concentration of the continuous gaseous sample. Note: It is not anticipated that significant methane concentrations exist in the subsurface at SWMU 1; however, the method of methane subtraction has been proposed to mitigate the potential that an FID measurement would be biased high due to the presence of methane, if present, in the subsurface.

In the unlikely event the LDA soil mixing vendor-specific PID/FID and/or GC data monitoring equipment becomes saturated due to the presence of high VOC concentrations and/or DNAPLs present in the subsurface, LDA soil mixing will be paused until appropriate adjustments are made (adjustments will vary depending on specific equipment type) to allow resumption of vapor analysis. LDA soil mixing will be restarted when appropriate adjustments are made in the field (based upon vendor specific equipment) to compensate for the elevated concentrations 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. The continuous monitoring of PID/FID and/or GC results in the vapor extraction stream is required at all times to effectively document mass removal rates per LDA soil mixing boring location.

**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; 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, after subtraction of methane, 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 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.0% ZVI will be applied.

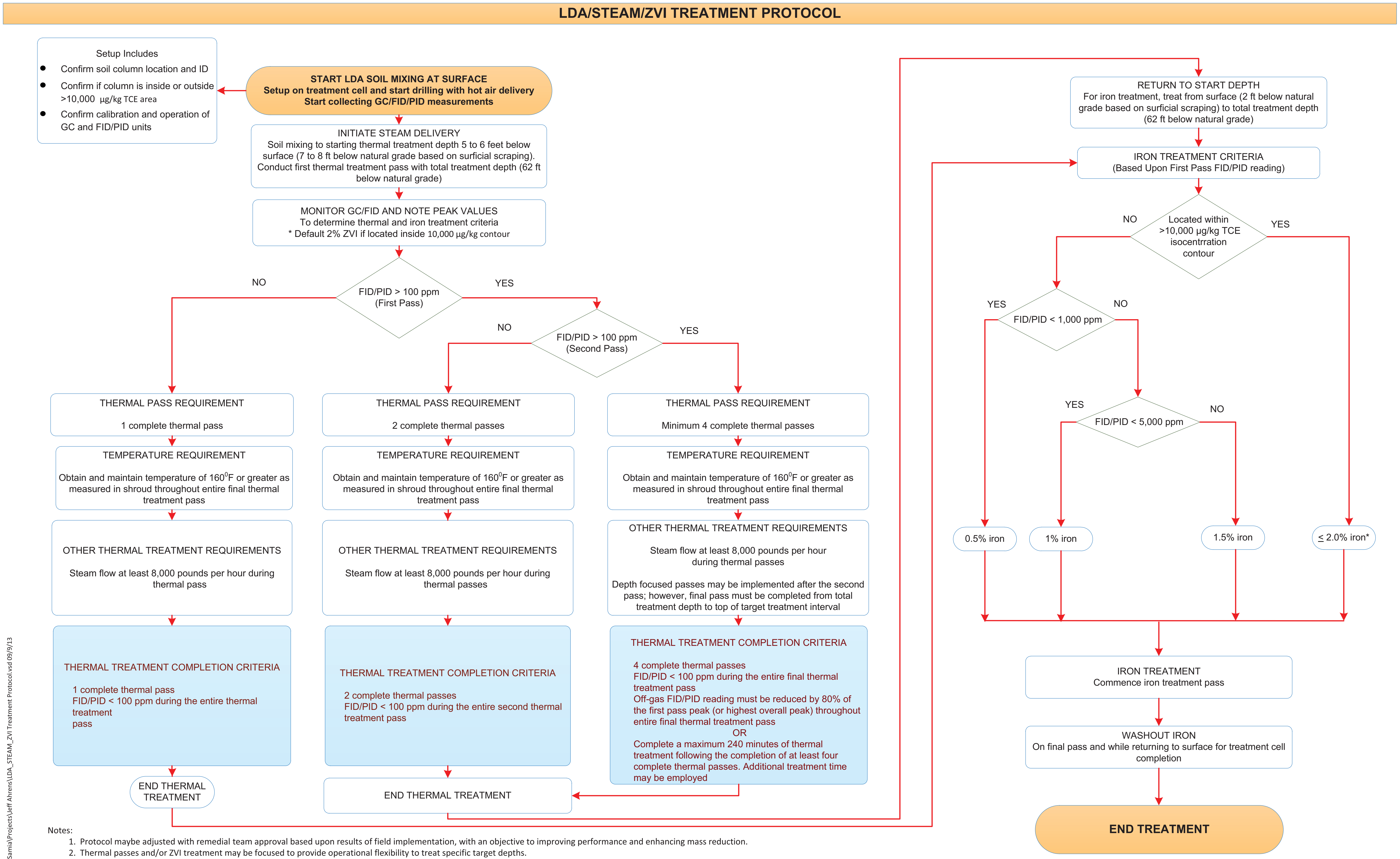
- If a PID/FID reading exceeding 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.5% ZVI will be applied.

- Based upon RDSI soil sampling results, the area within the greater than 10,000 µg/kg TCE isoconcentration contour area will be treated with a default application of no less than 1.5%, but not greater than 2% ZVI regardless of PID/FID response. This range of concentration has been presented based on practical limitations to injection of 2% ZVI observed at other sites.

A graphical depiction of decision criteria associated with ZVI dosing is presented in Figure 7. The ZVI dosing concentration will be measured as a percentage by weight of the column of soil being treated. The ZVI dosing strategy is consistent with the LDA soil mixing projects successfully implemented to treat TCE/DNAPL source areas at Cape Canaveral Air Force Station (USAF 2007; USAF 2008) and former Offutt Air Force Base (USACE 2012).

**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. A depiction of identified utilities is presented on the Estimated Extent of TCE Source Area, Figure 4, and the LDA Equipment Staging Layout, presented on Figure 8. Previously, two anomalies were found through geophysical techniques and these were excavated. One was a large concrete pipe that did not appear to be associated with the former operations of the SWMU. The second anomaly was not identified, but was believed to have been a result of the presence of small metal objects such as drum lids, bungs, metal shavings, etc.

**Contaminants of Concern.** The technology is designed specifically for the treatment of VOCs. Unacceptable concentrations of other contaminants will be addressed consistent with the details discussed previously in Section 1.5, 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.



## LDA/STEAM/ZVI TREATMENT PROTOCOL

Setup Includes
- Confirm soil column location and ID
- Confirm if column is inside or outside >10,000 µg/kg TCE area
- Confirm calibration and operation of GC and FID/PID units

**START LDA SOIL MIXING AT SURFACE**
**Setup on treatment cell and start drilling with hot air delivery**
**Start collecting GC/FID/PID measurements**

INITIATE STEAM DELIVERY
Soil mixing to starting thermal treatment depth 5 to 6 feet below surface (7 to 8 ft below natural grade based on surficial scraping). Conduct first thermal treatment pass with total treatment depth (62 ft below natural grade)

MONITOR GC/FID AND NOTE PEAK VALUES
To determine thermal and iron treatment criteria
* Default 2% ZVI if located inside 10,000 µg/kg contour

FID/PID > 100 ppm (First Pass) — NO / YES

FID/PID > 100 ppm (Second Pass) — NO / YES

THERMAL PASS REQUIREMENT
1 complete thermal pass

TEMPERATURE REQUIREMENT
Obtain and maintain temperature of $160^0$F or greater as measured in shroud throughout entire final thermal treatment pass

OTHER THERMAL TREATMENT REQUIREMENTS
Steam flow at least 8,000 pounds per hour during thermal pass

THERMAL TREATMENT COMPLETION CRITERIA
1 complete thermal pass
FID/PID < 100 ppm during the entire thermal treatment pass

END THERMAL TREATMENT

THERMAL PASS REQUIREMENT
2 complete thermal passes

TEMPERATURE REQUIREMENT
Obtain and maintain temperature of $160^0$F or greater as measured in shroud throughout entire final thermal treatment pass

OTHER THERMAL TREATMENT REQUIREMENTS
Steam flow at least 8,000 pounds per hour during thermal passes

THERMAL TREATMENT COMPLETION CRITERIA
2 complete thermal passes
FID/PID < 100 ppm during the entire second thermal treatment pass

END THERMAL TREATMENT

THERMAL PASS REQUIREMENT
Minimum 4 complete thermal passes

TEMPERATURE REQUIREMENT
Obtain and maintain temperature of $160^0$F or greater as measured in shroud throughout entire final thermal treatment pass

OTHER THERMAL TREATMENT REQUIREMENTS
Steam flow at least 8,000 pounds per hour during thermal passes

Depth focused passes may be implemented after the second pass; however, final pass must be completed from total treatment depth to top of target treatment interval

THERMAL TREATMENT COMPLETION CRITERIA
4 complete thermal passes
FID/PID < 100 ppm during the entire final thermal treatment pass
Off-gas FID/PID reading must be reduced by 80% of the first pass peak (or highest overall peak) throughout entire final thermal treatment pass
OR
Complete a maximum 240 minutes of thermal treatment following the completion of at least four complete thermal passes. Additional treatment time may be employed

RETURN TO START DEPTH
For iron treatment, treat from surface (2 ft below natural grade based on surficial scraping) to total treatment depth (62 ft below natural grade)

IRON TREATMENT CRITERIA
(Based Upon First Pass FID/PID reading)

Located within >10,000 µg/kg TCE isocentrration contour — NO / YES

FID/PID < 1,000 ppm — YES / NO

FID/PID < 5,000 ppm — YES / NO

0.5% iron

1% iron

1.5% iron

≤ 2.0% iron*

IRON TREATMENT
Commence iron treatment pass

WASHOUT IRON
On final pass and while returning to surface for treatment cell completion

**END TREATMENT**

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Notes:
1. Protocol maybe adjusted with remedial team approval based upon results of field implementation, with an objective to improving performance and enhancing mass reduction.
2. Thermal passes and/or ZVI treatment may be focused to provide operational flexibility to treat specific target depths.
3. * 2% represents maximum achievable ZVI dosage, actual applied is anticipated to range from 1.5-2.0 %.
4. During the collection of FID readings, methane corrected values shall be provided.
5. Remedial team includes representatives from EPA, KY DAQ, DOE, and DOE design team representatives.

**Figure 7. LDA/Steam/ZVI Treatment Protocol**

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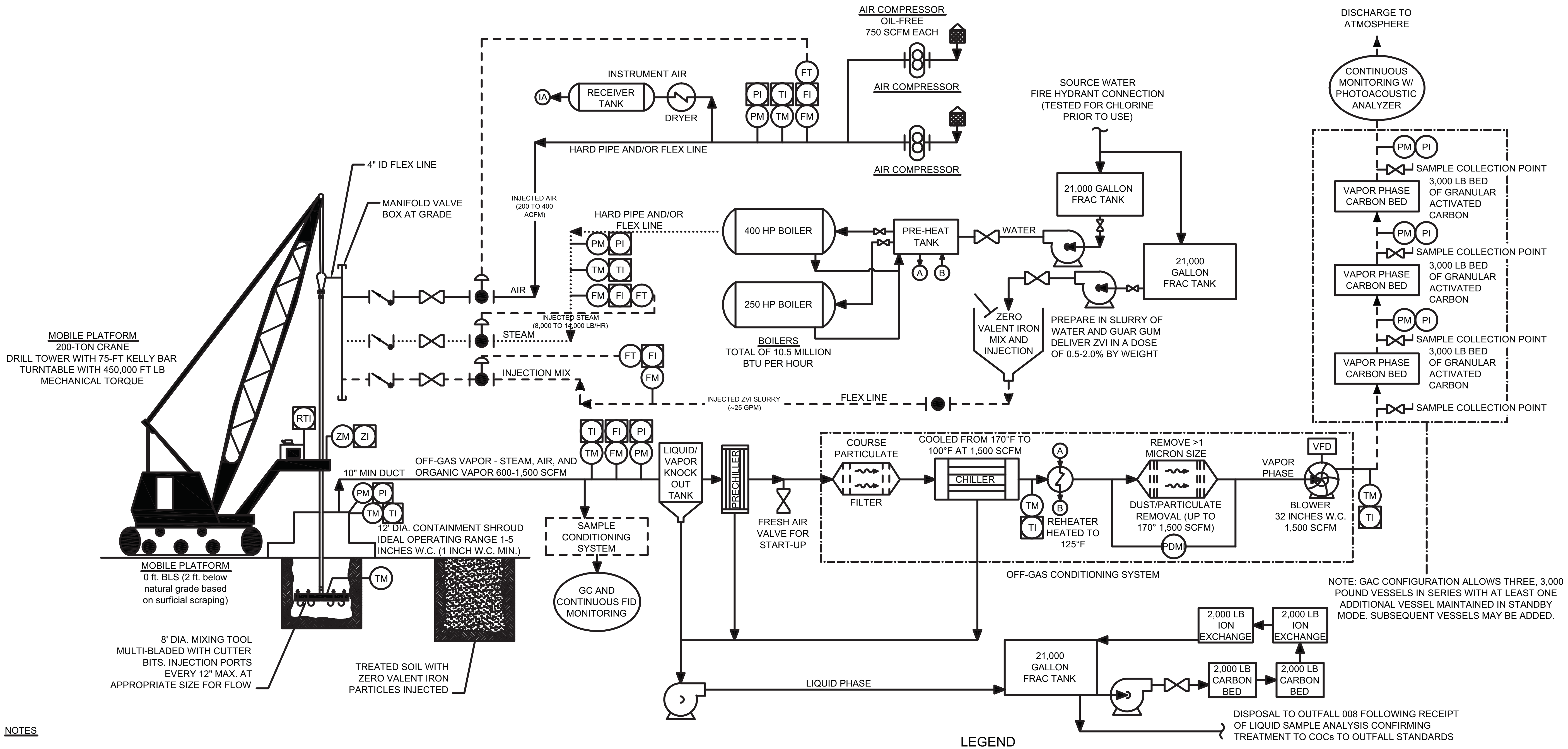

NOTES

1. AREA OUTSIDE THE CONTAINMENT SHROUD SHALL BE MONITORED MANUALLY WITH AN ORGANIC VAPOR ANALYZER TO VERIFY THAT OFF-GAS IS CAPTURED BY THE SHROUD.
2. THE CONTRACTOR SHALL PROVIDE AND OPERATE AN INTEGRATED DATA ACQUISITION SYSTEM (DAS) CAPABLE OF CONTINUOUS MONITORING AND RECORDING ALL PROCESS CONTROL PARAMETERS AT A CENTRAL LOCATION.
3. DAS SHALL BE CAPABLE OF PROVIDING DATA, AS INDICATED, IN REAL TIME FOR PROCESS CONTROL.
4. THE STORAGE TANKS SHOULD INCLUDE VENTS CONNECTED TO CARBON FILTERS TO CAPTURE FUGITIVE EMISSIONS.

LEGEND

| | |
|---|---|
| ● | BALL VALVE |
| | BUTTERFLY VALVE |
| | CHECK VALVE |
| | GATE VALVE |
| | PNEUMATIC ACTUATED |
| NC | NORMALLY CLOSED |
| NO | NORMALLY OPEN |
| | SAMPLING PORT |
| VFD | VARIABLE FREQUENCY DRIVE |
| | IN-LINE CENTRIFUGAL PUMP |
| ZM | POSITION MEASUREMENT |
| PM | PRESSURE MEASUREMENT |
| TM | TEMPERATURE MEASUREMENT |
| FM | FLOW MEASUREMENT |
| ZI | POSITION INDICATOR |
| PI | PRESSURE INDICATOR |
| TI | TEMPERATURE INDICATOR |
| FI | FLOW INDICATOR |
| FT | FLOW TRANSMITTER |
| PDM | PRESSURE DROP MEASUREMENT/INDICATOR |
| RTI | RUN TIME INDICATOR |
| ▢ | INDICATOR ON DAS |
| IA | INSTRUMENT AIR |
| A | FROM BOILER PRE-HEAT WATER TANK (180°F) |
| B | TO BOILER PRE-HEAT WATER TANK (170°F) |

Paducah SW Plume Remedial Design

Process Flow Diagram

Geosyntec consultants

FIGURE

8

Titusville, FL

June 2013

I:_CADD (PROJECTS)\NINASA\FIGURES\FR0743B.20\FR0743B-C010.DWG (6 June 2013) cgootan

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## 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 (See Section 1.2);
- Buried underground utilities and obstructions (See Section 4.2, Impact to Surrounding Structures, Utilities, and Operations, and Figures 4 and 9);
- Shape and depth of the treatment area (See Section 2 and Figure 6);
- Site geology (See Section 1.1);
- Site hydrogeology, including depth to groundwater and groundwater flow rate (See Section 1.1);
- Soil chemical characteristics, including percentage of organic carbon content (See Section 1.3);
- Contaminant-specific remediation goals, defined in the FFS (DOE 2010a) and listed in Table 4;
- Compliance with applicable or relevant and appropriate requirements (ARARs) (ROD DOE 2012a);
- Absence of low-volatility co-contaminants (at the time of LDA soil mixing within treatment area) (See Section 1.5);
- Options for wastewater disposal (See Section 4.4.1.4); and
- Selection of vapor treatment technology (See Section 4.4.1.5).

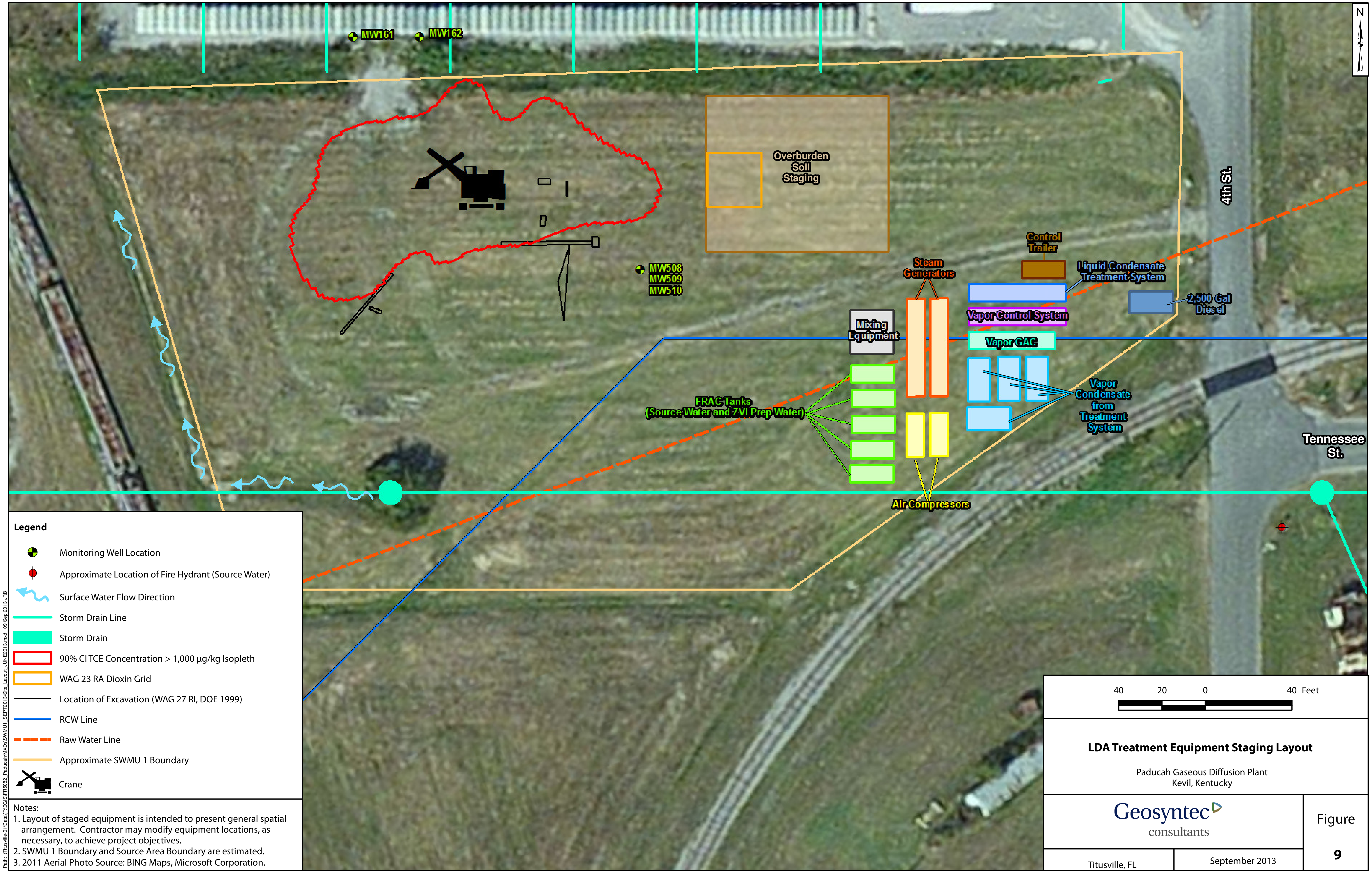
**Table 4. Cleanup Levels for the Oil Landfarm Source Area RA**

| Contaminant of Concern | Cleanup Levels 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).

## 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 treatment 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.



**Legend**

| | |
|---|---|
| ● | Monitoring Well Location |
| ⊕ | Approximate Location of Fire Hydrant (Source Water) |
| ↝ | Surface Water Flow Direction |
| — | Storm Drain Line |
| 🟩 | Storm Drain |
| ☐ | 90% CI TCE Concentration > 1,000 µg/kg Isopleth |
| ☐ | WAG 23 RA Dioxin Grid |
| — | Location of Excavation (WAG 27 RI, DOE 1999) |
| — | RCW Line |
| - - | Raw Water Line |
| — | Approximate SWMU 1 Boundary |
| ✕ | Crane |

Notes:
1. Layout of staged equipment is intended to present general spatial arrangement. Contractor may modify equipment locations, as necessary, to achieve project objectives.
2. SWMU 1 Boundary and Source Area Boundary are estimated.
3. 2011 Aerial Photo Source: BING Maps, Microsoft Corporation.

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**LDA Treatment Equipment Staging Layout**

Paducah Gaseous Diffusion Plant
Kevil, Kentucky

Geosyntec consultants

Titusville, FL
September 2013

Figure
9

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 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 then are 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 GAC placed in series to remove VOCs. If field-collected data during remedial implementation indicates that greater than anticipated volumes of vapor-phase GAC are required to achieve off-gas treatment, other treatment system components (such as a mobile thermal oxidation unit) may be incorporated to replace or supplement the GAC units. The need for other vapor treatment system components is considered highly unlikely, and specifics on this system have not been included in the design. The liquids from the VCS will be stored in frac tanks. The water in each frac tank will be analyzed for VOCs and nontarget/non-VOC contaminants, including polycyclic aromatic hydrocarbons (PAHs), PCBs, radionuclides, and heavy metals, consistent with the Memorandum of Agreement for the Southwest Plume FFS (DOE 2010c), to establish whether additional treatment measures will be necessary prior to discharge. If additional treatment is necessary, the water will be treated on-site via recirculation through the frac tank utilizing liquid-phase GAC and ion exchange resins (Purolite A530E or equivalent) for removal of VOCs and other contaminants, if present, prior to discharge at a PGDP outfall (e.g., Outfall 008).

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 8. General unit processes shown in Figure 8, 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 described in the following sections.

##### 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 (Manitowac 777, 200-ton crane or approved equivalent, with a minimum 75-ft long by 13.5 inch$^2$ diameter hollow drill stem (kelly bar) driven by a high-torque transmission (Hain turn-table or approved equivalent) 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 in the mixing area 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 multi-bladed 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 injection ports every 8 to 10 inches along the back side of the mixing blade (or approved equivalent) to achieve effective distribution of hot air/steam and injected ZVI throughout the mixed soil column. A spare mixing tool of similar diameter also will be maintained on-site. 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 mixing rig will be capable of reaching outward from the toe of the crawler tracks (crane front) up to two rows of overlapped column locations. Prior to initiating drilling activities for a given column, the Kelly bar will be checked for verticality utilizing a survey level. This check will be done in two perpendicular directions prior to proceeding with any drilling work and once during the first pass. Results will be logged. The kelly bar vertical alignment will be controlled by adjusting the crane mats, drill platform, or the cables that suspend the turntable and/or by slightly booming up or down as necessary. 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 two Sullair (or approved equal) electrically powered 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. The compressors will be capable of a turndown ratio greater than 75%. 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 actual air compressor capacity (acfm) and minimum temperature of 385ºF 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 after subtracting the methane values. Flow rate will be measured with an orifice plate connected to a Rosemount delta P instrument and monitored by the data acquisition system or approved equivalent.

The steam generating system will be comprised of two diesel-powered steam boilers (one 400-horsepower (HP) and one 250-HP or approved equivalent) with the capability of producing steam and/or hot air at a minimum temperature of 385°F from a facility-supplied water source that has been staged on-site in a minimum of two 21,000 gal frac tanks to provide time for residual chlorine to dissipate to a concentration of 0.03 mg/L or less (to be evaluated utilizing a Hach field chemistry test or equivalent), prior to utilization as makeup water for steam or ZVI injection. If residual chlorine concentrations remain elevated following a 24-hour stabilization period, an alternative approach to provide removal of residual chlorine, such as diffused aeration of the makeup water within the frac tank to assist in acceleration of the natural volatilization of residual chlorine, may be utilized. 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 after subtracting the methane values. 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.

Boilers may be subject to EPA area source Maximum Achievable Control Technologies (MACT) standards; however, 40 *CFR* Part 63, Subpart JJJJJJ (area source boiler MACT) 63.11195(h) indicates that temporary boilers are not subject to this subpart. Based on the definitions of a temporary boiler provided in 40 *CFR* Part 63, Subpart JJJJJJ (area 63.11237), it has been interpreted that the boilers used in this remediation process meet the definition of temporary boilers and will not be subject to this regulation. Regarding greenhouse gas emissions, we interpret that the remedial equipment would meet the definition of “portable equipment” under 40 *CFR* Part 98, Subpart A and, therefore, would be exempt from greenhouse gas reporting requirements under this regulation.

#### 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 minimum 12-ft diameter steel shroud to provide capture of VOCs. The shroud will cover the ground surface around the boring location that is penetrated by the rotating kelly bar providing a minimum 12-ft diameter radius of influence for vapor collection. The shroud will be set to penetrate the surface to approximately 1-ft bgs. The shroud provides the ability to capture off-gases beyond the diameter of the 8-ft diameter 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. 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. Establishment of the shroud vacuum prior to soil mixing provides a mechanism to confirm that the shroud provides an effective seal around the auger borehole location. In the event of shroud lifting issues during soil mixing, additional weight may be added to the shroud by the operator and/or soil may be placed around the periphery of the shroud to provide an effective seal to mitigate the potential escape of vapors.

The VCS will consist of a blower, liquid-vapor knock-out (KO)/demister tank, air filter, chiller, transfer pumps, and reheater/heat exchanger or equivalent. The vapor entering the shroud from the borehole 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 then will flow from the KO tank into a chiller unit used to cool the gas (typically to a temperature of less than 90°F). General VCS equipment specifications are included as follows:

- **Blower**—A centrifugal pressure blower rated for 1,800 cubic ft per minute at 31 inches total static pressure @ 13.4 BHP using a 15 hp 230-460/3/60 VAC totally enclosed fan cooled premium efficiency motor [for use with a variable frequency drive (VFD)]. A damper will be employed to control the pressure variations at the shroud due to varying flow losses because of variable duct length from one treatment area to another. National Electrical Manufacturers Association 4 rated

VFD motor speed control rated for a 15 hp motor and 460 VAC/3 phase input from a generator (or approved equivalent).

- **Knockout tank**—The KO tank will consist of a 44-inch diameter by 72-inch high steel vessel (or approved equivalent) with hose connections for processing air in and out, a sludge drain port with gate valve, and a connection for feeding to a transfer pump. The KO tank will include three float switches for pump on/off control and a high water alarm.

- **Chiller**—The chiller unit will consist of a TRANE 70T [840,000 British thermal units per hour (BTU)/hr]) air cooled water chiller using FREON 22 (or approved equivalent). This unit will be capable of cooling the gas flow temperature from approximately 160°F to less than 100°F at a flow rate of 1,300 scfm. The heat exchanger will be an Aerofin Type Rf coil 34.9 inch by 25 inch, six-row with copper fins on 5/8 inch copper tubing with a galvanized steel case. The housing for mounting the coil, inlet filters, inlet and outlet connections will be 14 gauge galvanized steel. The drain pan will be 304 stainless, 14 gauge, with a 3/4 inch national pipe thread drain connection.

- **Particulate Filter**—Included in the chiller unit housing will be a 25 inch by 16 inch by 2 inch stainless steel mesh filter (F-101) for particulates (or approved equivalent).

- **Condensate Pump and Discharge Pump**—These pumps will be commercial off-the-shelf, 1/2 hp water pumps (or approved equivalent) for pumping out the collected water from the knockout tank and chiller condensate to the VOC water holding tank and to the Outfall 008 discharge.

- **Reheater**—The reheat unit along with the blower heat of compression will raise the temperature more than 12°F and reduce the relative humidity to less than 80%. The coil is housed in the same housing as the chilled water heat exchanger and is designed to produce 150,000 BTU/hr maximum using 180°F water from the boiler preheat tank. A hand valve on the upstream side of the reheater will control the water flow and subsequent heat capacity.

Condensate water generated by the KO tank chiller will be transferred and stored in a 21,000-gal frac tank(s) and treated with liquid-phase GAC and ion exchange resins (Purolite A530E or equivalent) to remove constituents of concern prior to discharge to a PGDP outfall (e.g., Outfall 008), in accordance with ARARs. Additionally, recovered condensate water from each frac tank will be analyzed for VOCs and non-target/non-VOC contaminants, including PAHs, PCBs, radionuclides, and heavy metals, consistent with the Memorandum of Agreement for the Southwest Plume FFS (DOE 2010c), to establish whether additional treatment measures will be necessary prior to discharge. Cooled vapor 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 Liquid treatment system (liquid-phase carbon adsorption and ion exchange)

Condensate water generated by the KO tank chiller will be transferred and stored in a 21,000-gal fractionation tank(s), which will be filled to a capacity not greater than 18,000-gal. The frac tanks will be enclosed and vents will be covered with vapor-phase carbon filters to prevent fugitive VOC emissions. It is anticipated that condensate water may contain VOCs and/or some non-target/non-VOC contaminants (such as PAHs, PCBs, radionuclides, and heavy metals), which will require treatment prior to discharge. The collected condensate water will be treated in a closed-loop recirculation treatment system consisting of 2 liquid-phase GAC and 2 ion exchange resin columns connected in series to remove constituents of concern prior to discharge to a PGDP outfall (e.g., Outfall 008) (in accordance with ARARs). The liquid-phase carbon vessels will be utilized primarily for removal of VOCs, PAHs. and PCBs, if present in the condensate water. The ion exchange resin (Purolite A530E) will be utilized for removal/recovery of metals and radionuclides, if present in the condensate water. The GAC vessels will provide a total holding capacity of a maximum of 4,000 lb of virgin, liquid-phase GAC. The ion exchange resin columns will hold a maximum of 4,000 lb of Purolite A530E resin. Each vessel will be capable of treating a flow range of 40 to 60 gpm. Condensate water will be pumped via submersible pump capable of producing a flow rate of 50 gpm placed in the frac tank. Condensate water will be recirculated through the treatment system for a minimum of 24 hours (equal to four treatment volumes of collected condensate water). Following a 24-hour treatment period and prior to discharge, treated condensate water from each frac tank will be analyzed for VOCs and non-target/non-VOC contaminants, including PAHs, PCBs, radionuclides, and heavy metals, by the on-site laboratory facility on a 48-hour turnaround time basis. Laboratory analysis will establish whether additional treatment measures will be necessary or discharge may occur. If the treated condensate water has met the established treatment criteria for a PGDP outfall (e.g., Outfall 008), the treated effluent will be discharged accordingly. While laboratory results are pending, additional condensate water produced by the treatment system will be collected in a separate frac tank. The condensate water treatment system will be utilized for treating condensate water collected within other frac tanks while laboratory results are pending. The effectiveness of the treatment system will be evaluated based on the treatment performance data reported by the laboratory prior to discharge. If necessary, based on the findings of the laboratory data, the treatment system may be amended or modified, and spent media will be changed out to ensure that treatment objectives are being met prior to discharge to a PGDP outfall (e.g., Outfall 008).

#### 4.4.1.5 Vapor treatment system (vapor-phase carbon adsorption)

Conditioned vapors exiting the VCS will be treated on-site utilizing a minimum of three 3,000-vapor-phase GAC adsorption vessels connected in series. At least one additional vessel will be maintained at the site in standby mode. 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 a minimum of twice daily during active operations using a PID, FID, or Draeger-Tubes®. GAC vessel change out, if required, will occur when GAC breakthrough is documented, as indicated by an increase in initial GAC vessel exhaust concentration to a level that is within 50% of the influent concentration, indicating that breakthrough has occurred in the initial GAC vessel. If an air exhaust measurement of approximately 50% of the influent measurement is detected, planning will begin for carbon replacement. If field-collected data during remedial implementation indicate that greater than anticipated volumes of vapor-phase GAC are required to achieve off-gas treatment, other treatment system components (such as a mobile thermal oxidation unit) may be incorporated to replace or supplement the GAC units. The need for other vapor treatment system components is considered highly unlikely, and specifics on this system have not been included in the design. Discussions will be held among the FFA parties, should it be determined that more than GAC is needed for the SWMU 1 operation.

The results of the EVS-ES modeling using the RDSI soil results revealed a potential range of TCE mass within the source area of 1.4 gal to 29.3 gal. Based on a conservative range of total VOC contaminant mass in the SWMU 1 area ranging from 100 to up to 1,000 lb, and an assumed carbon adsorptive capacity and usage rate of 20% (20 lb VOCs/100 lb 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 500 to 5,000 lb (indicating that the 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. Off-gas from the vapor-phase polishing system will be discharged to the atmosphere through a 15-ft tall by 6-inch diameter stack. Off-gas emissions will be monitored by a photoacoustic analyzer. The analyzer will communicate with a control system to notify operations personnel in the event of an exceedance of discharge criteria. The analyzer utilized will be an Innova 1412 or equivalent that is capable of measuring over 300 different gases including the 5 VOCs mentioned here. The Innova can measure up to 5 gas components and water vapor in each air sample. The analyzer will be calibrated and equipped with optical filters for speciation of the five contaminants of concern expected at SWMU 1(TCE, vinyl chloride, *cis*-1,2 DCE, *trans*-1,2 DCE, and 1,1 DCE) or as recommended by the analyzer manufacturer or authorized representative. The optical filters will supply a maximum detection limit of less than 1 ppm for each gas with a minimum sample integration time of 5 seconds. The analyzer will alarm at the control system panel to notify operations personnel in the event of an exceedance of discharge criteria and to discontinue mixing and vacuum operations. The air dispersion modeling results included in Appendix D indicate that a maximum exhaust pollutant concentrations (with an applied safety factor of 1.5) results in property boundary concentrations that are significantly lower than the off-site limits; thus, the system will be shut down manually before emissions reach the quantities that will exceed acceptable risk levels.

#### 4.4.1.6 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 former 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 lb 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 (5 $yd^3$ High Shear Lightning Mixer or approved equivalent), a progressive cavity pump (L-12 Moyno pump or approved equivalent), and a high viscosity flow meter (Halliburton Turbine Water flow meter or approved equivalent). 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.

#### 4.4.1.7 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 (frequencies of data collection, monitoring, and associated reporting) 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, after methane subtraction 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.). Real-time monitoring of the point of atmospheric emission will be monitored with a photoacoustic analyzer. This monitoring will trigger an alarm notification to the equipment operator, which will trigger a manual shutdown of remedial equipment.

The Data Acquisition System will consist of the two SRI GCs 8610, and field instruments served by three Automation Direct 205 programmable logic controllers that provide data input to a personal computer (PC) (or approved equivalent). The data will be monitored and recorded in real time. The data will be displayed and recorded in engineering units in real time. PC application software will display, in real time, selected parameters and will record at a selected rate of 6 times a minute. The recorded data will be viewed and saved in a Microsoft Excel spreadsheet.

### 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. Figure 7 presents the LDA boring layout. 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]. Prior to full active remedial implementation, at least two test cells will be performed during implementation in the SWMU 1 treatment area to simulate active remediation, to ensure the system is functioning efficiently as designed, and to troubleshoot problems or issues that developed prior to active remediation. The test treatment cells will be conducted in an area of highest detected concentration and in an exterior cell of anticipated lowest concentrations at the site. At each of the test cell locations, soil samples will be collected from land surface to the total LDA boring depth at 5 ft increments within 2 weeks of completion of the test cells using hot soil sampling techniques. Collected soil samples will be analyzed for COCs to assess the effectiveness of the LDA borings in achieving soil cleanup criteria (with consideration that the ZVI will continue to reduce residual concentrations over time). As a result of this analysis and subsequent review by the FFA parties, adjustments to the mixing approach will be considered, if feasible. Among the parameters that could be modified are these:

- The rate of vertical ascent/descent
- The number of auger revolutions per minute during steaming/mixing
- The minimum steam delivery rate
- The number of auger revolutions per minute during ZVI placement

- Adjustment of the vacuum pressure in the shroud
- The number of vertical mixing passes

The implementation parameters listed above are not presented in order of prioritization of implementations. The need for implementation of these adjustments and the prioritization of adjustments will be discussed with the FFA parties following the completion of test cell mixing and the receipt of sample results. The information collected during the conduct of test cells will be used to discuss potential modifications to treatment decision criteria, if needed. Following test cell implementation, the test cell evaluation will include testing of the vapor condensate and off-gas discharges to help ensure that these are being handled appropriately. 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 as a best management practice to potential groundwater displaced outward during implementation. Real-time PID/FID data collected during the thermal treatment phase of remedial implementation will be shared with the project team (to include representatives from EPA, KDEP, DOE, and DOE design team representatives) on a weekly basis, at a minimum, to present the field-collected data from the previous week's field activity (Note: subject to field productivity, this likely will represent data collected from 10 to 20 treatment cell borings). Following the completion of the outer-most ring of LDA borings and completion of interior test cells (to be conducted in the first-phases of remedial implementation), the project team will discuss the potential need to conduct step-out LDA borings based on the outer-most ring results and the specific criteria that will be used for decision making protocol.

#### 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 thermal treatment depth of the cell in one direction, up or down). The thermal treatment depth will begin approximately 5 to 6 ft below the surface (2 ft below natural grade based on surficial scraping) for worker safety purposes and will continue to the base of the treatment cell [60 ft below the surface (2 ft below natural grade based on surficial soil removal)]. 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 presented in Figure 7.

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 (EZ Mud® or approved equivalent) may be utilized as a cutting fluid to assist in auger advancement in the formation, to provide flexibility to the LDA contractor in case the drilling penetration is impeded based on soil conditions. A field condition that could warrant using the drilling mud would be encountering, while drilling, a very dense layer or soils with a high friction coefficient where the injection of a drilling mud could assist in achieving LDA penetration. The drilling mud has no negative effect on thermal treatment processes. The drilling mud also has no impact on the ZVI injection process because the mixing blade provides the mechanism for distribution within the soil column. It is noted that drilling mud was applied in the remedial implementation at the Offutt Site, and a negative impact on the overall project performance at that Site was not observed or perceived. The GCs will process samples continuously at a frequency of approximately every 2 minutes for analysis; however, this sample processing rate may be reduced if the auger ascension/descension rate is reduced to less than 1 ft/min.

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. The final pass must have been completed from total treatment depth to top of target treatment interval and obtain completion criteria of an PID/FID concentration, after subtracting the methane value, and have a reduction of 80% of the highest peak PID/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 following the completion of at least four complete thermal passes. Additional treatment time may be employed.

The LDA/steam/ZVI treatment protocol is presented graphically in Figure 7. Please note that the intention of the LDA/steam/ZVI treatment protocol depicted in Figure 7 has not been presented with the intention to provide a rigid framework that will apply to each and every case that may be encountered during field implementation, but rather to describe the general protocol and procedures for what are anticipated to be representative of the most likely scenarios encountered during implementation. The field team and equipment operator will reserve the flexibility of field-based judgment to alter the Treatment Protocol only for the overall benefit and success of project implementation. If alterations to the treatment protocol are to be made during project implementation that result in relaxed treatment criteria from those described above, they will be discussed first with the remedial team (to include representatives from EPA, Kentucky KDEP, DOE, and DOE design team representatives). 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).

#### 4.4.2.2 Description of ZVI dosing

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 mass of ZVI to mass of soil application. Decisions will be 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 5,000 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 5,000 ppm (after subtracting the methane value) is observed on the first thermal treatment pass, an application of 1.5% ZVI will be applied.

- Based upon RDSI soil sampling results, the area within the greater than 10,000 µg/kg TCE isoconcentration contour area will be treated with a default application of no less than 1.5%, but not greater than 2% ZVI, regardless of PID/FID response. This range of concentration has been presented based on practical limitations to injection of 2% ZVI observed at other sites.

The ZVI dosing concentration will be measured as a percentage by weight of the column of soil being treated. The ZVI dosing strategy is consistent with the LDA soil mixing projects successfully implemented to treat TCE/DNAPL source areas at Cape Canaveral Air Force Station and former Offutt Air Force Base. The LDA/Steam/ZVI Treatment Protocol is presented graphically in Figure 7. Please note that the intention of the LDA/Steam/ZVI Treatment Protocol depicted in Figure 7 has not been presented with the intention of providing a rigid framework that will apply to each and every case that may be encountered during field implementation, but rather to describe the general protocol and procedures for what is anticipated to be representative of the most likely scenarios encountered during implementation. The field team and equipment operator will reserve the flexibility of field-based judgment to alter the Treatment Protocol only for the overall benefit and success of project implementation. If alterations to the treatment protocol are to be made during project implementation that result in relaxed treatment criteria from those described above, they will be discussed first with the remedial team (to include representatives from EPA, KDEP, DOE, and DOE design team representatives).

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. The vertical treatment of ZVI application will extend from the surface of the treatment cell (approximately 2 ft below natural grade based on surficial scraping) to the base of the treatment cell depth (approximately 62 ft below natural grade). This will not coincide with thermal treatment, which will commence at a depth of 5 to 6 ft bgs (7 to 8 ft below natural grade based on surficial scraping) which is a necessary measure for worker safety.

# 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 likely will include, but not be limited to, these items:

- Crawler crane (200-ton crawler crane such as a Manitowac 777 or approved equivalent) or heavy equipment capable of delivering required torque and soil mixing requirements to achieve target depth

- Flatbed truck

- Storage units (e.g., Conex boxes/Sealand containers)

- Drill turntable (Hain or approved equivalent)

- Excavator (CAT 322 or approved equivalent)

- Loader (Cat 928 or approved equivalent)

- High reach man lift (High Reach-Bil Jax 45XA—4WD or approved equivalent)

- 21,000-gal frac tank(s) for supply water staging and KO vessel water storage (Adler 21,000 closed top frac tank or approved equivalent)

- Telescopic forklift (CAT 3RN01724 or approved equivalent)

- Equipment storage trailer

The mixing rig will be mobilized to the site with multiple tractor-trailer components, as necessitated by the vendor-specific equipment. 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. The equipment required to achieve project objectives shall be based upon vendor-specific components proposed to achieve project objectives. Typical equipment includes the following:

- Mixer
- Liquid mixing tanks
- 400-hp or equivalent boiler generating steam at 385°F
- Liquid transfer pumps
- Hollow kelly bar (70-ft long) and swivel
- 8-ft auger
- Containment shroud (minimum 12-ft diameter)
- Vapor conditioning system, 70-ton chiller, or equivalent, with blower unit
- Process knockout tank
- Heat exchanger
- SVE Blower capable of 600 to 1,500 scfm at an approximate operating vacuum of 30 inches of water
- Data acquisition system
- Three 3,000 lb or equivalent vapor-phase carbon adsorption vessels
- Power generators

Additional detail related to equipment specification or approved equivalents is provided in Section 4.4.1, Equipment Summary, and associated subsections.

## 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. Approximately 750 kilovolt amperes (kVA) will be required to operate the *in situ* LDA soil mixing with hot air/steam and ZVI injection system (this may vary depending on contractor-specific equipment utilized to achieve the site treatment objectives), which will be obtained through an on-site generator to be supplied by the remediation vendor.

## 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 will be obtained from the fire hydrant located at the southeast intersection of 4th Street and Tennessee St. (see Figure 9) and will be hard piped to the treatment area via culverts that run beneath the streets and railroad tracks. Water will be collected and staged on-site in a minimum of two 21,000-gal frac tanks to provide time for residual chlorine to dissipate to a concentration of 0.03 mg/L or less (to be evaluated utilizing a Hach field chemistry test or equivalent) prior to utilization as makeup water for steam or ZVI injection. If residual chlorine concentrations remain elevated following a 24-hour stabilization period, an alternative approach to provide removal of residual chlorine may be utilized. Additionally, Water entering steam boiler units may require conditioning using water softening ion exchange units to prevent scaling of the units. If needed, water will be recirculated through weak acid cation exchange units (Marlo, Inc., MGT-300-2 Twin Alternating Softener System or approved equivalent) until field measurements of the water hardness (based on Hach field chemistry) achieve limits acceptable to the remediation equipment vendor. The need for water softening units will be determined by the LDA soil mixing contractor based upon operations at other sites and experience with the steam boiler units owned and operated by the contractor.

## 5.5 SITE PREPARATION

Site preparation also may include siting of an operations trailer, site surveying, utility locating, 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 potential contaminants that may be present and to facilitate soil mixing to desired depth, stockpiling the excavated soil, and then respreading the excavated soils after mixing is complete. These nonvolatile contaminants will not be treated by the soil mixing technology and will be addressed consistent with the approach discussed previously in Section 1.5, “Sequencing with Other Remedies.” Liner material such as polyethylene or Hypalon® will be placed under and over the stockpiled soil until completion of the RA. Figure 9 presents a conceptual LDA equipment layout that includes the stockpiling area. During excavation of the top 2 ft of soil, water sprays will be used as needed to prevent the generation of fugitive dust.

The excavated soil will be respread on the area that has been soil mixed. The replacement of the soil will be performed within one year of completion of the soil mixing operation. The soil placement will be delayed for two reasons:

1. The soil will be more stable to heavy equipment traffic, which will be the most efficient way of placing the soil, and

2. The one-year window will allow the performance of the postremedial soil monitoring to be performed without having to push direct-push technology tooling through the extra 2 ft of soil.

A layer of Visqueen or similar material will be placed at the base of the replaced soils to provide a marker bed between the mixed soil and the unmixed soil. If remedial efforts for the Soils OU have progressed in the selection of a remedial measure prior to soil replacement, and it is determined that use of the Visqueen will be detrimental to the potential Soils OU RA, the placement of the Visqueen will not be performed. Should the placement be cancelled, the FFA parties will be notified of the change to the in design to support the future Soils OU actions.

### 5.6 PERMITTING

Site-specific permits will be required for the implementation of the RA utilizing the selected *in situ* soil mixing and treatment system. Applicable site-specific permits include the following:

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

The use of best management practices related to storm water management is required for the construction within the SWMU 1 area because PGDP has a Kentucky Pollutant Discharge Elimination System permit. Accordingly, it is anticipated that silt fence will be installed in the site construction area as a component of a site-specific stormwater best management practice.

## 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. Systems will be designed to accommodate operational sampling and real-time monitoring for parameters, such as the following:

- **Subsurface Temperatures.** Monitored continuously using a combination of evaluation of vapor shroud off-gas temperature and daily review of auger mixing blade thermocouple data. Subsurface temperatures will be documented for each soil mixing location.

- **VOC Concentrations in Recovered Vapor.** Monitored continuously during soil mixing at each boring location with PID/FID recorded continuously with depth. GCs will continuously process samples at a frequency of approximately every 2 to 5 minutes for analysis during soil mixing activities. Documentation of PID/FID response with depth (per treatment pass) and GC data (every 2 to 5 minutes) will be collected for each soil mixing location.

- **VOC Concentrations in the Worker Breathing Zone.** Due to the concentrations of VOCs present and the potential for release into the breathing zone as a result of the soil mixing activities, real-time air monitoring will be conducted during the course of all intrusive work associated with soil mixing consistent with the requirements of the project-specific Health and Safety Plan for the remedial action.

- **Shroud Extraction Vacuum, Temperature, and Flow Rate.** Continuous monitoring and recording of shroud vacuum at each boring location to document vacuum requirements achieved. Continuous monitoring of shroud temperature and air flow rate and documentation at each boring location that temperatures meet criteria and that flow rate from shroud exceeds air injection rate, as required.

- **Compressed Heated Air/Steam Delivery Pressure, Temperature and Flow Rate.** Continuous monitoring at each auger location to document heated air/steam delivery pressure, temperature and flow rate. Documentation at each boring location to include information on quantities delivered, confirmation of compressed heated air/steam and documentation at each boring location to document vacuum requirements achieved. Continuous monitoring of shroud temperature and air flow rate and documentation at each boring location that temperatures meet criteria and that flow rate from shroud exceeds air injection rate, as required.

- **ZVI Injection Quantity, Temperature, Pressure, and Flow Rate.** Continuous monitoring at each auger location to document ZVI mass applied, temperature, pressure, and flow rate. Documentation at each boring location to include information on quantities delivered, temperature, pressure, and flow rate during delivery.

- **Vapor-Phase Effluent Discharge Flow Rate and VOC Concentration.** Monitoring of vapor phase flowrate and VOC concentration and monitoring of vapor-phase carbon for efficiency and loading.

- **VOC Concentration in Condensed Liquids from the Vapor Stream.** Fluid sampling of condensed liquids.

- **PCB, PAH, Radionuclide, and Heavy Metals.** Concentration in a subset of condensed liquids from the vapor stream and vapor-phase effluent for each frac tank prior to release.

- **Heat Exchanger Air Temperatures and Relative Humidity.** Recorded and documented for each auger boring location.

- **Vapor-Phase Effluent Discharge Temperature, Flow Rate, and CVOC Concentration**. Monitor vapor phase flow rate and VOC concentration and monitoring of vapor-phase carbon for efficiency and loading. Measurements of discharge temperature and flow rate will be recorded by the Data Acquisition System at a rate of 6 times per minute. To monitor the GAC for breakthrough, the effluent from each GAC vessel will be monitored daily during active operations using a PID or FID, after methane subtraction. Additionally, off-gas emissions will be monitored by a photoacoustic analyzer. The analyzer will communicate with a control system to notify operation personnel in the event of an exceedance of discharge criteria. The set point at the stack that will cause the vapor extraction and treatment system to shut down will be the maximum exhaust pollutant concentrations (with an applied safety factor of 1.5) as presented in Appendix D, Table D.4.

## 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 assess the performance of the remedial action and to support the five-year assessment period to evaluate remedial performance against the established objectives. Given the potential that residual TCE contamination may remain following soil mixing with steam injection, the addition of ZVI is used as polishing measure. The residual contaminant concentrations are expected to persist until such time that movement (based upon flow and/or diffusion) facilitates contact between the contaminant and the ZVI, thereby allowing the contamination to undergo chemical reduction. Field conditions also will have changed as a result of the soil mixing and injections. The field conditions following the treatment are expected to be as follows:

- Soil will be unstable due to mixing operations and destruction of soil structure,

- Increased water content resulting from hot air/steam injection may result in decreased density and soil strength, and

- Soil temperatures will be elevated due to injection of steam/hot air which will increase worker health and safety concerns.

Because of these field conditions and subsurface conditions, the implementation of postremedial sampling and monitoring may be delayed following the completion of soil mixing. The FFA parties will determine time frame for installation of the post. The requirements for the postremedial work will be documented in a Postremedial Sampling and Analysis section of the RAWP with specifics on boring approach, locations, sampling, contaminant analysis, and the collection of information necessary to complete the required five-year assessments. The areas to be evaluated generally will include the following:

- Postremedial soil sampling for VOCs and levels and distribution profiles in mixed and unmixed areas;

- Installation of postremedial MWs to monitor the progress of contaminant reduction in the RGA groundwater following the mixing process and placement of the ZVI;

- Postremedial soil temperature evaluation; and

- Postremedial evaluation of soil homogeneity and ZVI distribution.

Following completion of the soil mixing process, the previously excavated surface soils will be respread to bring the ground surface back to grade with the surrounding unmixed area. The soils from the surface to a depth of 10 ft contained in the mixing area will require recharacterization due to being disturbed by the mixing process. DOE intends to recharacterize those soils as part of the Soils OU at the appropriate time in the future.

### 6.2.1 Posttreatment Sampling and Analysis

Following cessation of active remedial operations with *in situ* soil mixing with hot air/steam and ZVI injection, monitoring will be conducted to assess the near-term performance of the RA and to support the required CERCLA Five-Year Reviews.

Posttreatment sampling and analysis are intended to achieve three main goals:

1. Assessment of the heating of the subsurface,

2. Assessment of the placement of ZVI for continued VOC reduction,[1] and
3. Assessment of the success of deep soil mixing to achieve the primary project goal of reduction of VOC concentrations to the RA cleanup levels in the treated source zone.

In addition, posttreatment actions will include the installation of upper RGA wells at the perimeter of the treated source zone to monitor the progress of contaminant reduction in the RGA groundwater following soil mixing. The location of the monitoring wells will be determined by the FFA parties following the completion of the soil mixing operations. It is expected that a reduction in the VOC contaminant concentrations in the RGA groundwater over time after the RA is indicative of supporting Goal 3.

In the area of the treated source zone, soil temperatures may be significantly elevated due to injection of steam/hot air. In addition, the soil may be inherently unstable because soil mixing will destroy soil structure and hot air/steam injection may result in decreased soil density and strength. These subsurface conditions require that the implementation of posttreatment sampling and installation of MWs will be delayed by six months following the completion of soil mixing. The delay is advantageous because contaminant concentrations may remain elevated until the guar carrier for the ZVI degrades, allowing the VOC contamination to be reduced by the ZVI.

### 6.2.2 Soil Sampling

The RDSI for SWMU 1 included soil sampling and VOC analysis in 22 locations to determine the areal extent and depth of the source zone. These VOC analyses along with other SWMU subsurface soil VOC analysis provide a baseline for evaluating the effectiveness of the remedial action in reducing the VOC concentrations in the treated areas to the cleanup levels. The posttreatment characterization fieldwork will duplicate the collection of VOC contaminant concentrations in the UCRS soils by twinning the boring locations and collecting samples. The samples will be collected using the same approach used in the RDSI. The project then will be able to evaluate how effective the soil mixing for remedial action was at reducing the VOC contaminant concentrations in the treatment area. The posttreatment characterization fieldwork will include continuous logging of soil conductivity and temperature and sampling of soil borings to the total depth of mixing in 11 of the original RDSI soil boring locations (Figure 10). Eight of the soil borings will be located within the treated source zone, and 3 of the soil borings will be located on the perimeter. Four additional soil boring will be installed at contingent locations based on the data collected as a result of the soil mixing operations. These locations (see Table 5) are representative of both the range of VOC contamination and the areal extent of the treated source zone.

A direct push technology rig equipped with an electrical conductivity probe and a thermocouple will provide the continuous logs of electrical conductivity and temperature of the soil column throughout the depth of the treated source zone. These logs will support assessments of the vertical distribution of ZVI and the residual heat in the treated source zone.[2] The soil sampling to support the posttreatment assessment will remain consistent with the data quality objectives (DQOs) and Quality Assurance Project Plan (QAPP) developed for the RDSI. The direct push technology rig will be used to sample soils within the treated source zone and at perimeter locations, with similar methods used during the RDSI. Analyses of these soil samples will support an assessment of the reduction of VOC levels within the treated source zone and verify the distribution of ZVI.

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[1] The VOCs of interest to this remedial action are 1,1-DCE; *cis*-1,2-DCE; *trans*-1,2-DCE; TCE; and vinyl chloride. VOC samples will be analyzed using EPA SW-846 Method 8260.

[2] ZVI is significantly more electrically conducted than native soil. Any significant inhomogeneity of ZVI distribution will be apparent on the electrical conductivity log.

## Locations of SWMU 1 Posttreatment and Collocated RDSI Soil Characterization Borings

| Postremedial Characterization | | RDSI Soil Boring ID | Approximate Plant Coordinates | |
|---|---|---|---|---|
| Electrical Conductivity Boring ID | Soil Boring ID | | East | North |
| 001-330 | | | -6854.4 | -1699.2 |
| | 001-331 | 001-303 | -6854.4 | -1697.2 |
| 001-332 | | | -6834.0 | -1721.1 |
| | 001-333 | 001-309 | -6834.0 | -1719.1 |
| 001-334 | | | -6880.4 | -1722.0 |
| | 001-335 | 001-310 | -6880.4 | -1720.0 |
| 001-336 | | | -6959.3 | -1721.8 |
| | 001-337 | 001-312 | -6959.3 | -1719.8 |
| 001-338 | | | -6900.4 | -1740.9 |
| | 001-339 | 001-313 | -6900.4 | -1738.9 |
| 001-340 | | | -6810.0 | -1752.6 |
| | 001-341 | 001-314 | -6810.0 | -1750.6 |
| 001-342 | | | -6920.2 | -1762.1 |
| | 001-343 | 001-315 | -6920.2 | -1760.1 |
| 001-344 | | | -6872.3 | -1764.3 |
| | 001-345 | 001-316 | -6872.3 | -1762.3 |
| 001-346 | | | -6900.2 | -1802.5 |
| | 001-347 | 001-318 | -6900.2 | -1800.5 |
| 001-348 | | | -6920.3 | -1722.0 |
| | 001-349 | 001-320 | -6920.3 | -1720.0 |
| 001-350 | | 001-322 | -6801.5 | -1700.6 |
| | 001-351 | | -6801.5 | -1698.6 |
| 001-352 | | n/a | TBD* | TBD* |
| | 001-353 | | TBD* | TBD* |
| 001-354 | | n/a | TBD* | TBD* |
| | 001-355 | | TBD* | TBD* |
| 001-356 | | n/a | TBD* | TBD* |
| | 001-357 | | TBD* | TBD* |
| 001-358 | | n/a | TBD* | TBD* |
| | 001-359 | | TBD* | TBD* |

## Locations of SWMU 1 Posttreatment and Existing Groundwater Monitoring Wells

| Monitoring Wells | | Approximate Plant Coordinates | |
|---|---|---|---|
| Post-treatment | Existing | East | North |
| MW517 | | TBD* | TBD* |
| MW518 | | TBD* | TBD* |
| MW519 | | TBD* | TBD* |
| MW520 | | TBD* | TBD* |
| MW521 | | TBD* | TBD* |
| MW522 | | TBD* | TBD* |
| | MW161 | -6917 | -1667 |

| | |
|---|---|
| 🟦 | Existing Monitoring Well |
| 🟨 | Proposed New Monitoring Well |
| 🟥 | Proposed Soil Boring |

Legend

| | |
|---|---|
| ● | Soil Sampling Location |
| 🟪 | 90% CI TCE Concentration > 10,000 µg/kg Isopleth |
| 🟦 | 90% CI TCE Concentration > 1,000 µg/kg Isopleth |
| 🟩 | 90% CI TCE Concentration > 500 µg/kg Isopleth |
| 🟨 | Nominal TCE Concentration > 73 µg/kg Isopleth |
| — | Plant Water Line |
| — | Storm Drain Line |
| ● | Storm Drain |

Location
Depth BGS
001-132 |TCE 5 <300 10 <135
Result

| Contour | Area (SF) | Area (SF) Exclusive |
|---|---|---|
| 73 | 13,497 | 3,569 |
| 1,000 | 9,928 | 6,272 |
| 10,000 | 3,656 | 3,656 |

Notes:
1. Results are presented in micrograms per kilogram (µg/kg).
2. Sampling depths are in feet below ground surface (ft bgs).
3. *TBD - Location will be determined by FFA parties.

Path: (Titusville-01\Data)T:\GIS\FR5082_Paducah\MXDs\SWMU_1_APR2013\Data Labels Postings Revised May 2013.mxd 12 Jun 2013 JRB

10 5 0 10 20 Feet

**Estimated Extent of TCE Source Area**

Paducah Gaseous Diffusion Plant
Kevil, Kentucky

Geosyntec consultants

Kennesaw | 12-Jun-2013

Figure 10

## Table 5. Locations of SWMU 1 Posttreatment and Collocated RDSI Soil Characterization Borings

| Postremedial Characterization | | RDSI Soil Boring ID | Approximate Plant Coordinates | |
|---|---|---|---|---|
| Electrical Conductivity Boring ID | Soil Boring ID | | East | North |
| 001-330 | | 001-303 | -6854.4 | -1699.2 |
| | 001-331 | | -6854.4 | -1697.2 |
| 001-332 | | 001-309 | -6834.0 | -1721.1 |
| | 001-333 | | -6834.0 | -1719.1 |
| 001-334 | | 001-310 | -6880.4 | -1722.0 |
| | 001-335 | | -6880.4 | -1720.0 |
| 001-336 | | 001-312 | -6959.3 | -1721.8 |
| | 001-337 | | -6959.3 | -1719.8 |
| 001-338 | | 001-313 | -6900.4 | -1740.9 |
| | 001-339 | | -6900.4 | -1738.9 |
| 001-340 | | 001-314 | -6810.0 | -1752.6 |
| | 001-341 | | -6810.0 | -1750.6 |
| 001-342 | | 001-315 | -6920.2 | -1762.1 |
| | 001-343 | | -6920.2 | -1760.1 |
| 001-344 | | 001-316 | -6872.3 | -1764.3 |
| | 001-345 | | -6872.3 | -1762.3 |
| 001-346 | | 001-318 | -6900.2 | -1802.5 |
| | 001-347 | | -6900.2 | -1800.5 |
| 001-348 | | 001-320 | -6920.3 | -1722.0 |
| | 001-349 | | -6920.3 | -1720.0 |
| 001-350 | | 001-322 | -6801.5 | -1700.6 |
| | 001-351 | | -6801.5 | -1698.6 |
| 001-352 | | n/a | TBD* | TBD* |
| | 001-353 | | TBD* | TBD* |
| 001-354 | | n/a | TBD* | TBD* |
| | 001-355 | | TBD* | TBD* |
| 001-356 | | n/a | TBD* | TBD* |
| | 001-357 | | TBD* | TBD* |
| 001-358 | | n/a | TBD* | TBD* |
| | 001-359 | | TBD* | TBD* |

*Location of contingency borings will be selected based on data collected during the soil mixing operations.

If it is determined that direct push technology dual-tube PVC sampling liners are not feasible due to subsurface temperature conditions, the method of sample collection may be modified to hollow-stem auger system with a thin-tube type sample collection or a split-spoon type sampler. The FFA parties will discuss the method of sampling to be utilized to insure the sampling goals will be met. If the posttreatment soil sampling does not meet the cleanup levels set out in Table 4, additional soil sampling will be performed in the area(s) not meeting cleanup levels a minimum of 6 months following the initial posttreatment sampling to further evaluate the impact the ZVI has on additional VOC reductions over time. If the additional posttreatment sampling does not result in achievement of cleanup levels, the FFA will discuss the results and determine an appropriate course of action. The ROD for this action does not identify a contingent remedy for implementation should the UCRS soil cleanup goals not be attained.

### 6.2.3 Monitoring Well Construction and Sampling

**Placement and Construction of RGA Monitoring Wells:** MW161 is an RGA MW located immediately downgradient of the treated source zone, screened over the interval 78–83 ft bgs (elevation 289 to 294 ft amsl). (The HU5 gravel interval of the RGA extends over the approximate elevations of 270 to 310 ft amsl.) Previous sampling and analysis of MW161 documents dissolved TCE levels between 1,100 µg/L (June 13, 2005) and 2,800 µg/L (May 14, 2012) since 2005. This RA is expected to reduce the transport of dissolved VOCs to the RGA and to result in declining TCE levels in MW161. To provide for a broader and continuing assessment of future dissolved VOC levels in the area of the treated source zone, four MWs will be installed in the top of the HU5 gravel interval of the RGA as part of the posttreatment field sampling efforts (two upgradient of the treated source zone and two downgradient) (Figure 10). Table 6 provides information concerning the MWs to be installed. FFA parties will convene prior to monitoring well installation and review data collected from the soil mixing operations and will reach a consensus on monitoring well placement strategy. The four MWs will be constructed with 5-ft length screen (screened approximately 65–70 ft below the original average soil grade; well screen elevations of 302.5 to 307.5 ft amsl). Each of these wells will be equipped with dedicated sampling pumps. Trends in dissolved VOC levels in MW161 and the six wells to be installed will be criteria for future assessment of this SWMU 1 RA.

**Sampling Analysis and Schedule:** The RDSI for SWMU 1 included groundwater sampling and analysis in MW161 to assess preremediation VOC levels and indicators of VOC biodegradation activity. The focus of near-term monitoring as part of the posttreatment action will be to assess the decline in dissolved VOC levels directly resulting from soil mixing and the degradation of VOCs associated with the injection of steam/hot air and ZVI. Groundwater sampling to support the posttreatment assessment will remain consistent with the DQOs and QAPP developed for the RDSI. An assessment of the level of biodegradation activity may be of interest in the future, if follow-on RA is required.

To assess the potential near-term decline in VOC levels in the MWs, groundwater samples will be collected for VOC analysis on a quarterly basis for a one-year term following construction of the MWs and will be collected semiannually during the second year. Subsequent monitoring frequencies will be dictated by the site’s Environmental Monitoring Plan, which is updated annually in compliance with DOE Order 450.1A. The continued sampling under the Environmental Monitoring Plan also will provide the necessary data to support the preparation of five-year reviews required under CERCLA.

**Table 6. Locations of SWMU 1 Posttreatment and Existing Groundwater Monitoring Wells**

| Monitoring Wells | | Approximate Plant Coordinates | |
|---|---|---|---|
| **Posttreatment** | **Existing** | **East** | **North** |
| MW517 | | TBD* | TBD* |
| MW518 | | TBD* | TBD* |
| MW519 | | TBD* | TBD* |
| MW520 | | TBD* | TBD* |
| MW521 | | TBD* | TBD* |
| MW522 | | TBD* | TBD* |
| | MW161 | -6917 | -1667 |

*FFA parties will determine approximate plant coordinates.

# 7. DATA MANAGEMENT

A project-specific data management and implementation plan will be included in the RAWP.

# 8. HEALTH AND SAFETY

A general health and safety plan overview will be included in the RAWP and a project-specific health and safety plan will be developed for field implementation.

# 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.

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# APPENDIX A

# SWMU 1 SOURCE AREA EXISTING ANALYTICAL DATA

**Appendix A information included on CD (see back cover).**

# APPENDIX B

# ENVIRONMENTAL VISUALIZATION SOFTWARE EVALUATION AND VOC MASS ESTIMATE

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Written by: **Raphael Siebenmann** Date: **6/13/2013** Reviewed by: Date:

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

# DRAFT SWMU 1 TCE Extent and Mass Estimate

## PURPOSE

Utilizing the results of LATA-provided soil sampling data, Geosyntec has developed estimates of the extent and mass of trichloroethene (TCE) in soils above the Regional Gravel Aquifer (RGA) at solid waste management unit 1 (SWMU 1), using C Tech's Environmental Visualization Software (EVS). Provided soil sampling data was collected during evaluation of the Upper Continental Recharge System (UCRS) (1998 and 2004) and Remedial Design Support Investigation (RDSI) (2012) sampling of SWMU 1 soils completed within and immediately surrounding the defined SWMU 1 source area to a maximum depth of 64.1 feet below land surface (ft bls). The purpose of this calculation package is to document the methods used in the calculation of the TCE extent and mass

## METHODS

Several interpolation techniques, including kriging, kriging using the 90% confidence interval (CI) about the data, inverse distance weighting (IDW), and nearest neighbor were evaluated, with kriging ultimately being selected as the primary interpolation technique. The techniques are further described below:

- Kriging is a stochastic technique similar to inverse distance weighted averaging in that it uses a linear combination of weights at known points to estimate the value at the grid nodes. Kriging is named after D.L. Krige, who used kriging's underlying theory to estimate ore content. Kriging uses a variogram (a.k.a. semivariogram) which is a representation of the spatial and data differences between some or all possible "pairs" of points in the measured data set. The variogram then describes the weighting factors that will be applied for the interpolation.

- IDW is a method of interpolation that estimates values by averaging the values of sample data points in the neighborhood of each data point. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process. With IDW, the significance of known points on the interpolated values is controlled based on their distance from the output point. A power of two is most commonly used with IDW and is the default.

- Nearest neighbor interpolation is a simple method of interpolation which assigns a value based on the nearest given point.

It is acknowledged that there are significant uncertainties associated with providing a mass estimate of DNAPL using kriging. However, using kriging is still a useful and valid approach to estimate the extent of the source area at various isoconcentration levels below the threshold of residual saturation. Kriging also provides insight about the mass distribution at differing isoconcentration levels. Uncertainty has been considered by estimating mass at different levels of statistical confidence. By kriging data at every node of the model, an average value along with a standard deviation is calculated, thus providing a range of estimated TCE concentrations and ultimately mass. A level of significance of 0.1, the i.e. 90% confidence interval (CI), was used in modeling the geometry and mass of TCE in order to address uncertainty in the estimates.

Due to elevated detection limits at select locations (typically within the range of 500 to 900 µg/kg compared to the SWMU 1 treatment standard for TCE of 73 µg/kg), data from the historic 1998 and 2004 UCRS investigations were analyzed in EVS using 1 µg/kg for the detection limit for non-detect (ND) results. This detection limit is consistent with the typical detection limits observed in the RDSI data.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Written by: | **Raphael Siebenmann** | Date: | **6/13/2013** | Reviewed by: | | Date: | |
| Client: | **Paducah** | Project: | **SWMU 1 TCE Mass Estimate** | Project/ Proposal No.: | **FR5082** | Phase No.: | **01** |

Due to duplicate sampling results in the historical datasets, i.e. multiple TCE analytical results for a given sampling locations and depth interval, a set of decision rules were develop to select the most appropriate result to use in the modeling. The following were the rules followed in selecting a value when duplicate results were available:

- For two detects take the highest value
- For two detects with qualifiers, take the value that has the lowest number of qualifiers
- If both non-detect values are the same, use the data point with the lowest detection limit.
- If one data point is detect and the other is estimated, take the detected value.
- If one data point is non-detect and the other is estimated, take the estimated value

## ABOUT EVS

EVS is a software suite for the earth sciences that provides analysis and visualization tools for a wide range of applications. One of the main functions of the software is to interpolate data in both three and four dimensions.

C Tech's software is used by government agencies, universities and companies around the world. Customers include the United Nations, U.S. Environmental Protection Agency (USEPA), Environment Canada, U.S. Geological Survey, British Geological Survey, U.S. Army Corps of Engineers, U.S. Department of Energy (DOE) Laboratories, U.S. Nuclear Regulatory Commission, U.S. Department of Transportation, and the majority of the world's largest engineering and environmental consulting firms (C Tech, 2013).

EVS employs an expert system variogram analysis procedure that examines the spatial distribution and number of points in the input data set, and calculates a variogram that is a best fit to the data under the constraints imposed upon it by the user. In all of EVS's variogram algorithms, if a parameter has a default value of 0 and the user does not change it, then no constraints are being placed on the procedure and the algorithm will calculate, use, and return those parameters which provide the best fit of the variogram to the data (C Tech, 2013).

EVS is similar to other Environmental Decision Support Software (DSS), such as SitePro and Spatial Analysis and Decision Assistance (SADA), and was evaluated by USEPA and DOE in 1998 alongside five other DSS packages. EVS underwent an environmental technology verification report in March, 2000 (USEPA, 2000) that concluded that "the main strengths of EVS-PRO are its outstanding 3-D visualization capabilities and its capability to rapidly process, analyze and visualize data" and "the demonstration showed the EVS-PRO software can be used to generate reliable and useful analyses for evaluating environmental contamination problems."

Written by: **Raphael Siebenmann** Date: **6/13/2013** Reviewed by: Date:

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

## MODEL INPUT PARAMETERS

The following model input parameters were used.

| **Parameter**[1] | **Default (Yes/No)**[2] | **Value/Setting** | **Description/Explanation**[3] |
|---|---|---|---|
| **Geology Setup** | | | |
| Search Distance | Yes | 0 | The search distance (reach) field defines the radial distance (in user units - ft in this case) from any given model node that the kriging module will look for data points to be included in the estimation of the model parameter at that node. The default value of reach is 0, which results in the module calculating a reach value, which is approximately two-thirds of the longest distance between any two data points in the data set. |
| Points | Yes | 20 | The Points parameter defines the maximum number of data points (within the specified reach) that will be considered for the parameter estimation at a model node. The default value for points is 20, which generally provides reasonably smooth modeled parameter distributions. |
| Quadrant Search | Yes | Disabled | The Quadrant Search toggle changes the method by which data sample points are selected for inclusion in the kriging matrix. If this is on, the "Points" parameter switches to "Max Points in Quadrant". The geology was modeled as one unit, therefore quadrant search was disabled. |
| X Res/ Y Res | Yes | 81 / 81 (results in approx. 4.2 $ft^2$ grid) | The X Res and Y Res parameters specify the number of grid nodes that will be included within the model domain. |
| Convex Hull Offset | Yes | 10% | The Boundary Offset parameter sets the distance that the convex hull for the kriging domain will be set outside of the actual convex hull of the data. This parameter allows the user to specify the distance outside of the actual data in which the parameter values will be extrapolated. The distance is a percentage of the diagonal extent in the X-Y plane. |
| **Geology Model Semivariogram Output Parameters** | | | |
| Range | Yes | 65 ft | Range - the approximate distance at which spatial autocorrelation between data point pairs ceases or the distance at which the difference between the semivariogram and the sill is negligible. |
| Sill | Yes | 0.05 $ft^2$ | Sill - the semivariance value at which the variogram model levels out (plateau). |

| | | | |
|---|---|---|---|
| Nugget | Yes | 0 ft | Nugget - the intercept of the semivariance model. EVS uses a nugget of zero, which forces the estimated value to be equal to the known value of data points that fall exactly on a grid point in the modeled domain, thus honoring actual data points. |
| **Chemistry Setup** | | | |
| X / Y / Z Resolution | Yes | 71 | The X / Y / Z resolution parameters specify the number of grid nodes that will be included within the model domain. |
| Adaptive Gridding | Yes | Active | Adaptive Gridding refines the grid automatically to place grid nodes at all of the measured data points. The adaptive grid will result in a kriged parameter distribution that honors all of the measured data points exactly. |
| Proportional Gridding | Yes | Active | Proportional gridding results in the number of nodes specified for the Z Resolution will be distributed (proportionately) over the geologic layers in a manner that is approximately proportional to the fractional thickness of each layer relative to the total thickness of the geologic domain. |
| Min Cells Per Layer / Units | Yes | 2 | Min Cells per layer - establishes a minimum number of cells (in the Z direction) per layer. |
| Min Layer Thickness | Yes | 0.00001 | Minimum layer thickness forces layers thinner than the specified value to have a minimum thickness and therefore not pinch out completely. |
| Krig 3D Chemistry Input | | TCE | TCE concentrations in soil were kriged in the model domain. 1 µg/kg was used for non-detect results. |
| Statistical Method | Yes | Ordinary Kriging | |
| Octant Search | No | Enable | An Octant is any of the eight parts into which three mutually perpendicular planes divide space. Octant search - a maximum of N points (defined by user) in each of the eight octants surrounding the interpolation point are used in the calculations. This method results in better performance with clustered data. The Octant Search toggle changes the method by which data sample points are selected for inclusion in the kriging matrix. If this is on, the "Points" parameter switches to "Max Points in Octant". Searching is performed for each of the eight Octants surrounding the point to be kriged. Within each octant a maximum number of points (up to one-fourth of the total points) are selected. Then, points are taken sequentially from each octant up to the maximum number of total points or until all octant's points have been used. |

| | | | | | |
|---|---|---|---|---|---|
| Written by: | **Raphael Siebenmann** | Date: | **6/13/2013** | Reviewed by: | Date: |

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|---|---|---|---|
| Client: **Paducah** | Project: **SWMU 1 TCE Mass Estimate** | Project/ Proposal No.: **FR5082** | Phase No.: **01** |

| | | | |
|---|---|---|---|
| Anisotropy | No[4] | 1 | The Horiz./Vert. Anisotropy Ratio parameter allows the model to consider the effects of anisotropy in the conductivity of soil matrices to fluid flow. In most cases, geologic materials are deposited with platy clay minerals oriented horizontally, and thus flow of water in both the saturated and unsaturated zone can be slower in the vertical direction than in the horizontal direction. Also, ore deposition can occur along horizontal or vertical fault or fracture systems. Chemical constituents being transported with flowing fluids may therefore show a larger degree of spreading in one or the other direction. The Horiz./Vert. Anisotropy Ratio allows the kriging algorithm to specify a multiplication factor to be used to apply biased weighting on data points in horizontal and vertical directions away from a given model node. The default value for fluid flow is 10, which allows data points in a horizontal direction away from a model node to influence the kriged value at that node 10 times more than data points an equal distance away in a vertical direction. When the property being modeled is not related to fluid flow or other processes that might be affected by matrix anisotropy, then the recommended value is 1, i.e. isotropic. |
| **Chemistry Model Semivariogram Output Parameters** | | | |
| Range | Yes | 106 ft | Range - the approximate distance at which spatial autocorrelation between data point pairs ceases or the distance at which the difference between the semivariogram and the sill is negligible. |
| Sill | Yes | 3 ft2 | Sill - the semivariance value at which the variogram model levels out (plateau). |
| Nugget | Yes | 0 ft | Nugget - the intercept of the semivariance model. EVS uses a nugget of zero, which forces the estimated value to be equal to the known value of data points that fall exactly on a grid point in the modeled domain, thus honoring actual data points. |
| **Volumetric Parameters** | | | |
| Soil Density | No | 1.50 g/cc | Soil density of the soil matrix in which the chemicals resides. |
| Chemical Density | No | 1.46 g/cc | Chemical density at (20 °C) |

**Notes:**

1. Input parameters for kriging software (Environmental Visualization System - Premier 9.82, C-Tech Corporation).

2. Indicates whether value used is the software default.
3. Parameter descriptions adapted from "C Tech Help System for EVS & MVS 9.8" by C Tech Development Corp.
4. Software default assumes fluid flow. 1 is the software's suggested value for vadose zone modeling.

## RESULTS

As shown below, the interpolation of the 2012 RDSI investigation estimates that 40.7 kg of TCE is present is SWMU 1 soils.

Mass estimates were calculated using kriging, kriging using the 90% CI, IDW, and nearest neighbor. The results of the EVS-ES modeling using the historical results and the RDSI soil results are presented below.

| | Kriging | 90% CI Kriging | IDW | Nearest Neighbor |
|---|---|---|---|---|
| Isoconcentration Level µg/kg | Mass of TCE (gal) | | | |
| 73 | 8.9 | 29.3 | 1.4 | 24.8 |
| 1,000 | 8.0 | 28.1 | 0.5 | 23.7 |
| 10,000 | 4.2 | 19.8 | 0.1 | 18.0 |

From a mass distribution perspective, both the 90% CI kriging and nearest neighbor interpolation indicate that 96% of the estimated mass is located within the greater than 1,000 µg/kg isocontour area. The EVS estimated weight calculated is less than the weight estimated in the SI.

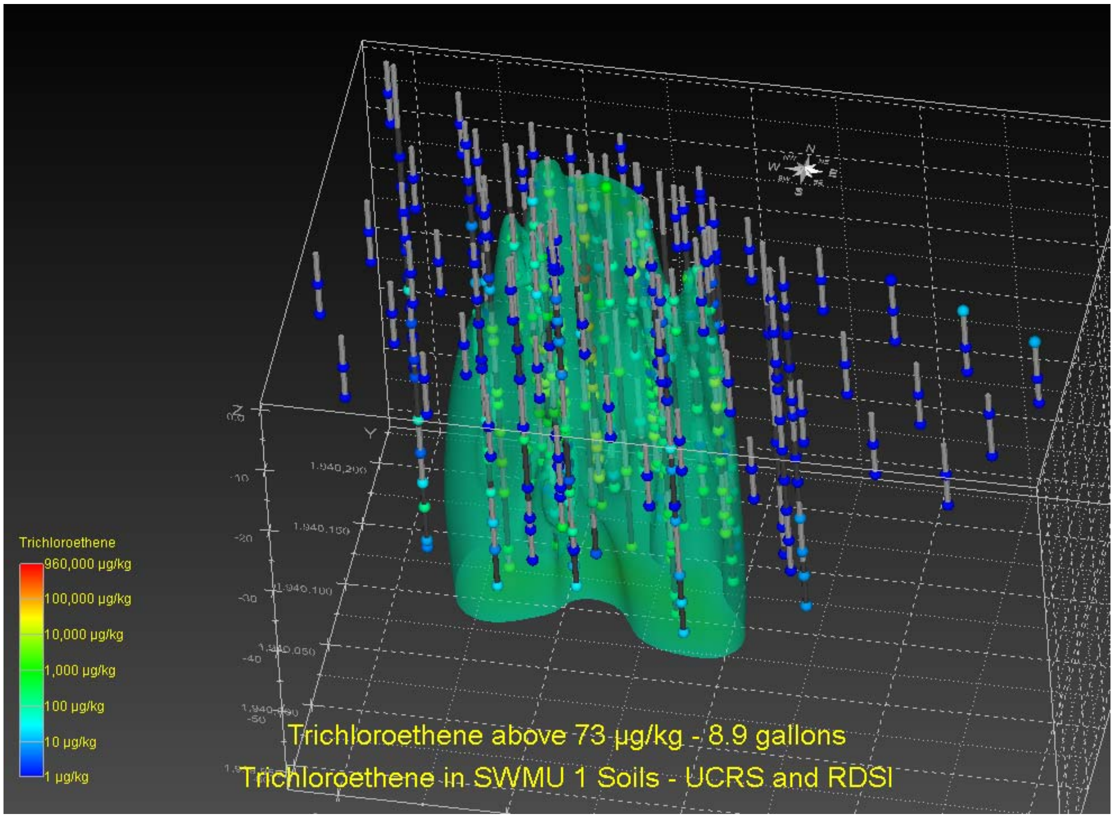
The horizontal extent of the 73 µg/kg isocontour using nominal kriging interpolation is estimated to be approximately 13,500 square ft. The 1,000 µg/kg and 10,000 µg/kg isocontours using the 90% CI kriging interpolation are estimated to be approximately 9,900 square ft and 3,700 square ft respectively.

Modeling results have been included in this calculation package as “4DIM files”, which are freely rotatable 3D model. Key screenshots of the model are presented below:

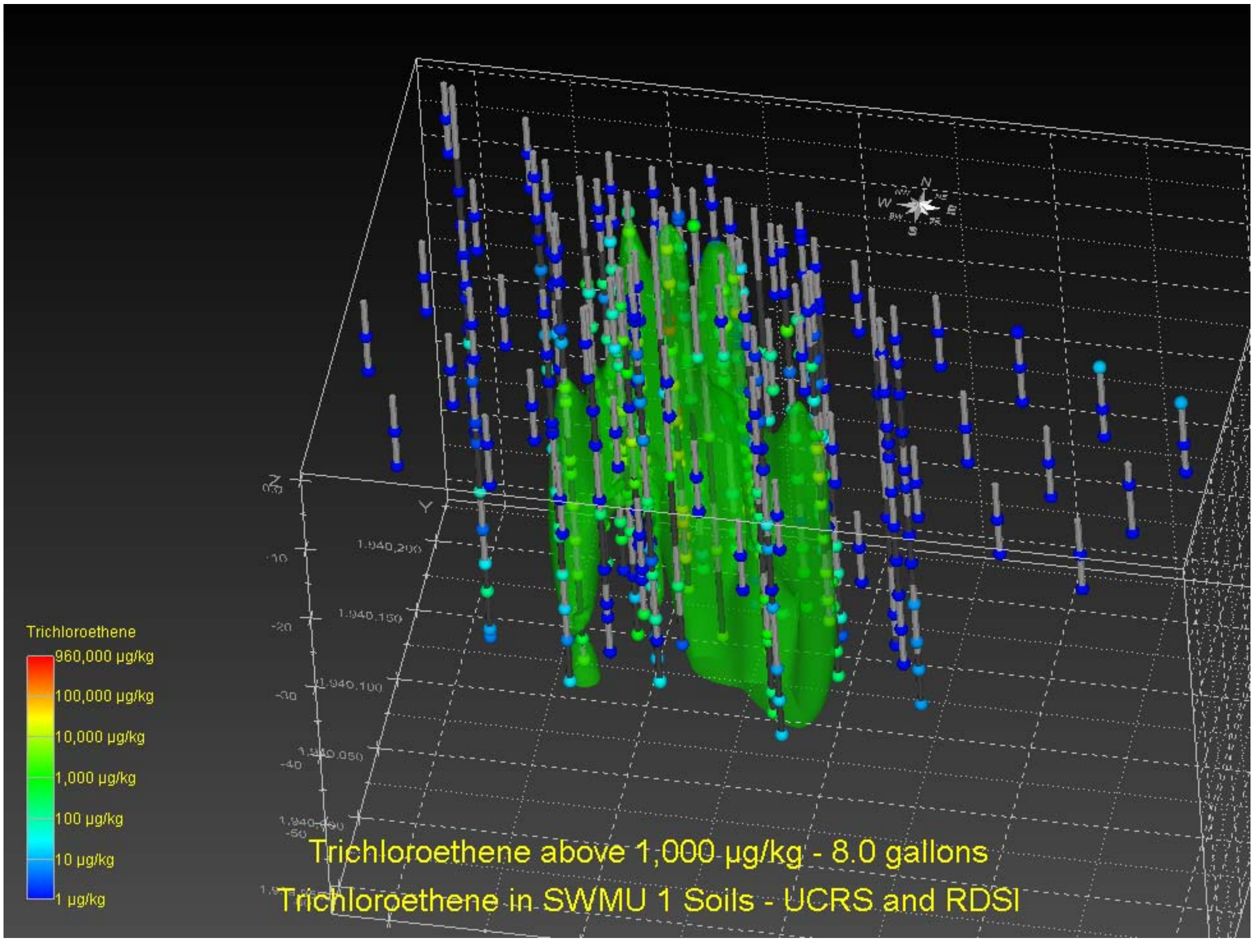
Written by: **Raphael Siebenmann** Date: **6/13/2013** Reviewed by: Date:

Client: **Paducah** Project: **SWMU 1 TCE Mass Estimate** Project/ Proposal No.: **FR5082** Phase No.: **01**

Kriging results for TCE above 73 µg/kg

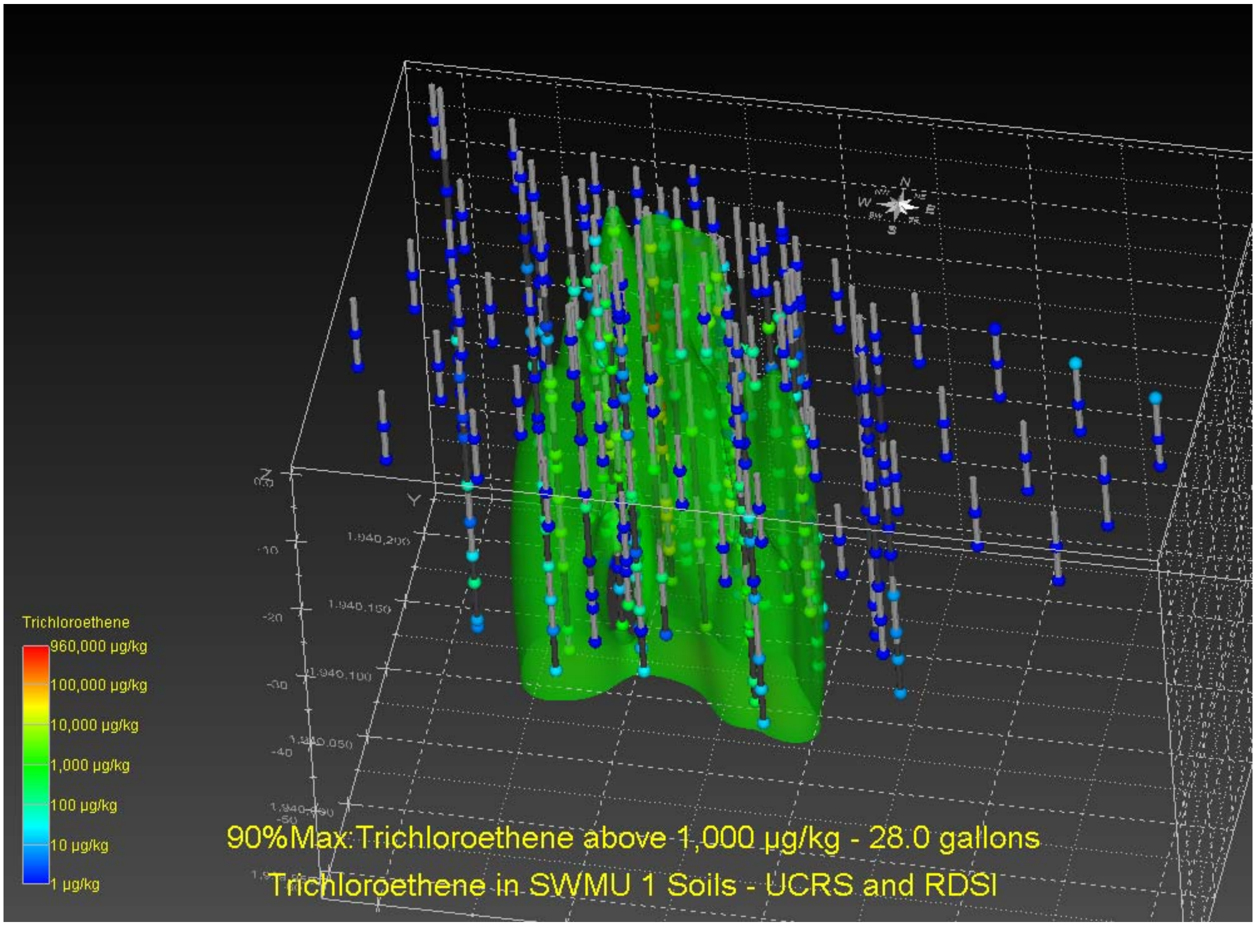


Kriging results for TCE above 1,000 µg/kg



Kriging results for TCE above 1,000 µg/kg using 90% CI

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Written by: | **Raphael Siebenmann** | Date: | **6/13/2013** | Reviewed by: | | Date: | |
| Client: | **Paducah** | Project: | **SWMU 1 TCE Mass Estimate** | Project/ Proposal No.: | **FR5082** | Phase No.: | **01** |



## REFERENCES

C Tech Development Corporation. Web. 4 February 2013. http://www.ctech.com

USEPA, March 2000. “Environmental Technology Verification Report. Environmental Decision Support Software. C Tech Development Corporation. Environmental Visualization System Pro (EVS-PRO). EPA/600/R-00/047.

**Appendix B information included on CD (see back cover).**

# APPENDIX C

# STANDARD PENETRATION TEST RESULTS SUMMARY AND GEOTECHNICAL DATA

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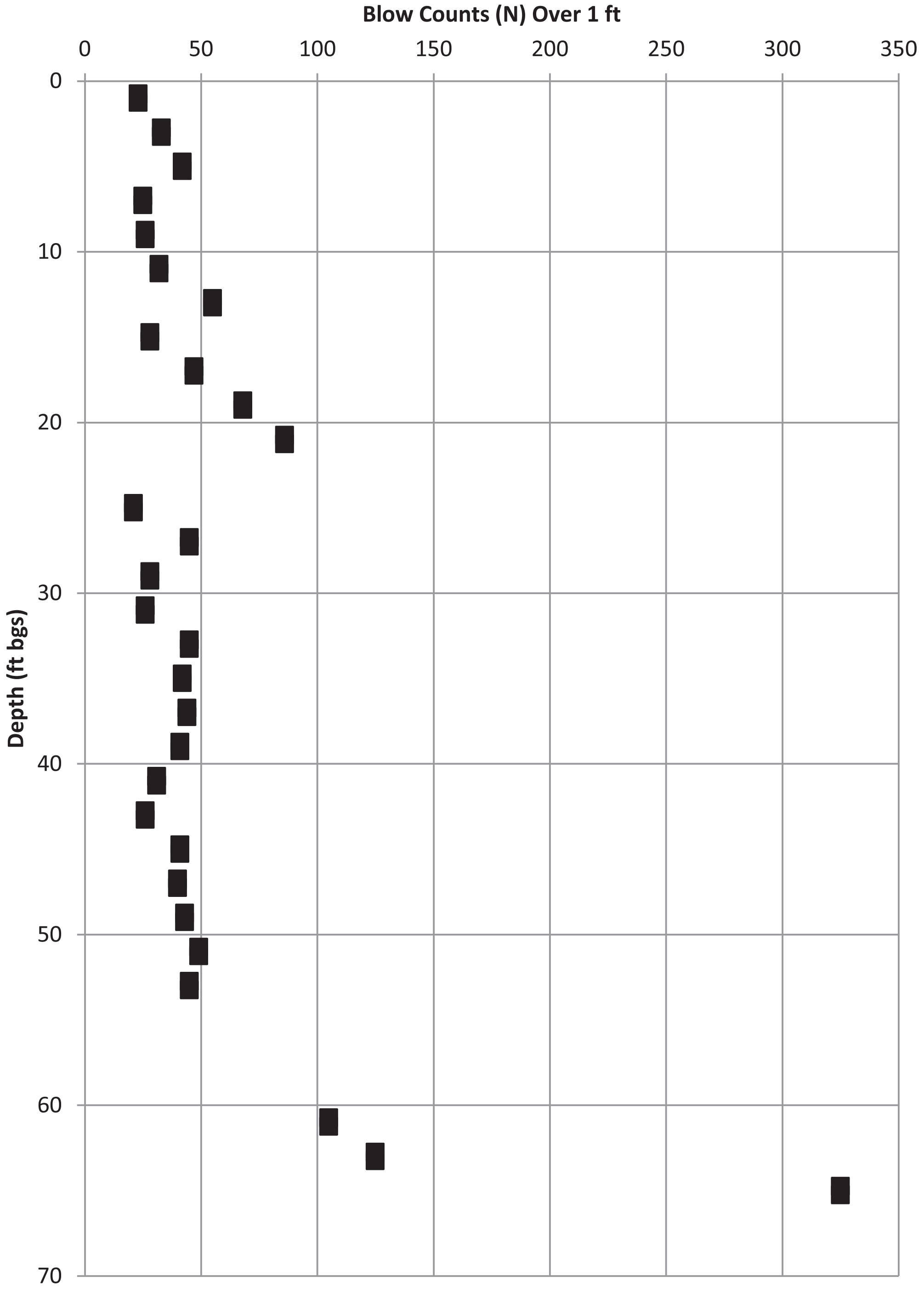
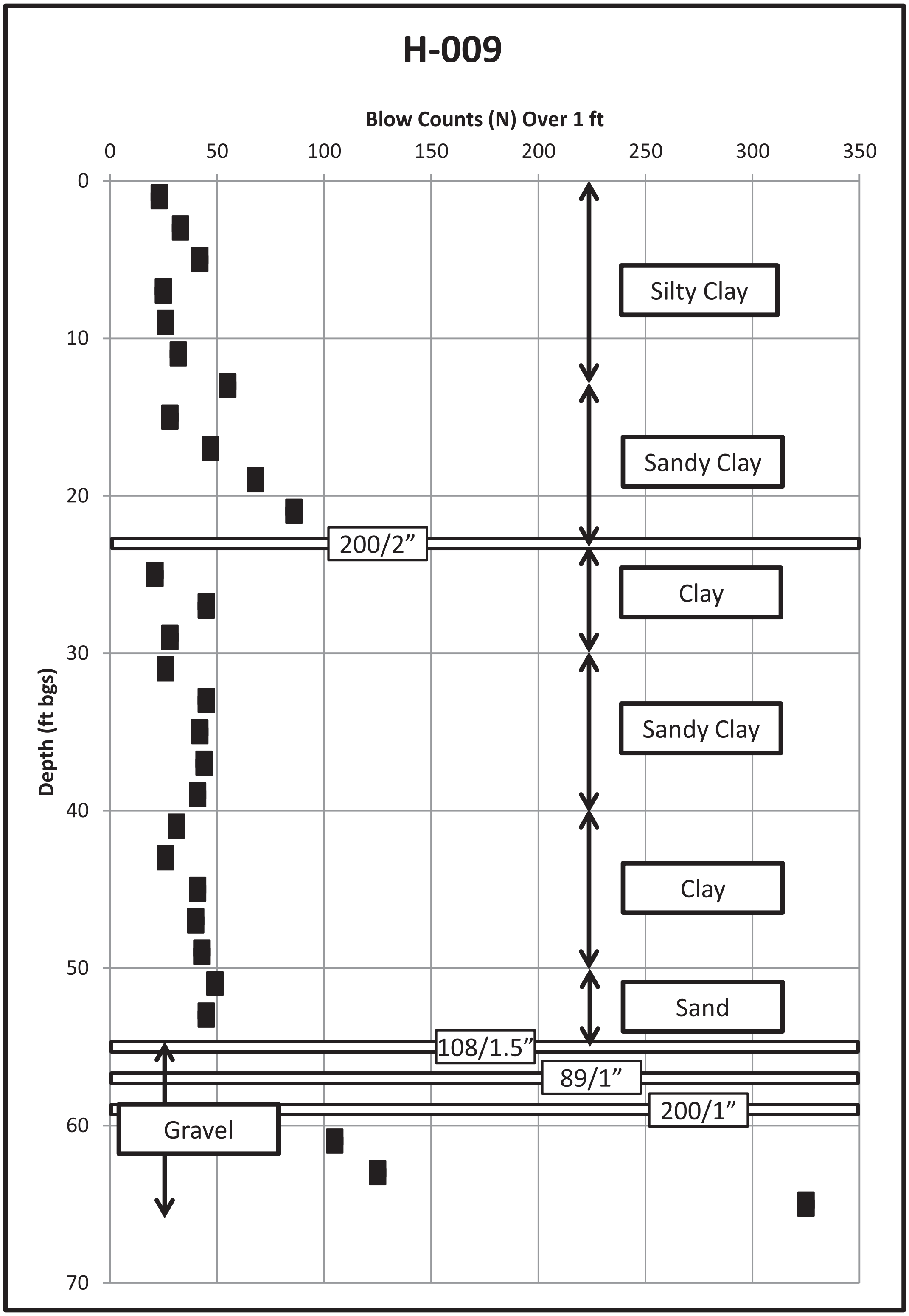
## H-009



Blow Counts (N) Over 1 ft
0
50
100
150
200
250
300
350
Depth (ft bgs)
0
10
20
30
40
50
60
70

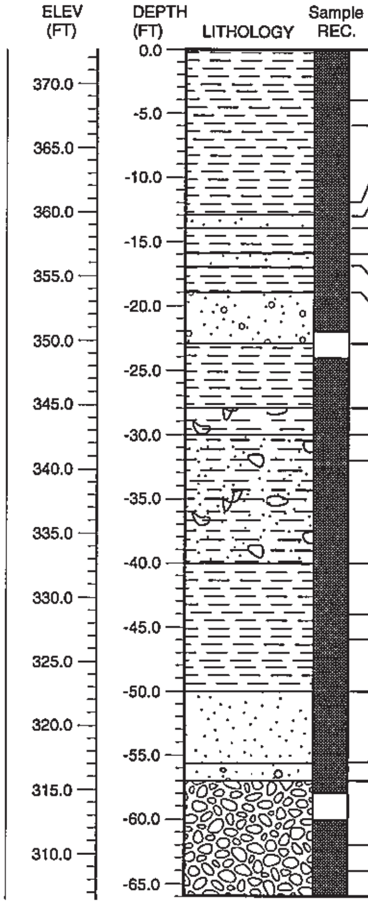

H-009
Blow Counts (N) Over 1 ft
0
50
100
150
200
250
300
350
Depth (ft bgs)
0
10
20
30
40
50
60
70
Silty Clay
Sandy Clay
200/2”
Clay
Sandy Clay
Clay
Sand
108/1.5”
89/1”
200/1”
Gravel

Location Inside PGDP, (W6875 - S1766)

**H-009**

TD 66'

GL 372.5'



LITHOLOGIC DESCRIPTION / COMMENTS

**Silty Clay** stiff, with some sand and organic matter, lt. gray and red-brown with black staining

**Silty Clay** as above, moderate yellow-brown

**Silty Clay** stiff, lt. gray

**Clay** stiff, lt. gray

**Sand** dense, f-m, with some silt and clay, yellow-brown, dry

**Sandy Clay** stiff, lt. gray, moist

**Sand** dense, f-m, with clay, yellow-brown, dry

**Sandy Clay** hard, lt. gray and yellow-brown, damp

**Gravelly Sand** dense with some clay, clay decreases downward, lt. brown-gray, moist

**Clay** plastic, dk. yellow-orange to red-brown, some quartz grains, moist to wet

**Clay** stiff, with some gravel, lt. gray and red-brown, moist

**Sandy Clay** stiff, with gravel and sand, lt. gray and red-brown, moist

**Sandy Clay** stiff, with gravel and interbeds of sand, m, dk. yellow-orange and red-brown, moist

**Clay** lean, hard, with 10% sand, pale yellow-brown, dk. yellow-brown with orange mottling, damp

**Clay** as above with tr. gravel

**Clay** as above with no gravel and lt. red streaks, damp to moist

**Sand** well sorted, m-c, pale yellow-brown, orange-pink, and dk. yellow-orange, moist

**Gravelly Sand** c, with 45% gravel, gray-orange and pale yellow-brown, moist

**Gravel** dense, 80% chert gravel, 1/4 to 11/4 in, with 20% sand, pale yellow-brown, wet

**Gravel** dense, as above, grades to dk. yellow-orange, wet

**Gravel** dense, with 15% sand, c, pale yellow-brown, wet

TD 66

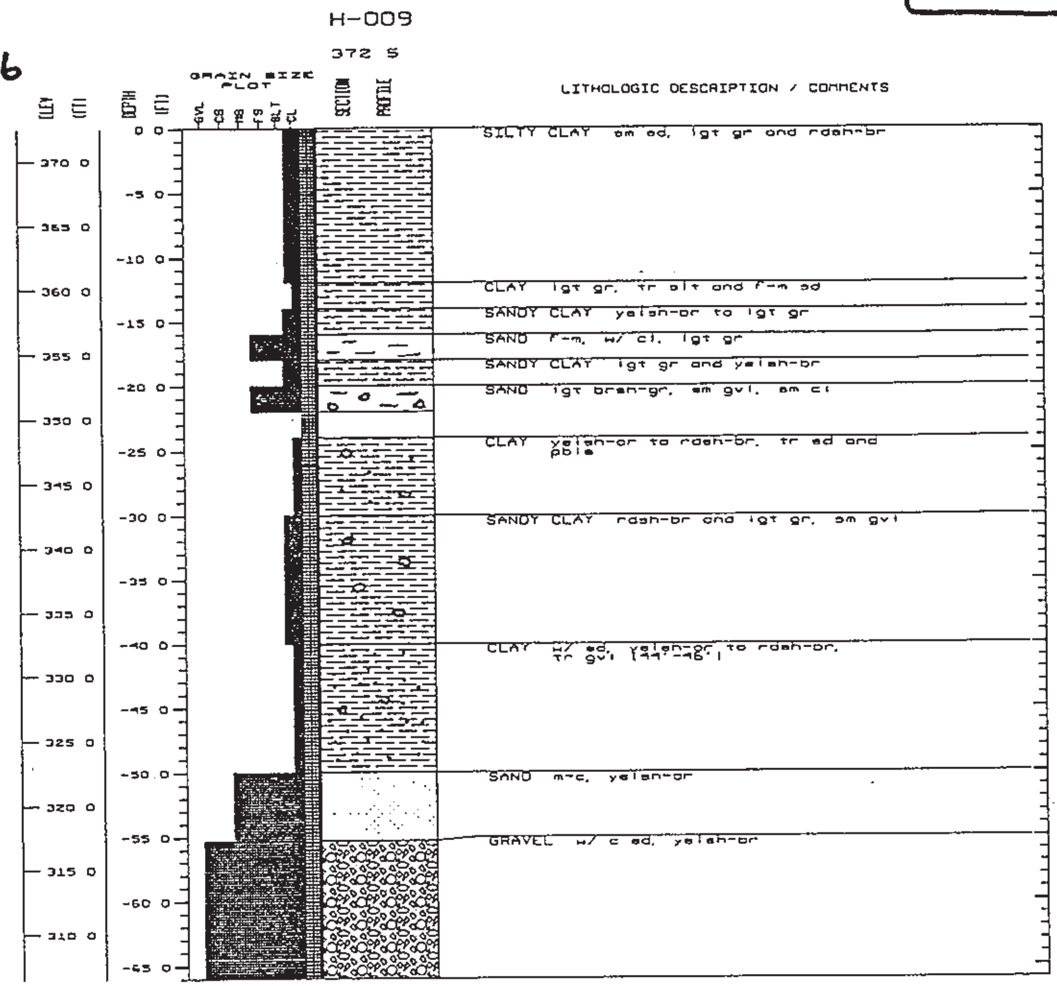
H-009

W 6875 - S1766

See location Map H-050

loc. Inside P6DP, SW1/4, C-745 cluster

near MW 161 H-208



MAP D

Detailed Loc. Map CH$_2$M Hill Phase II, Vol. 2, Fig 4-2

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 1 OF 3 |

## SOIL BORING LOG

PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm

ELEVATION DRILLING CONTRACTOR Geotek Engineering

DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger

WATER LEVEL AND DATE START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE |  |  | STANDARD PENETRATION TEST RESULTS | SOIL DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|
|  | INTERVAL | TYPE AND NUMBER | RECOVERY (FT) | 6"-6"-6" (N) | SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION |
| 0 | 0-2 | 4213 | 0.75' | 9-11-12-12 (23) | SILTY CLAY WITH SAND, VERY LIGHT GRAY (N8) WITH IRON STAINING, MODERATE REDDISH BROWN (10 YR 4/6) AND BLACK ORGANIC STAINING, DAMP, LOW PLASTICITY, VERY STIFF, SOME VEGETABLE MATTER, (CL) | BACKGROUND RAD-40-45 CPM<br>HNU-0 PPM<br>SAMPLE<br>HNU-0 PPM<br>RAD-160 CPM |
| 2 | 2-4 |  |  | 14-14-19-30 (33) | SAME AS ABOVE, BUT WITHOUT VEGETABLE MATTER, HARD, (CL) | HNU-0.8 PPM<br>RAD-40-45 CPM |
| 4 | 4-6 |  | 1.0' | 30-24-18-30 (42) | SAME AS ABOVE, COLOR CHANGING TO MODERATE YELLOWISH BROWN (10 YR 5/4), HARD, (CL) | HNU-20 PPM (IN SPOON)<br>RAD-40 CPM<br>COMPOSITED SAMPLE 4213 AT 1500 |
| 6 | 6-8 | 4214 | 1.25' | 13-12-13-14 (25) | SAME AS ABOVE, COLOR CHANGING BACK TO GRAY (N8), VERY STIFF, (CL) | HNU-18 PPM (IN SPOON)<br>RAD-40 CPM |
| 8 | 8-10 |  | 1.5' | 11-12-14-18 (26) | SAME AS ABOVE, COLOR GRAY (N8) AND YELLOWISH BROWN (10 YR 5/4), VERY STIFF, (CL) | HNU-30 PPM (IN SPOON)<br>RAD-40 CPM |
| 10 | 10-12 |  | 2.0' | 13-13-19-19 (32) | SAME AS ABOVE, VERY LIGHT GRAY (N8), HARD, (CL) | HNU-30 PPM (IN SPOON)<br>RAD-45 CPM<br>COMPOSITED SAMPLE 4214 AT 1520 |
| 12 | 12-14 | 4215 | 2.0' | 13-19-36-48 (55) | CLAY (CH), VERY LIGHT GRAY (N8), MOIST, HARD, PLASTIC, CHANGING TO WELL-GRADED SAND, WITH SOME SILT AND CLAY, MODERATE YELLOWISH BROWN (10 YR 5/4), DRY, VERY DENSE, FINE-MEDIUM, (SW-SC) | HNU-31 PPM<br>RAD-45 CPM |
| 14 | 14-16 |  | 2.0' | 6-14-14-15 (28) | SANDY CLAY, VERY LIGHT GRAY AND MODERATE YELLOWISH BROWN (N8 AND 10 YR 5/4), MOIST, VERY STIFF, (CL) | HNU-0.2 PPM<br>RAD-45 CPM |
| 16 | 16-18 |  | 1.5' | 19-20-27-30 (47) | WELL GRADED SAND, WITH CLAY, LIGHT GRAY (N7), MOIST, DENSE, FINE-MEDIUM, (SW), CHANGING TO SANDY CLAY, LIGHT GRAY (N7), AND YELLOWISH BROWN (10 YR 5/4), DAMP, HARD, (CL) | HNU-85 PPM<br>RAD-40 CPM<br>COMPOSITED 4215 AT 1600 |
| 18 | 18-20 | 4216 |  | 26-32-36-48 (68) | SANDY CLAY SAME AS ABOVE, (CL), CHANGING TO WELL-GRADED SAND, LIGHT BROWNISH GRAY (5 YR 6/1), VERY DENSE, DAMP-MOIST, COARSE PEBBLES AND SOME CLAY, (SW) | HNU-16 PPM<br>RAD-0 CPM |
| 20 | 20-22 |  |  | 26-40-46-50 (86) | WELL GRADED SAND AS ABOVE, MOIST, VERY DENSE, VERY LITTLE CLAY WITH LENSES OF GRAVEL, (SW) | HNU- 14.5 PPM<br>RAD- |
| 22 | 22-24 |  |  | 200/2" | NO SAMPLE |  |
| 24 | 24-26 |  | 2.0' | 7-7-14-19 (21) | CLAY, DARK YELLOWISH ORANGE (10 YR 6/6), MOIST, VERY STIFF, PLASTIC, (CH) | HNU-20 PPM<br>RAD-35-40 CPM<br>COMPOSITED SAMPLE 4216 AT 0825 |
| 26 | 26-28 | 4218 | 1.8' | 14-18-27-30 (45) | CLAY SAME AS ABOVE, COLOR CHANGING TO MODERATE REDDISH BROWN (10 R 4/6), MOIST-WET, HARD, SOME COARSE SAND GRAINS, (CH) | HNU-31 PPM<br>RAD-40 CPM |
| 28 | 28-30 |  | 2.0' | 15-15-13-14 (28) | CLAY SAME AS ABOVE, MODERATE REDDISH BROWN AND LIGHT GRAY (10 R 4/6 AND N7), MOIST, VERY STIFF, LOW PLASTICITY, SOME LARGE PEBBLES, (CL) | HNU-25 PPM<br>RAD-40-45 CPM<br>AUGER TO 30', STOP TO SET CASING |
| 30 |  |  |  |  |  |  |

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 2 OF 3 |

## SOIL BORING LOG

PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm
ELEVATION DRILLING CONTRACTOR Geotek Engineering
DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger
WATER LEVEL AND DATE START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE INTERVAL | SAMPLE TYPE AND NUMBER | SAMPLE RECOVERY (FT) | STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N) | SOIL DESCRIPTION SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL | COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION |
|---|---|---|---|---|---|---|
| 30 | 30-32 | 4218 | 2.0' | 6-9-17-29 (26) | SANDY CLAY, MODERATE REDDISH BROWN AND LIGHT GRAY (10 R 4/6 AND N7), MOIST, VERY STIFF, LOW PLASTICITY, WITH GRAVEL SOME LARGE PEBBLES, (CL) | HNU=0.2 PPM<br>RAD=40-45 CPM<br>RESUMED SAMPLING 1/9/90, COMPOSITED SAMPLE 4218 AT 1345 |
| 32 | 32-34 | 4219 | 2.0' | 17-19-26-21 (45) | SANDY CLAY, SAME AS ABOVE , MODERATE REDDISH BROWN AND DARK YELLOWISH ORANGE (10 YR 6/6), HARD, WITH GRAVEL, (CL) | HNU=0 PPM<br>RAD=40-45 CPM |
| 34 | 34-36 | | 2.0' | 17-17-25-29 (42) | SANDY CLAY, SAME AS ABOVE, MODERATE REDDISH BROWN, HARD, WITH GRAVEL AND LAYERS OF MEDIUM SAND, (CL) | HNU=0.2 PPM<br>RAD=40 CPM |
| 36 | 36-38 | | 2.0' | 18-18-26-27 (44) | SANDY CLAY SAME AS ABOVE | HNU=3.0 PPM<br>RAD=40 CPM<br>COMPOSITED SAMPLE 4219 AT 1420 |
| 38 | 38-40 | 4220 | 2.0' | 16-17-24-26 (41) | CLAY SAME AS ABOVE | HNU=0 PPM<br>RAD=40 CPM |
| 40 | 40-42 | | 2.0' | 13-13-18-21 (31) | LEAN CLAY WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2) WITH DARK YELLOWISH ORANGE (10 YR 6/6) STREAKING, SOME MOTTLING WITH ORANGE, DARK DISCOLORATION, DAMP, HARD, <10% FINE SAND, (CL) | RESUMED SAMPLING 1/10/90 AT 1000<br>HNU=0 PPM<br>RAD=40 CPM |
| 42 | 42-44 | | 2.0' | 13-13-13-14 (26) | LEAN CLAY WITH SAND SAME AS ABOVE, VERY STIFF, ≈15% SAND IN LOWER ≈0.3' OF SPOON, (CL) | HNU=0 PPM<br>RAD=45 CPM |
| 44 | 44-46 | 4221 | 2.0' | 18-17-24-26 (41) | LEAN CLAY WITH SAND SAME AS ABOVE, HARD, MODERATE RED STREAKS (5 R 5/4), 2 SMALL (≈<1" DIAMETER) PIECES OF GRAVEL, (CL) | HNU=0.2 PPM<br>RAD=45 CPM |
| 46 | 46-48 | | 2.0' | 18-18-22-25 (40) | LEAN CLAY WITH SAND SAME AS ABOVE, HARD, NO GRAVEL, (CL) | HNU=0.2 PPM<br>RAD=45 CPM |
| 48 | 48-50 | | 2.0' | 18-18-25-26 (43) | LEAN CLAY WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2) WITH DARK YELLOWISH ORANGE (10 YR 6/6) AND LIGHT RED (5 R 6/6) STREAKS, DAMP-MOIST, HARD, 1 PEBBLE, COAL LENSES, (CL) | HNU=0.2 PPM<br>RAD=45 CPM<br>COMPOSITED SAMPLE 4221 AT 0900 |
| 50 | 50-52 | 4223 | 1.75' | 18-23-26-27 (49) | POORLY GRADED SAND, PALE YELLOWISH BROWN (10 YR 6/2), SLIGHT MODERATE ORANGE PINK (10 R 7/4) AND DARK YELLOWISH ORANGE (10 YR 6/6) STREAKS, MOIST, DENSE, MEDIUM GRAINED, NO GRAVEL, (SP) | HNU=0.2 PPM<br>RAD=45CPM |
| 52 | 52-54 | | 2.0' | 25-18-27-28 (45) | SAND SAME AS ABOVE, (SP) | HNU=0.8 PPM<br>RAD=52-54 CPM |
| 54 | 54-56 | | 1.7' | 108/1.5" | POORLY GRADED SAND, PALE YELLOWISH BROWN (10 YR 6/2), SOME MODERATE ORANGE PINK (10 R 7/4) AND DARK YELLOWISH ORANGE (10 YR 6/6) STREAKS, MOIST, VERY DENSE, MEDIUM-COARSE GRAINED, GRAVEL IN LOWER ≈0.4', (SP) | HNU=0.8 PPM<br>RAD=45 CPM<br>COMPOSITED SAMPLE 4223 AT 0930 |
| 56 | 56-57 | 4224 | 0.8' | 89/1" | WELL-GRADED SAND, COARSE SAND WITH ≈45% GRAVEL, QUARTZ CRYSTALS, PALE YELLOWISH BROWN (10 YR 6/2) WITH GRAYISH ORANGE (10 R 7/4) STREAKS, WET, VERY DENSE. | HNU=0 PPM<br>RAD=40 CPM |
| | 57-58 | | 1.2' | 200/1" | GRAVEL, (GW) | |
| 58 | 58-60 | | NO SAMPLE TAKEN | | | |
| 60 | | | | | | |

| PROJECT NUMBER | BORING NUMBER |
|---|---|
| SED28178.FS | H-009 SHEET 3 OF 3 |

# SOIL BORING LOG

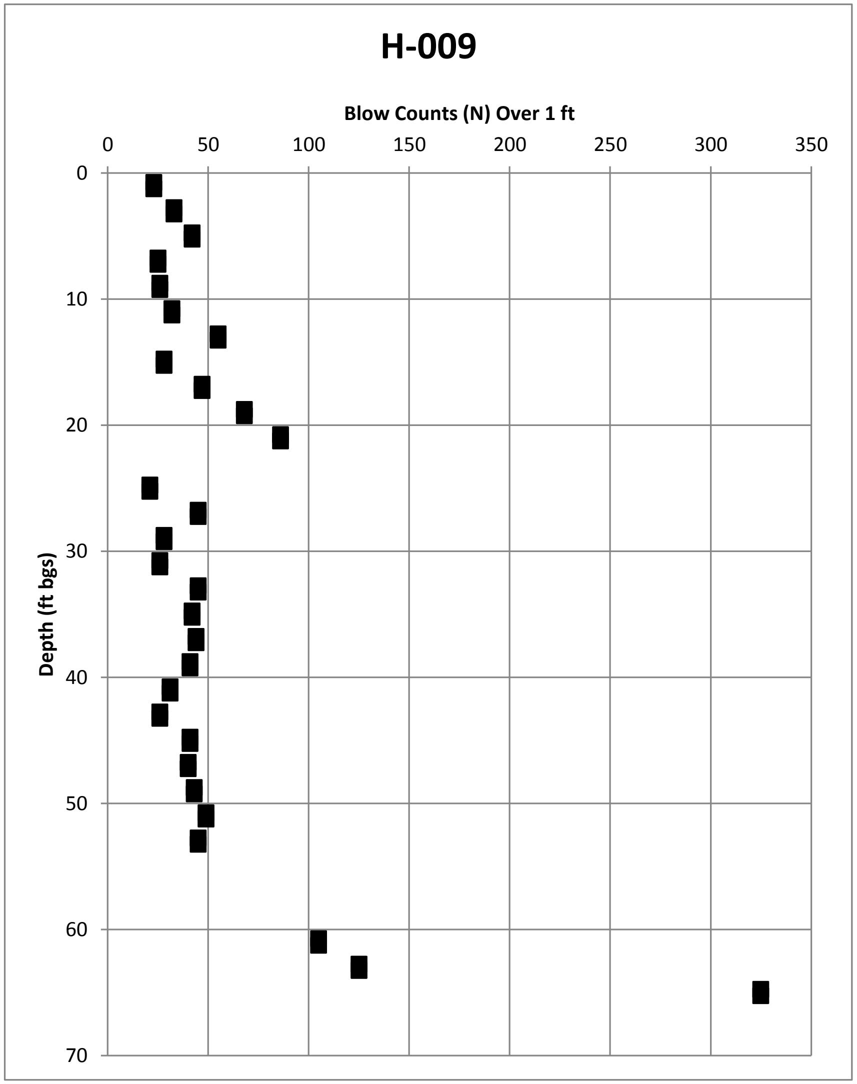
PROJECT PGDP Phase I Site Investigation LOCATION WMU 1, Oil Landfarm
ELEVATION DRILLING CONTRACTOR Geotek Engineering
DRILLING METHOD AND EQUIPMENT Mobile B-53, Hollow Stem Auger
WATER LEVEL AND DATE START 1/6/90 FINISH 1/10/90 LOGGER Bill Cocke

| DEPTH BELOW SURFACE (FT) | SAMPLE | | | STANDARD PENETRATION TEST RESULTS | SOIL DESCRIPTION | COMMENTS |
|---|---|---|---|---|---|---|
| | INTERVAL | TYPE AND NUMBER | RECOVERY (FT) | 6"-6"-6" (N) | SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL | DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS. TESTS AND INSTRUMENTATION |
| 60 | 60-62 | 4224 | 0.5' | 60-40-65-100 (105) | WELL GRADED GRAVEL WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2), SAND ≈20%, WET, VERY DENSE, SAND ≈20%, GRAVELS ≈1/4" TO 1-1/4" DIAMETER, QUARTZ, CHERT, (GW) | HNU=0 PPM<br>RAD=40 CPM |
| 62 | 62-64 | | 1.5' | 60-65-60-74 (125) | WELL GRADED GRAVEL WITH SAND, PALE YELLOWISH BROWN (10 YR 6/2), GRADES INTO DARK YELLOWISH ORANGE (10 YR 6/6), WET, VERY DENSE, GRAVELS ≈1/4">1/2" DIAMETER, QUARTZ, CHERT, (GW) | HNU=0 PPM<br>RAD=40 CPM<br>COMPOSITED SAMPLE 4224 AT 1215, (56-58' AND 60-64' NO SAMPLE AT 58-60') |
| 64 | 64-66 | 4225 | 1.7' | 135-160-165-175 (325) | WELL GRADED GRAVEL, WET, VERY DENSE, GRAVEL ≈1/4-2" DIAMETER, MOSTLY CHERT, SOME SAND ≈15%, COARSE GRAINED, PALE YELLOWISH BROWN (10 YR 6/2), (GW) | HNU=0 PPM<br>RAD=30-40 CPM<br>COMPLETED SAMPLE 4225 AT 1606 (64-66')<br>TD OF BORING, 66.0' |
| 66 | | | | | | |
| 68 | | | | | | |
| 70 | | | | | | |
| 72 | | | | | | |
| 74 | | | | | | |
| 76 | | | | | | |

**H-009**

| SPT Results (N)* | | SPT Results Refusal | Depth |
|---|---|---|---|
| 23 | | | 0.75 |
| 23 | | | 1.25 |
| 33 | | | 2.75 |
| 33 | | | 3.25 |
| 42 | | | 4.75 |
| 42 | | | 5.25 |
| 25 | | | 6.75 |
| 25 | | | 7.25 |
| 26 | | | 8.75 |
| 26 | | | 9.25 |
| 32 | | | 10.75 |
| 32 | | | 11.25 |
| 55 | | | 12.75 |
| 55 | | | 13.25 |
| 28 | | | 14.75 |
| 28 | | | 15.25 |
| 47 | | | 16.75 |
| 47 | | | 17.25 |
| 68 | | | 18.75 |
| 68 | | | 19.25 |
| 86 | | | 20.75 |
| 86 | | | 21.25 |
| | 200 | 200/2" | 22.75 |
| | 200 | 200/2" | 23.25 |
| 21 | | | 24.75 |
| 21 | | | 25.25 |
| 45 | | | 26.75 |
| 45 | | | 27.25 |
| 28 | | | 28.75 |
| 28 | | | 29.25 |
| 26 | | | 30.75 |
| 26 | | | 31.25 |
| 45 | | | 32.75 |
| 45 | | | 33.25 |
| 42 | | | 34.75 |
| 42 | | | 35.25 |
| 44 | | | 36.75 |
| 44 | | | 37.25 |
| 41 | | | 38.75 |

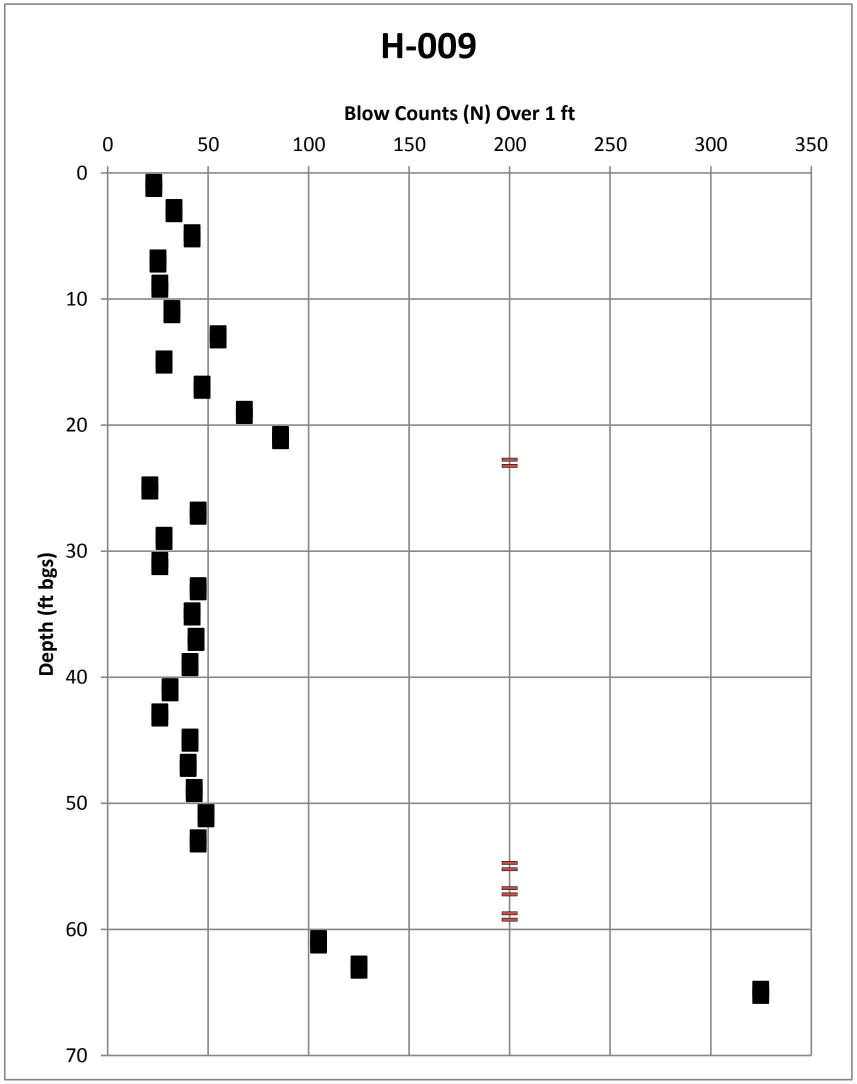
* sum of middle two 6-inch intervals



**H-009**

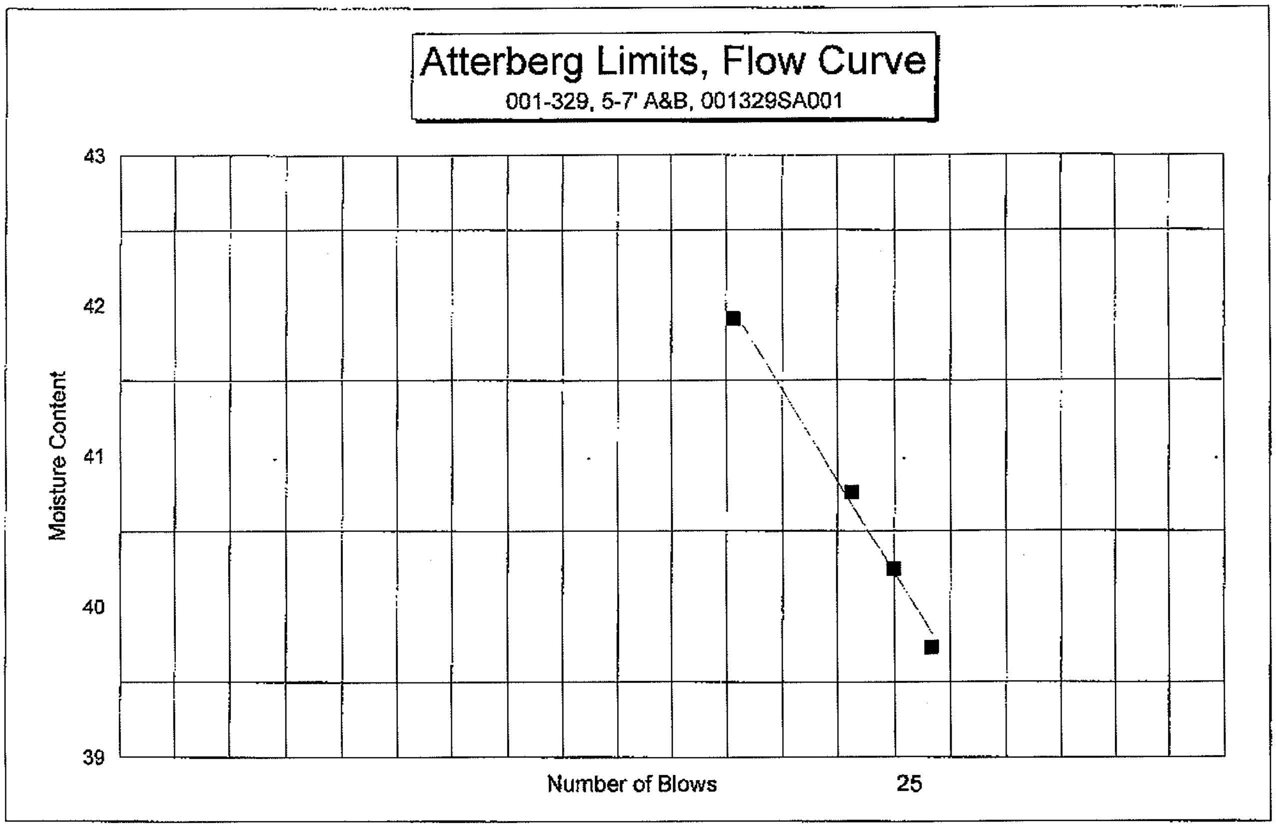
| SPT Results (N)* | | SPT Results Refusal | Depth |
|---|---|---|---|
| 41 | | | 39.25 |
| 31 | | | 40.75 |
| 31 | | | 41.25 |
| 26 | | | 42.75 |
| 26 | | | 43.25 |
| 41 | | | 44.75 |
| 41 | | | 45.25 |
| 40 | | | 46.75 |
| 40 | | | 47.25 |
| 43 | | | 48.75 |
| 43 | | | 49.25 |
| 49 | | | 50.75 |
| 49 | | | 51.25 |
| 45 | | | 52.75 |
| 45 | | | 53.25 |
| | 200 | 108/1.5" | 54.75 |
| | 200 | 108/1.5" | 55.25 |
| | 200 | 89/1" | 56.75 |
| | 200 | 89/1" | 57.25 |
| | 200 | 200/1" | 58.75 |
| | 200 | 200/1" | 59.25 |
| 105 | | | 60.75 |
| 105 | | | 61.25 |
| 125 | | | 62.75 |
| 125 | | | 63.25 |
| 325 | | | 64.75 |
| 325 | | | 65.25 |

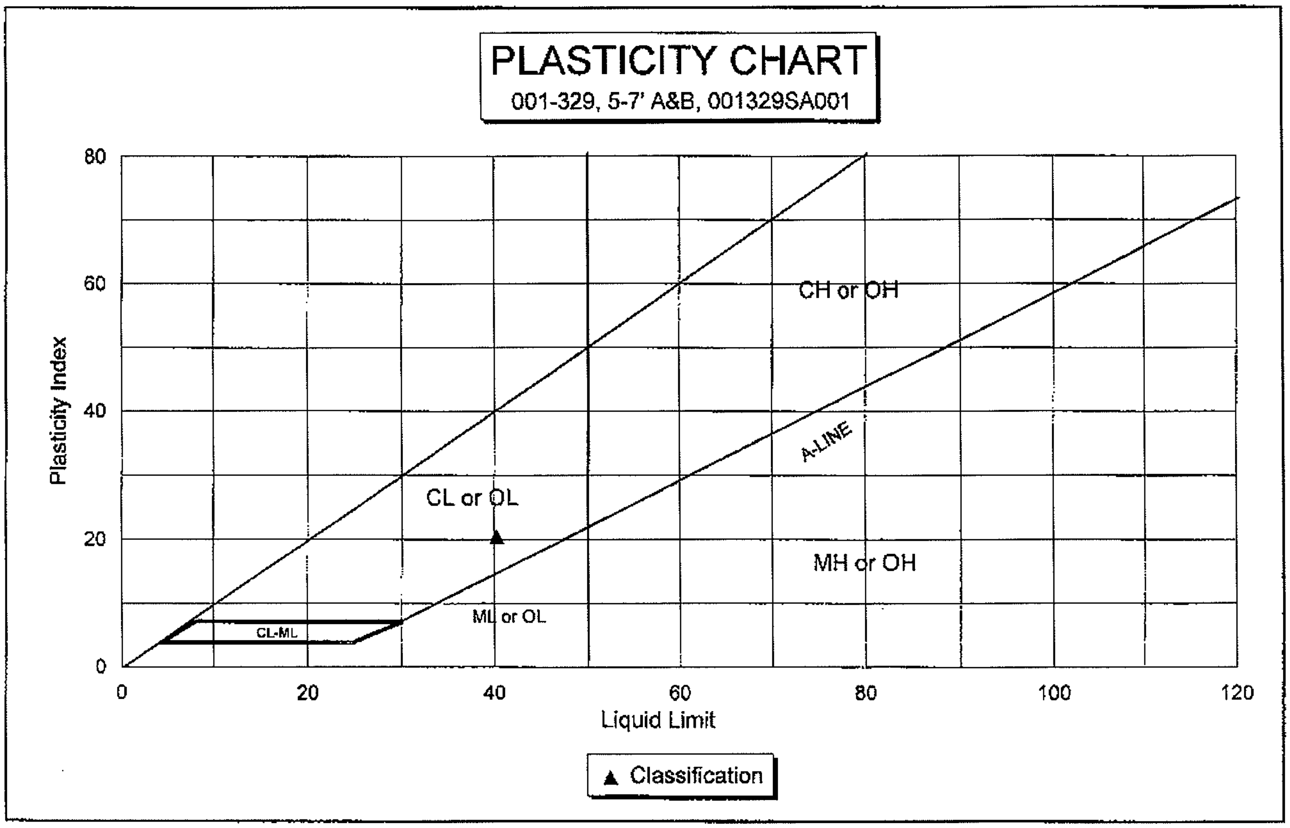
* sum of middle two 6-inch intervals

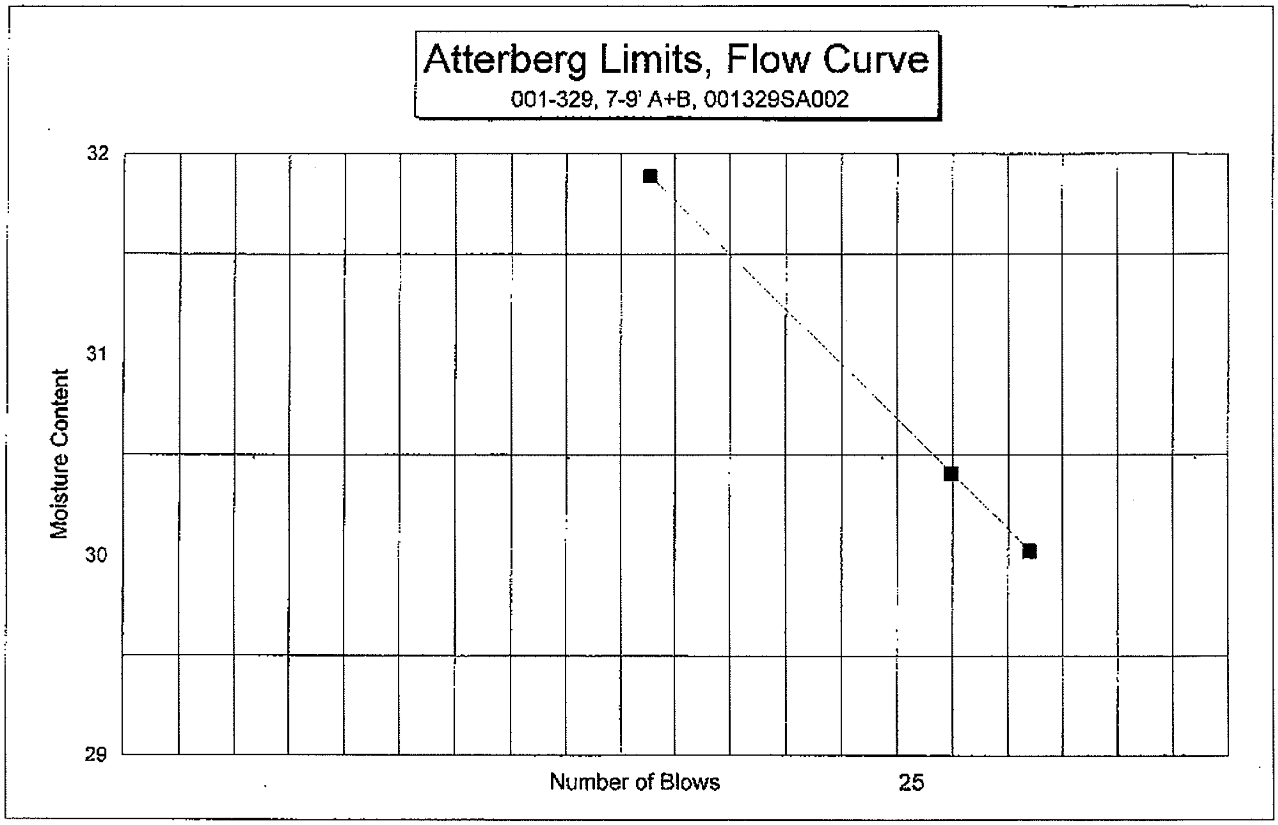


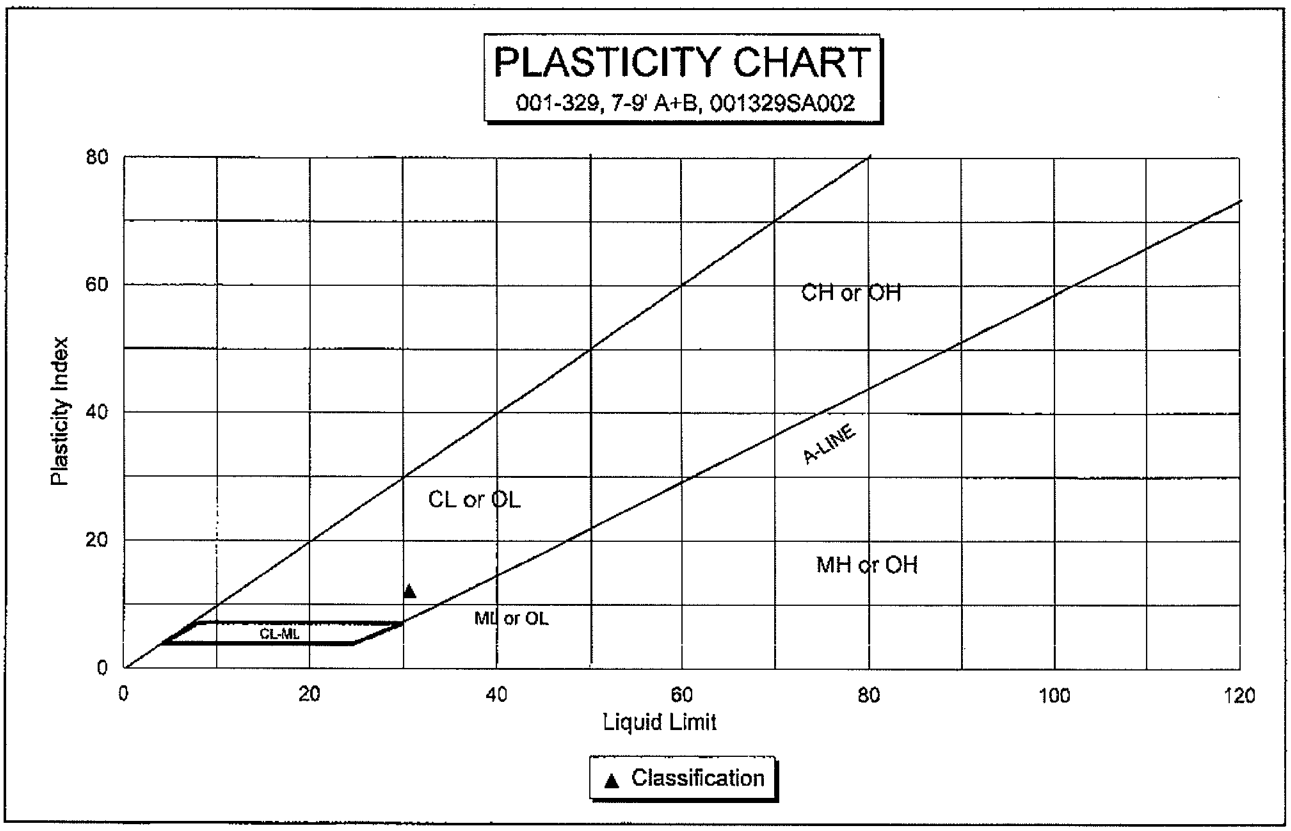
## Geotechnical Soil Data
## Soil Boring: 001-239
## SWMU 1: C-746-C Oil Landfarm

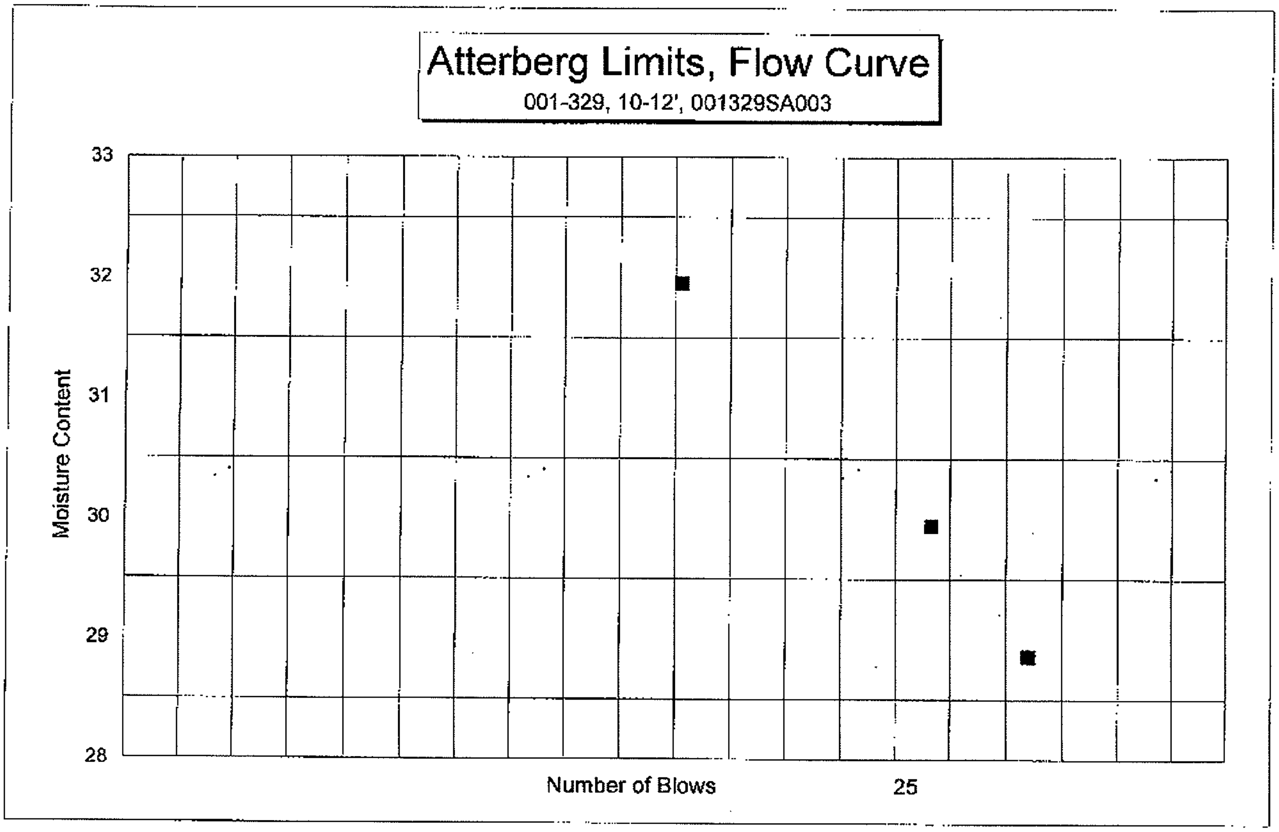
| Sample | Depth | Moisture Content | pH | Liquid Limit | Plastic Limit | Plasticity Index | Atterberg Classificatiion | Fraction of Organic Carbon |
|---|---|---|---|---|---|---|---|---|
| | (ft) | (%) | (Std Units) | | | | | (mg/Kg) |
| 001329SA001 | 5.0-7.0 | 22.8 | 5.54 | 40.2 | 19.9 | 20.4 | CL | |
| 001329SA002 | 7.0-9.0 | 23.3 | 7.15 | 30.7 | 18.6 | 12.1 | CL | |
| 001329SA003 | 10.0-12.0 | 21.4 | 6.63 | 30.1 | 15.2 | 15.0 | CL | |
| 001329SA004 | 16.5-17.5 | 15.8 | 6.97 | 24.3 | 14.2 | 10.1 | CL | |
| 001329SA005 | 18.5-19.5 | 8.2 | 7.49 | 30.1 | 12.4 | 17.7 | CL | |
| 001329SA006 | 20.5-21.5 | 12.2 | 7.42 | 36.6 | 11.1 | 25.6 | CL | |
| 001329SA007 | 30.0-32.0 | 19.6 | 7.51 | 25.3 | 10.5 | 14.8 | CL | |
| 001329SA008 | 40.0-42.0 | 14.2 | 7.08 | 18.7 | 13.6 | 5.1 | CL-ML | |
| 001329SA009 | 50.0-50.9 | 17.9 | 7.53 | 20.7 | 11.8 | 8.9 | CL | |
| 001304FOC1 | 14.9 | | | | | | | 5,900 |
| 001304FOC2 | 26.5 | | | | | | | 430 |
| 001304FOC3 | 42.5 | | | | | | | 230 |
| 001307FOC1 | 12.5 | | | | | | | 740 |
| 001307FOC2 | 23.5 | | | | | | | 680 |
| 001307FOC3 | 33 | | | | | | | 360 |
| 001318FOC1 | 13 | | | | | | | 290 |
| 001318FOC2 | 20.5 | | | | | | | 240 |
| 001318FOC3 | 41 | | | | | | | 920 |

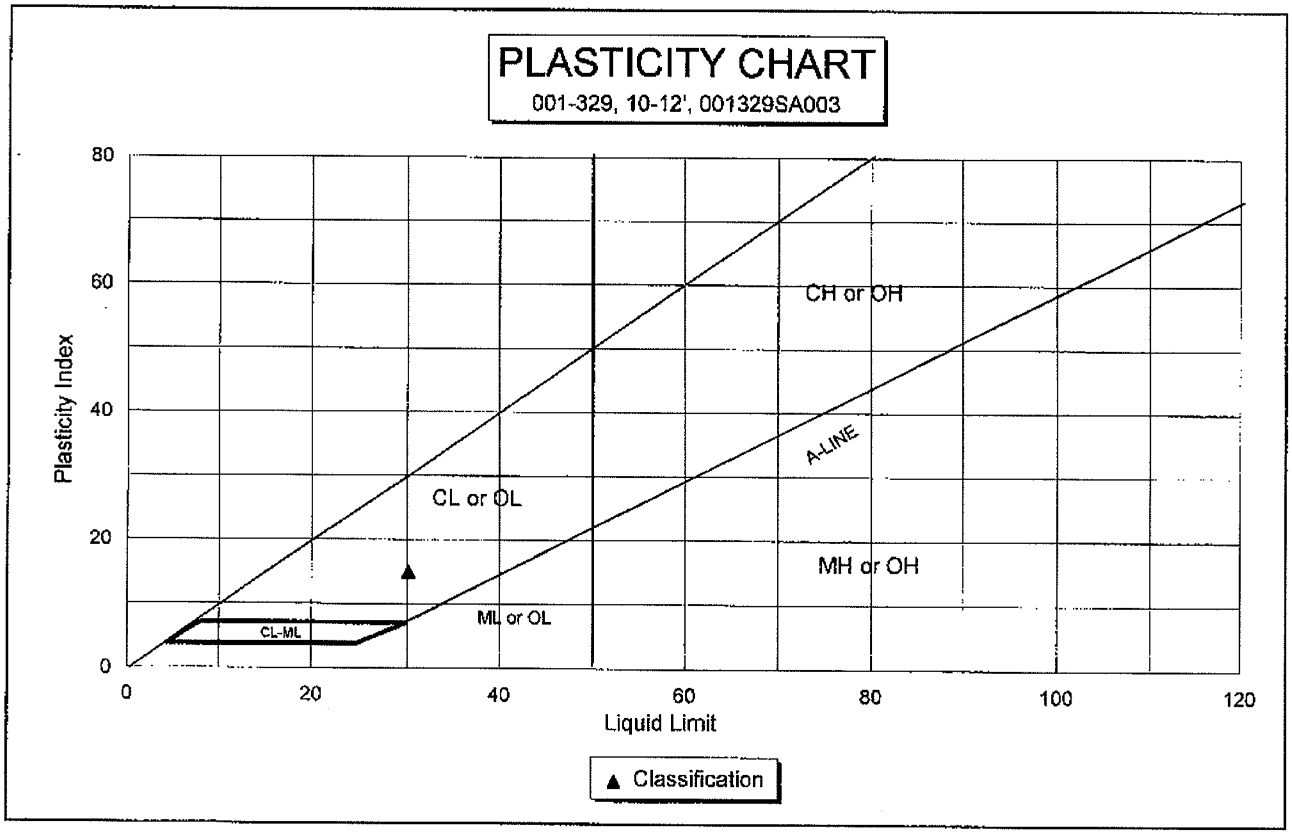

Atterberg Limits, Flow Curve
001-329, 5-7' A&B, 001329SA001
43
42
41
40
39
Moisture Content
Number of Blows
25

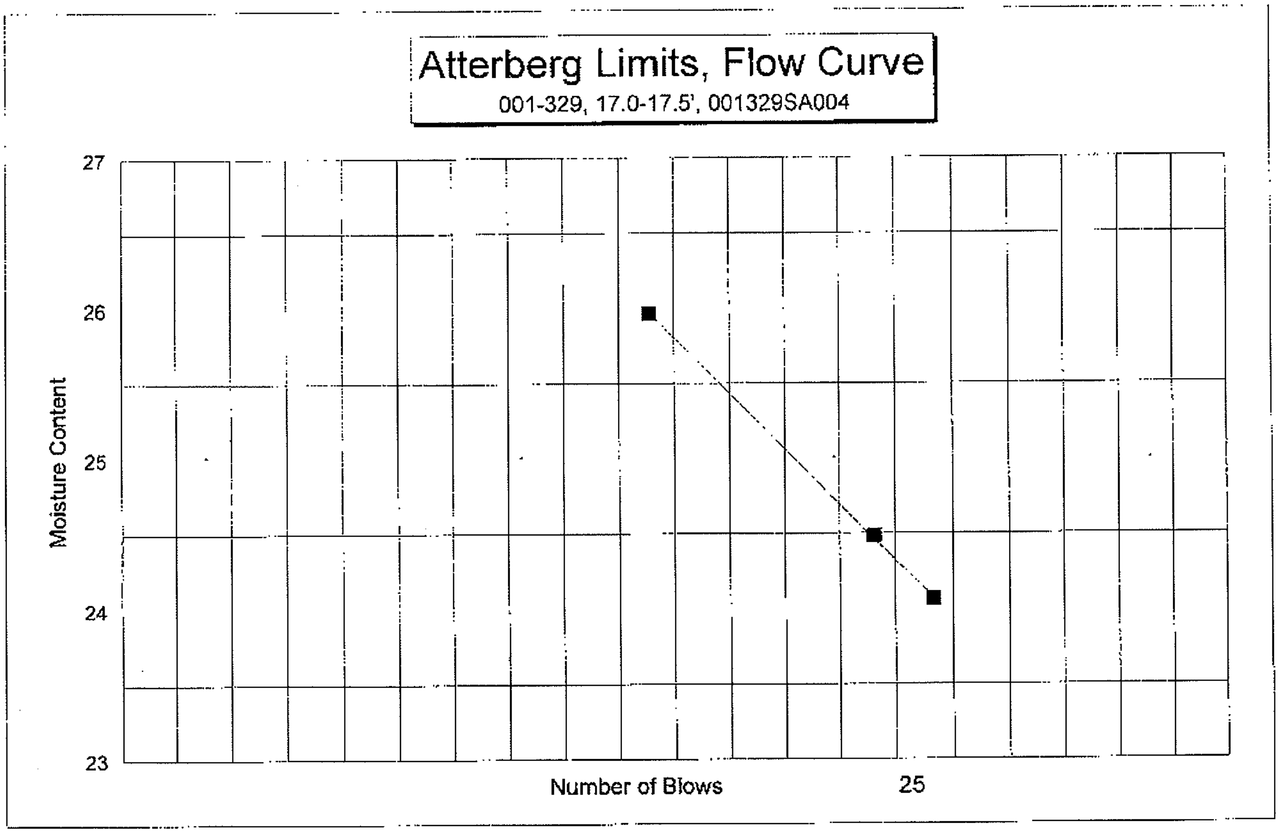

PLASTICITY CHART
001-329, 5-7' A&B, 001329SA001
80
60
40
20
0
Plasticity Index
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
▲ Classification

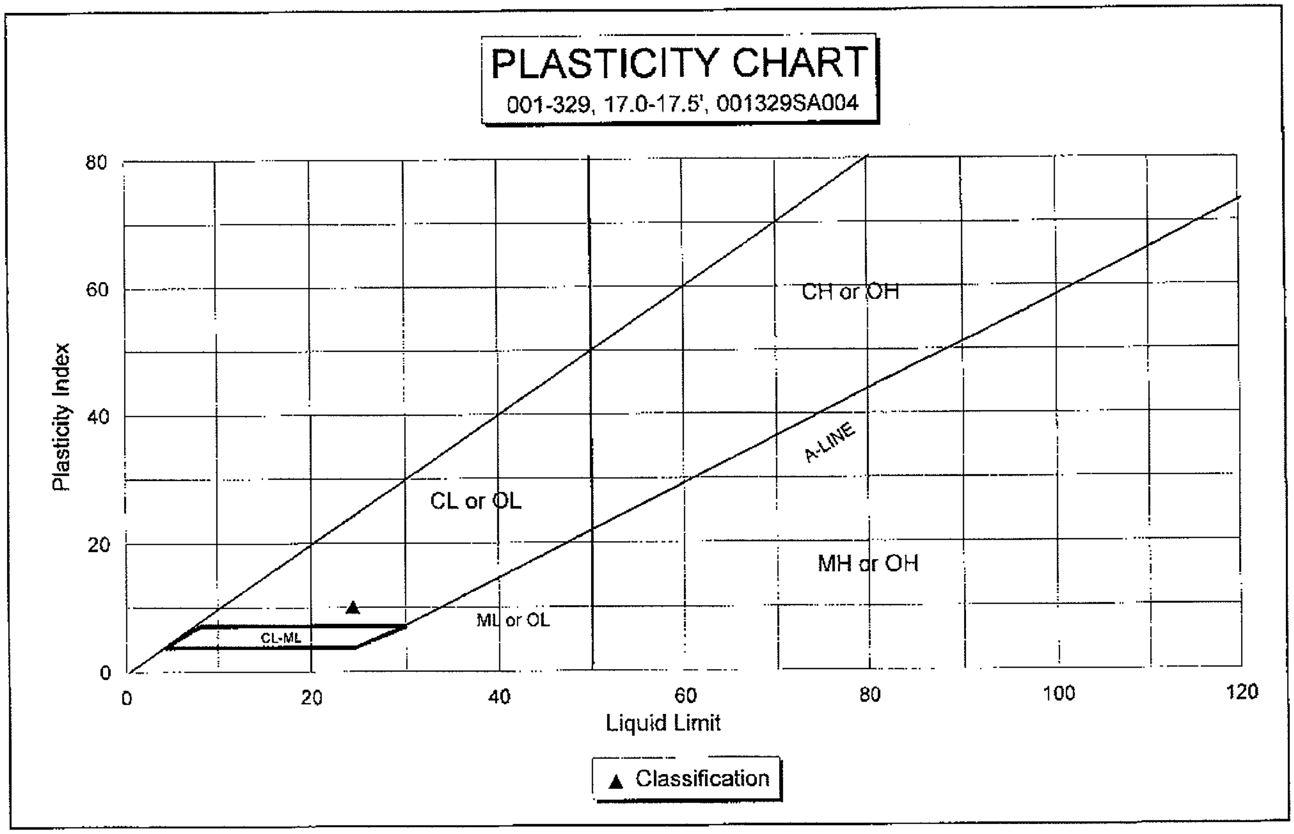

Atterberg Limits, Flow Curve
001-329, 7-9' A+B, 001329SA002
Moisture Content
32
31
30
29
Number of Blows
25

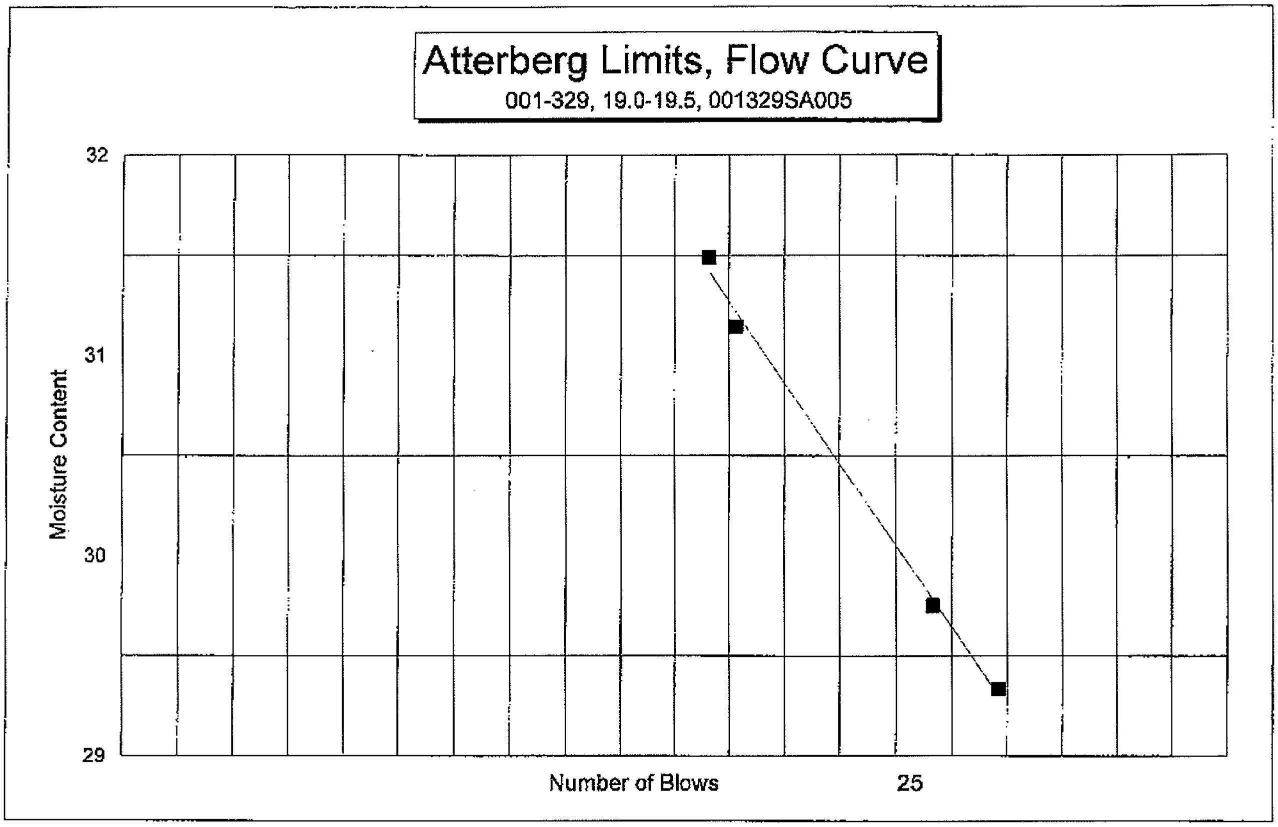

PLASTICITY CHART
001-329, 7-9' A+B, 001329SA002
Plasticity Index
80
60
40
20
0
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
0
20
40
60
80
100
120
Liquid Limit
▲ Classification

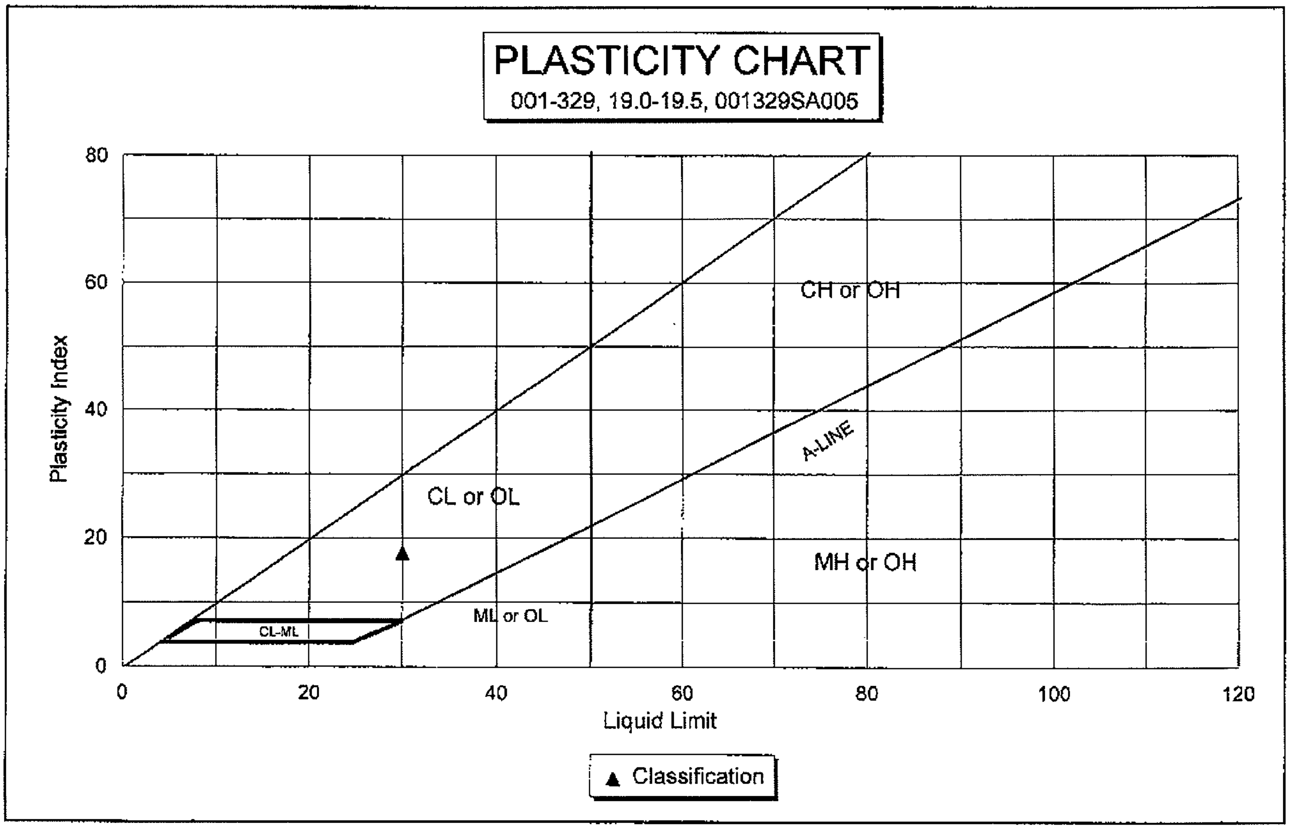

Atterberg Limits, Flow Curve
001-329, 10-12', 001329SA003
Moisture Content
33
32
31
30
29
28
Number of Blows
25

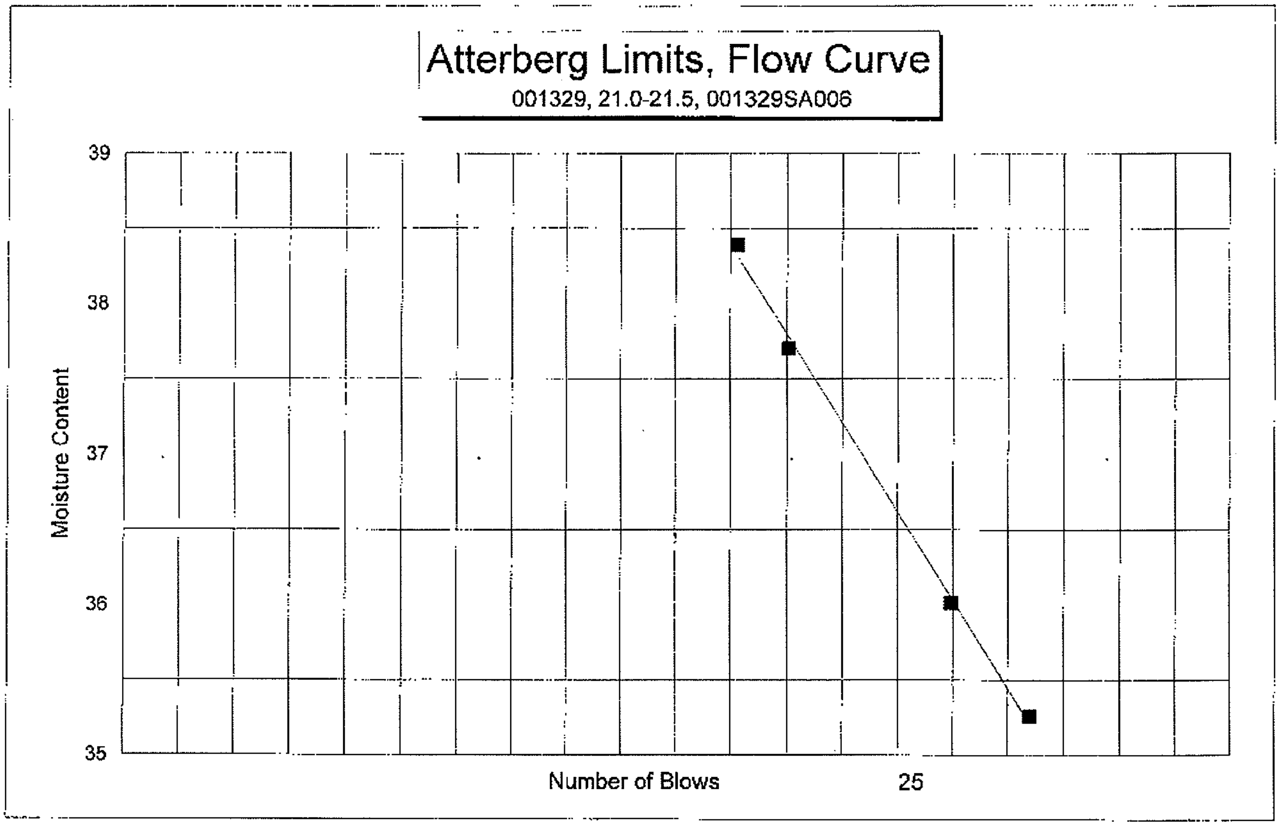

PLASTICITY CHART
001-329, 10-12', 001329SA003
Plasticity Index
80
60
40
20
0
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification


Atterberg Limits, Flow Curve
001-329, 17.0-17.5', 001329SA004
27
26
25
24
23
Moisture Content
Number of Blows
25


PLASTICITY CHART
001-329, 17.0-17.5', 001329SA004
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

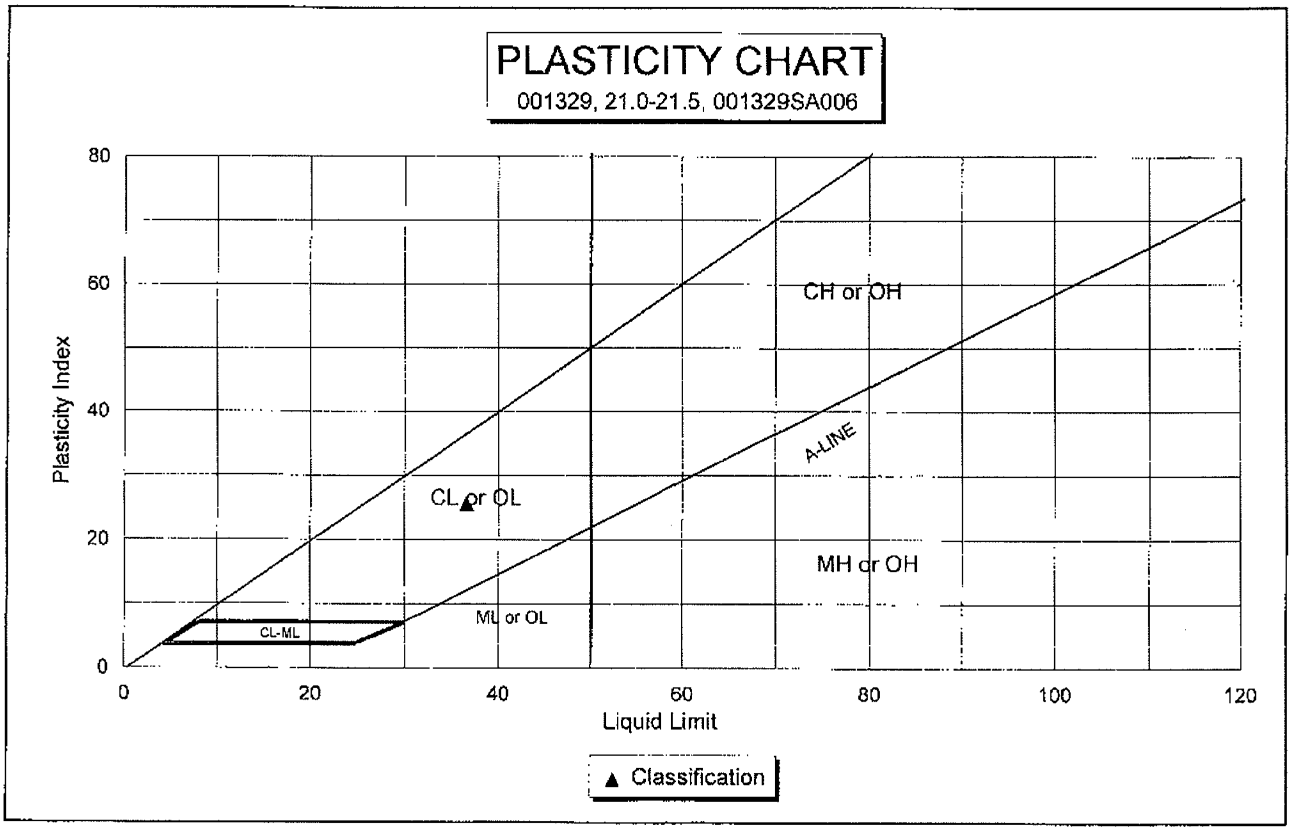

Atterberg Limits, Flow Curve
001-329, 19.0-19.5, 001329SA005
32
31
30
29
Moisture Content
Number of Blows
25


PLASTICITY CHART
001-329, 19.0-19.5, 001329SA005
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification



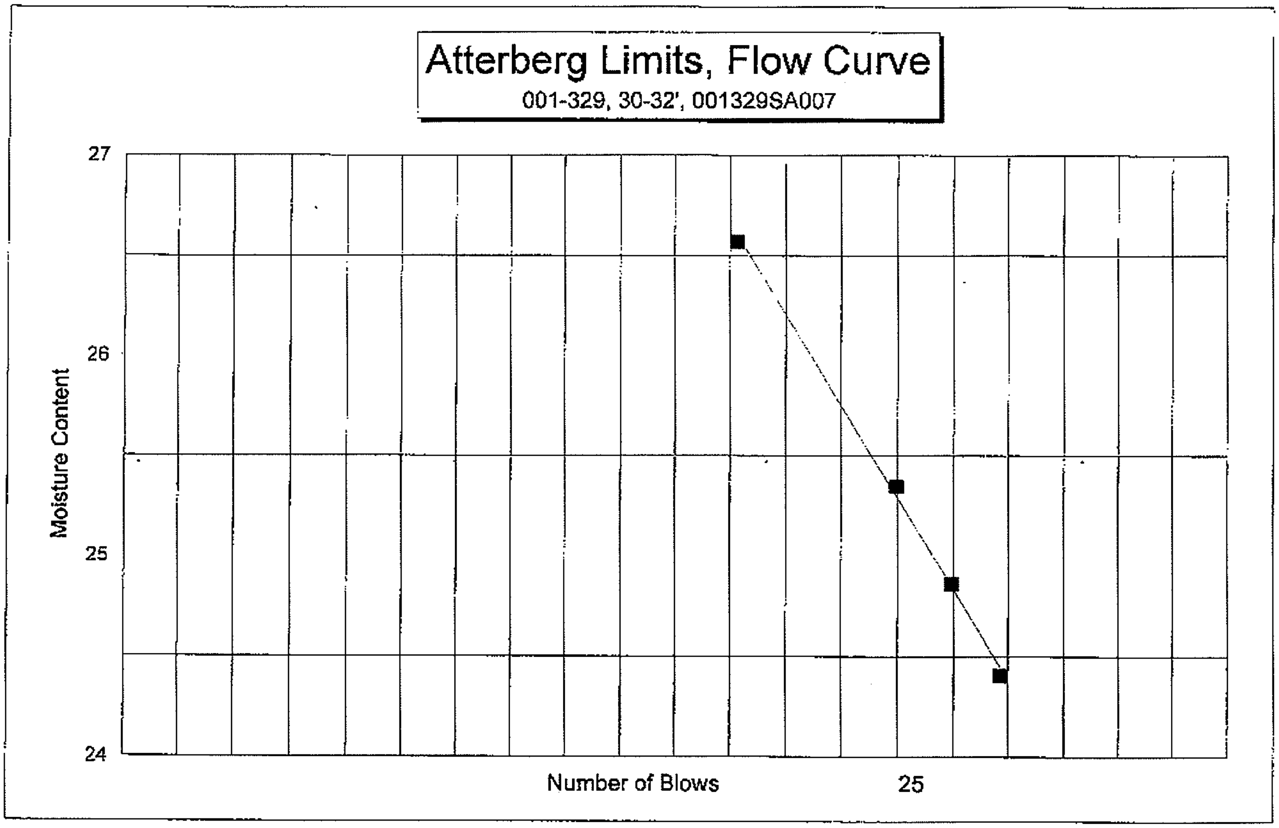
Atterberg Limits, Flow Curve

001329, 21.0-21.5, 001329SA006



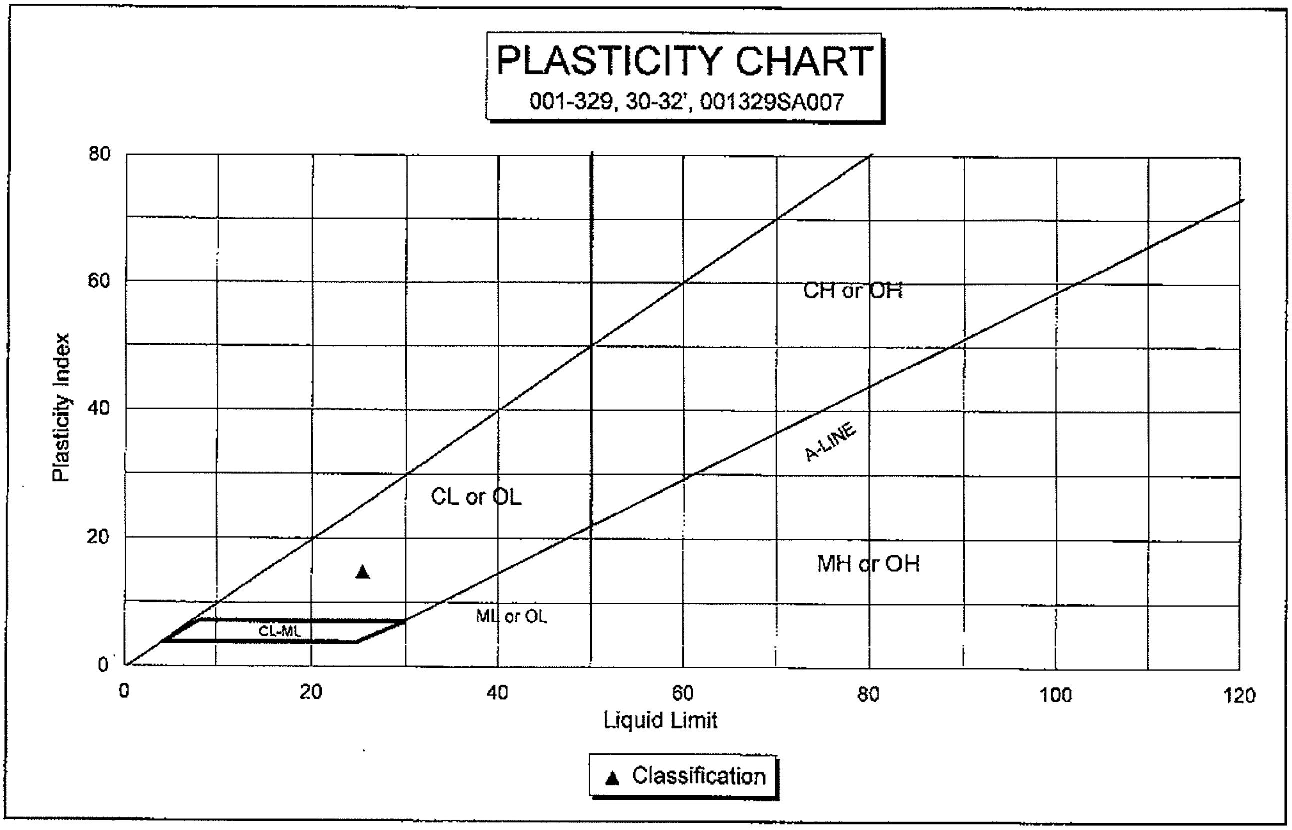
PLASTICITY CHART

001329, 21.0-21.5, 001329SA006



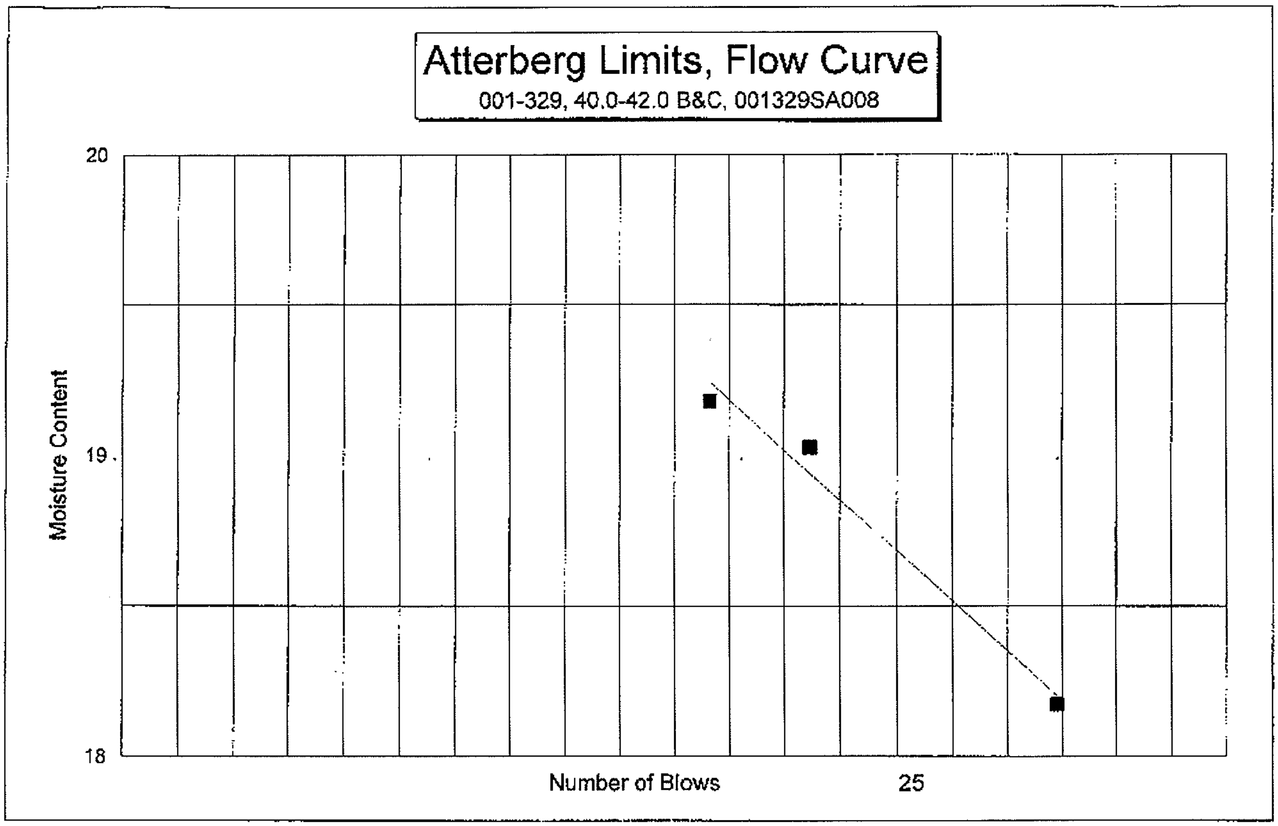
Atterberg Limits, Flow Curve

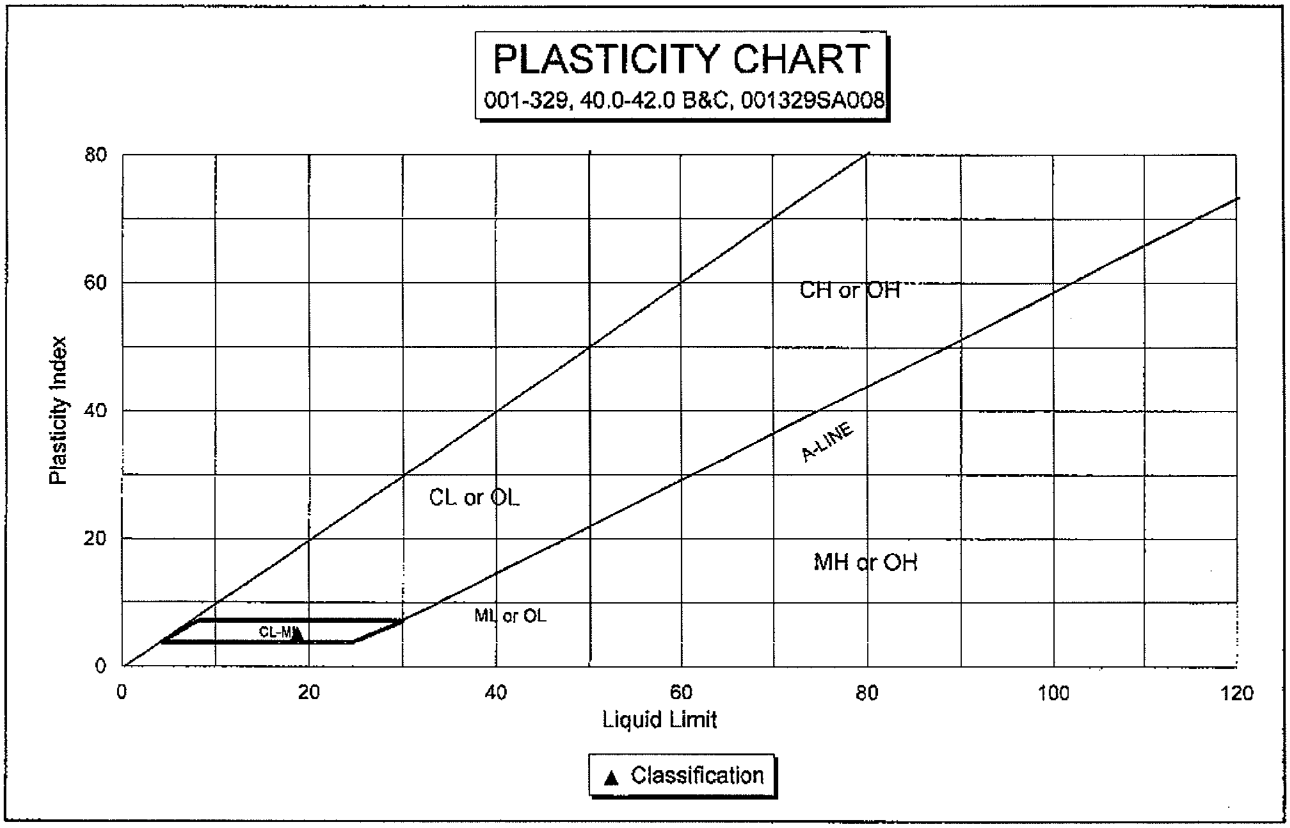
001-329, 30-32', 001329SA007

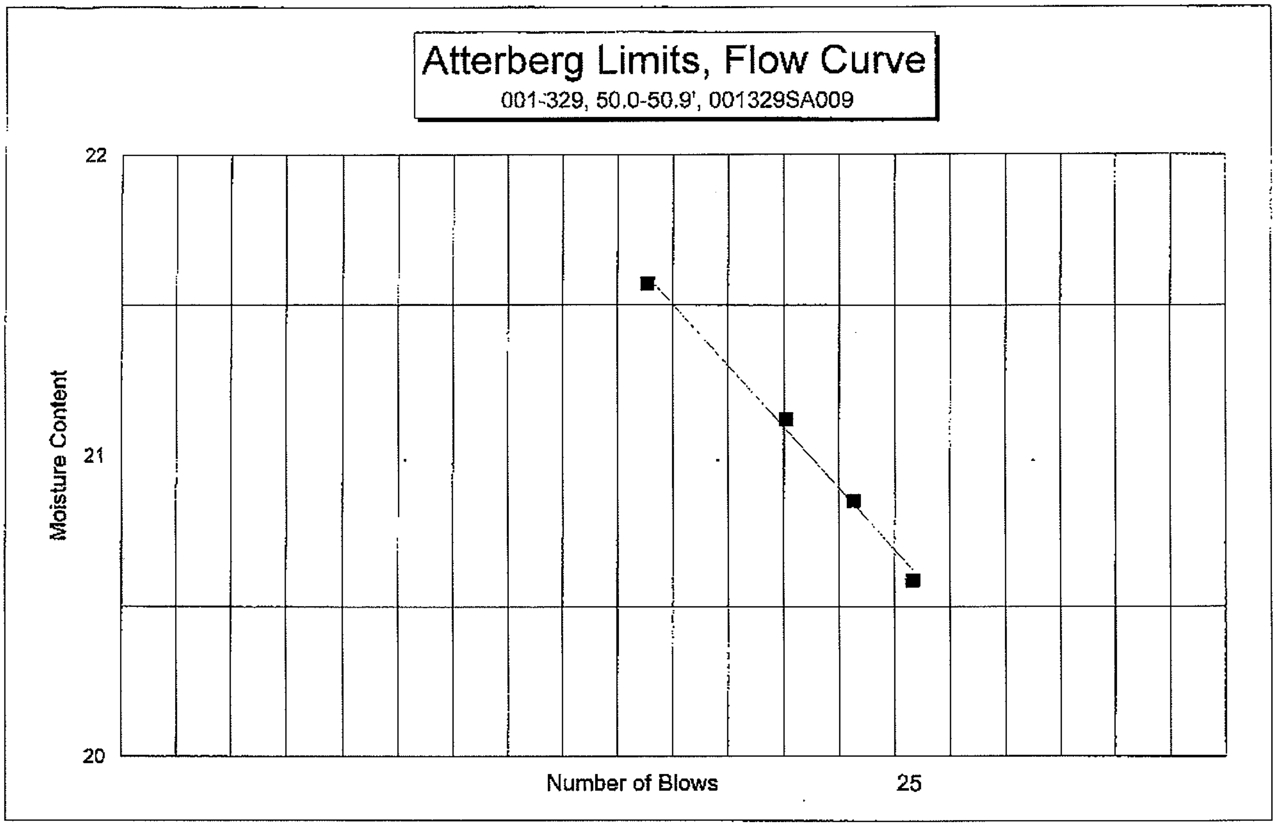


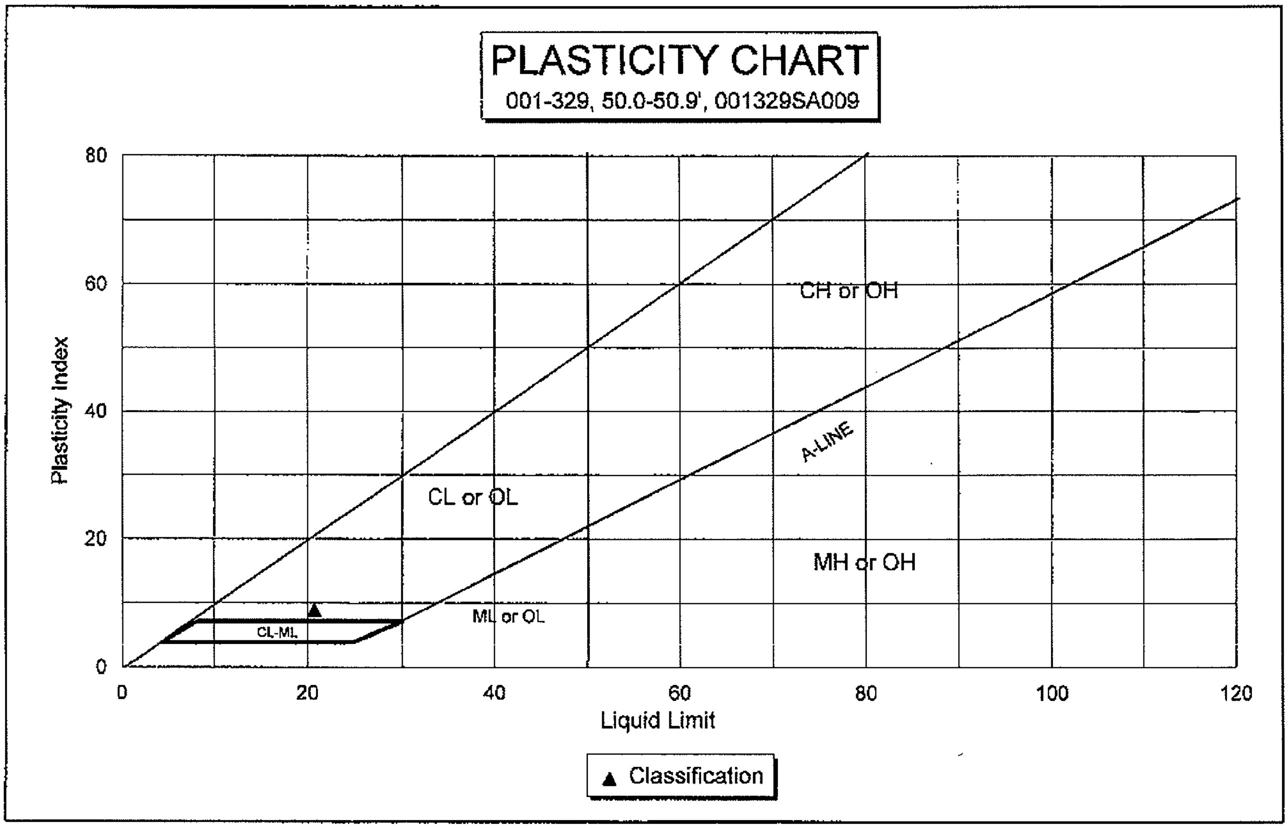
PLASTICITY CHART

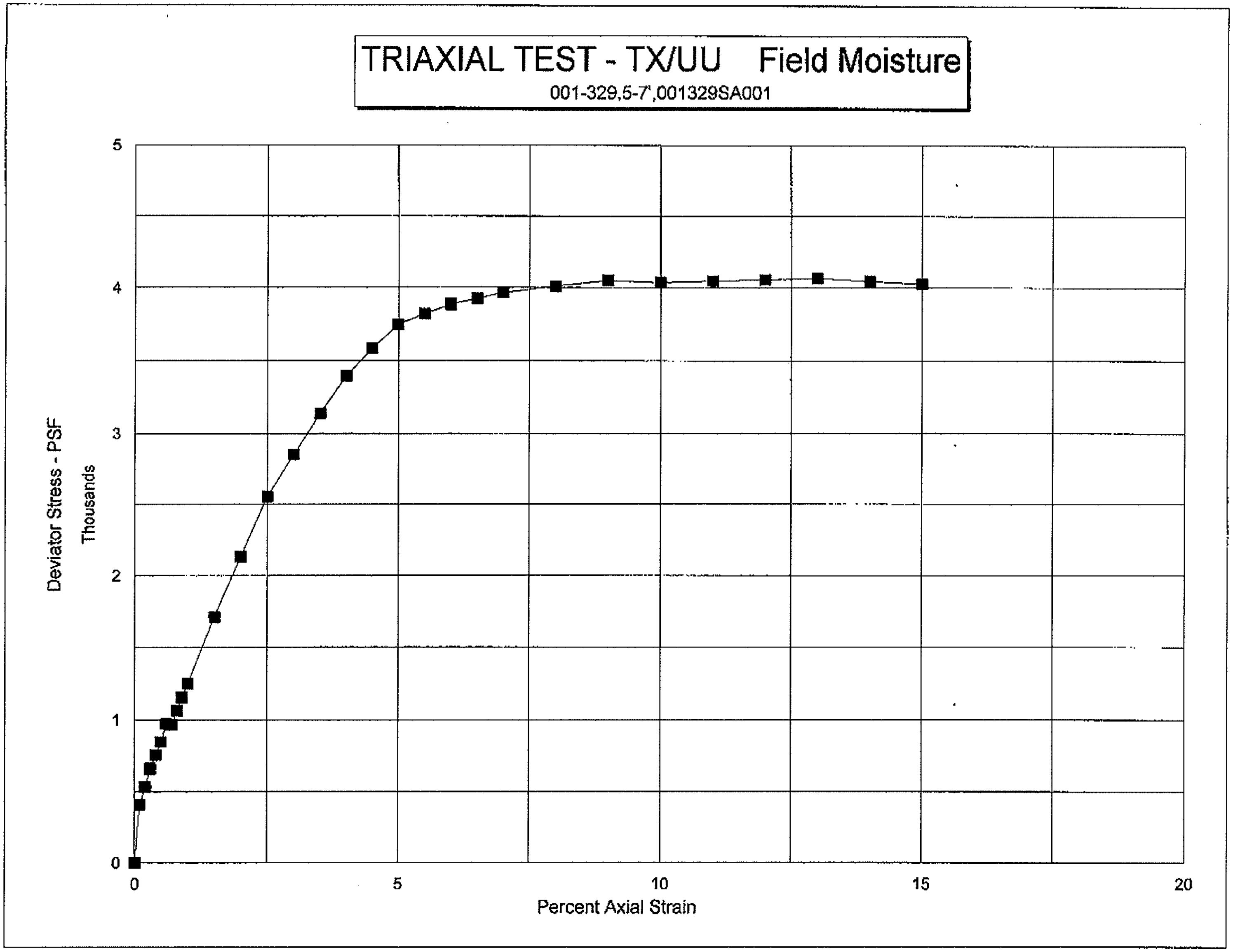
001-329, 30-32', 001329SA007

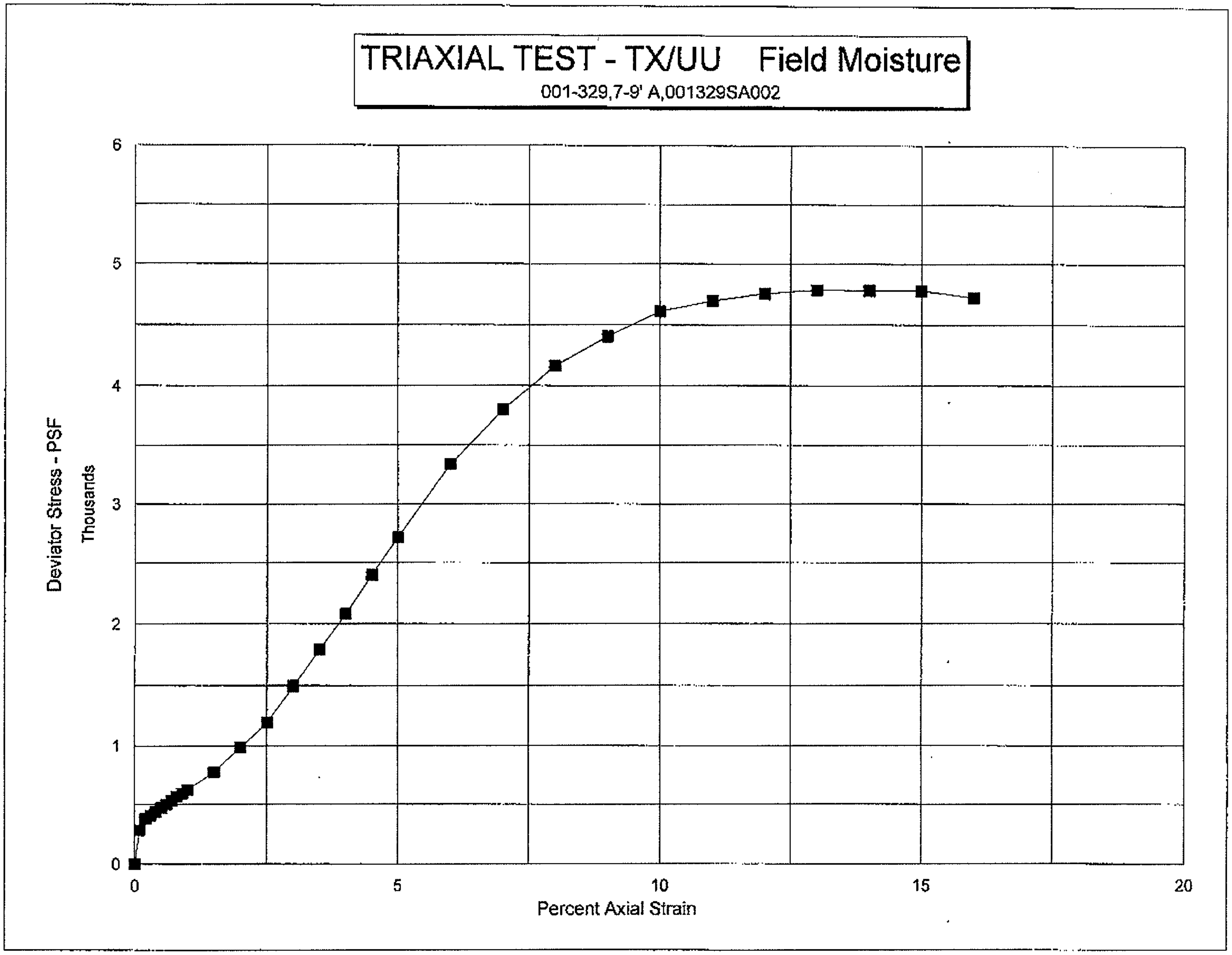

Atterberg Limits, Flow Curve
001-329, 40.0-42.0 B&C, 001329SA008
20
19
18
Moisture Content
Number of Blows
25

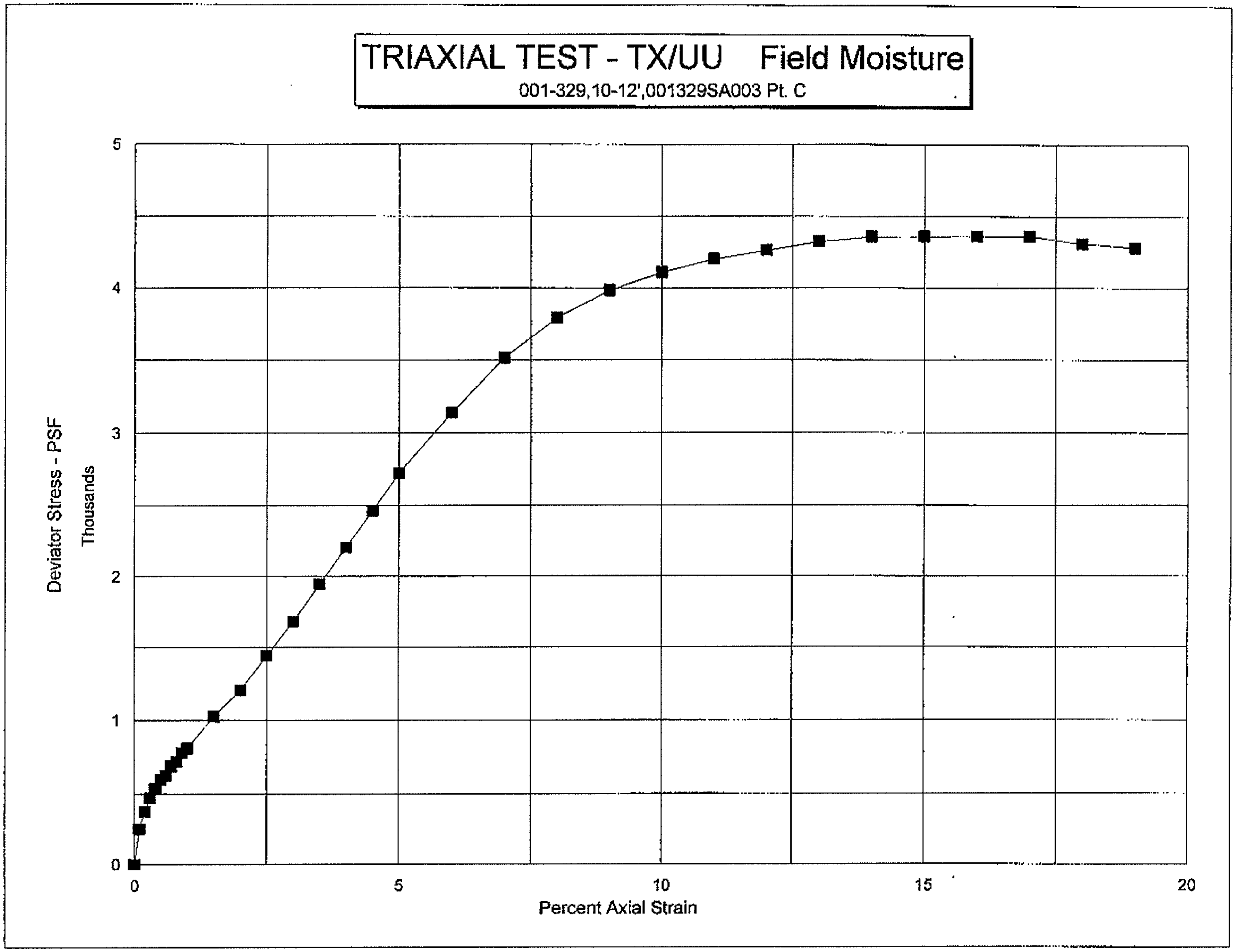

PLASTICITY CHART
001-329, 40.0-42.0 B&C, 001329SA008
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification


Atterberg Limits, Flow Curve
001-329, 50.0-50.9', 001329SA009
22
21
20
Moisture Content
Number of Blows
25


PLASTICITY CHART
001-329, 50.0-50.9', 001329SA009
80
60
40
20
0
Plasticity Index
0
20
40
60
80
100
120
Liquid Limit
CH or OH
A-LINE
CL or OL
MH or OH
ML or OL
CL-ML
▲ Classification

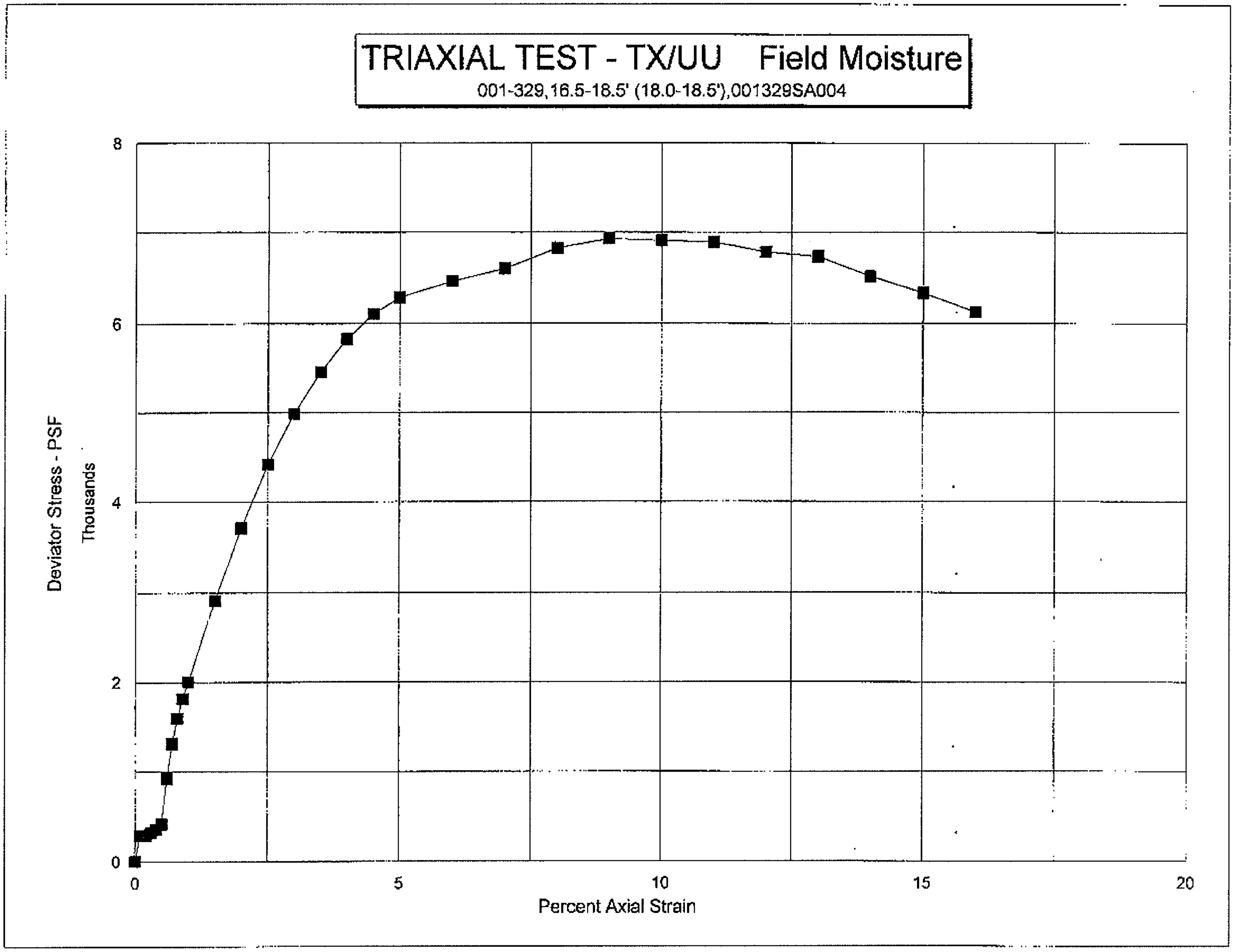

TRIAXIAL TEST - TX/UU Field Moisture
001-329,5-7',001329SA001
Deviator Stress - PSF
Thousands
5
4
3
2
1
0
0
5
10
15
20
Percent Axial Strain


TRIAXIAL TEST - TX/UU Field Moisture
001-329,7-9' A,001329SA002
Deviator Stress - PSF
Thousands
0
1
2
3
4
5
6
0
5
10
15
20
Percent Axial Strain



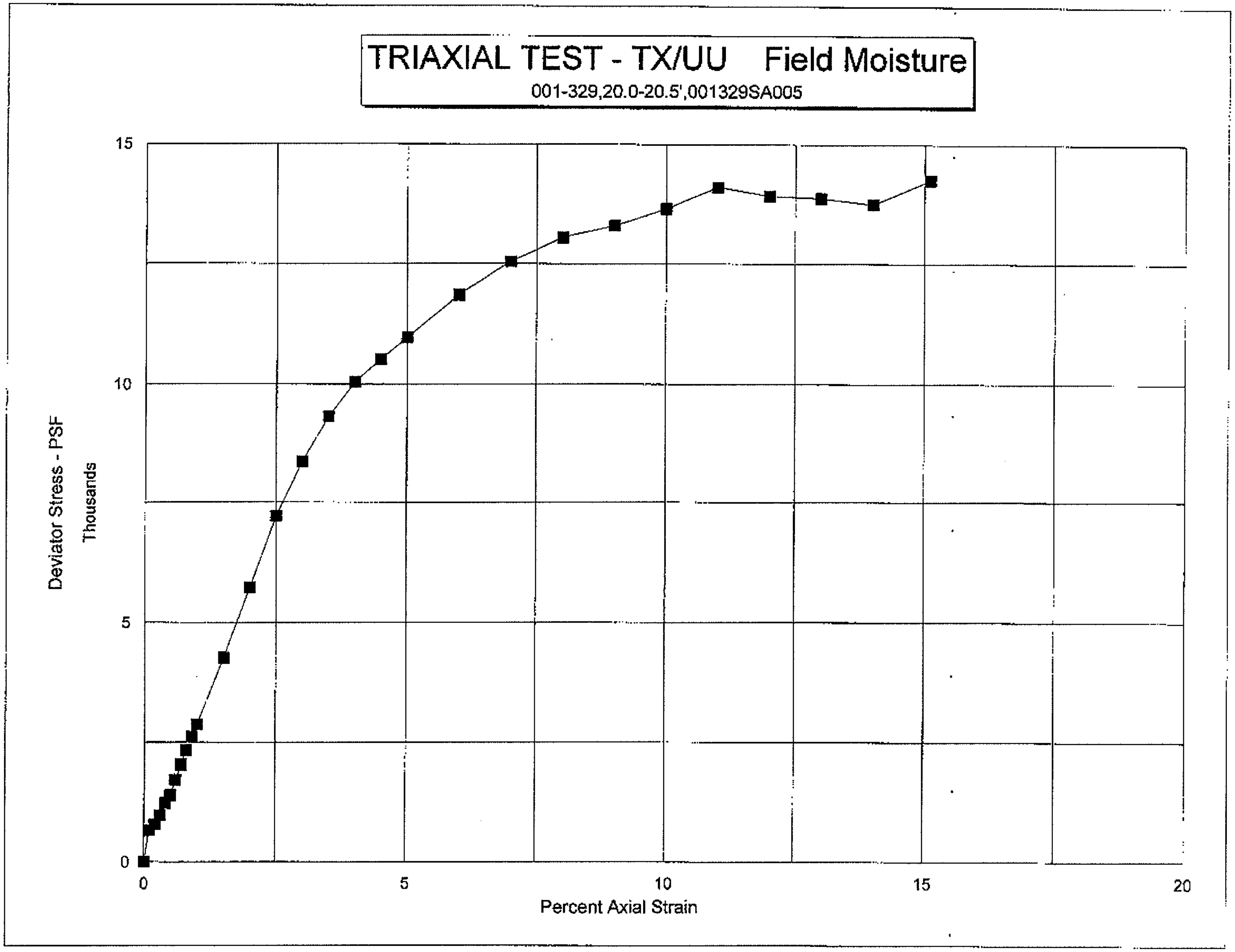
TRIAXIAL TEST - TX/UU Field Moisture

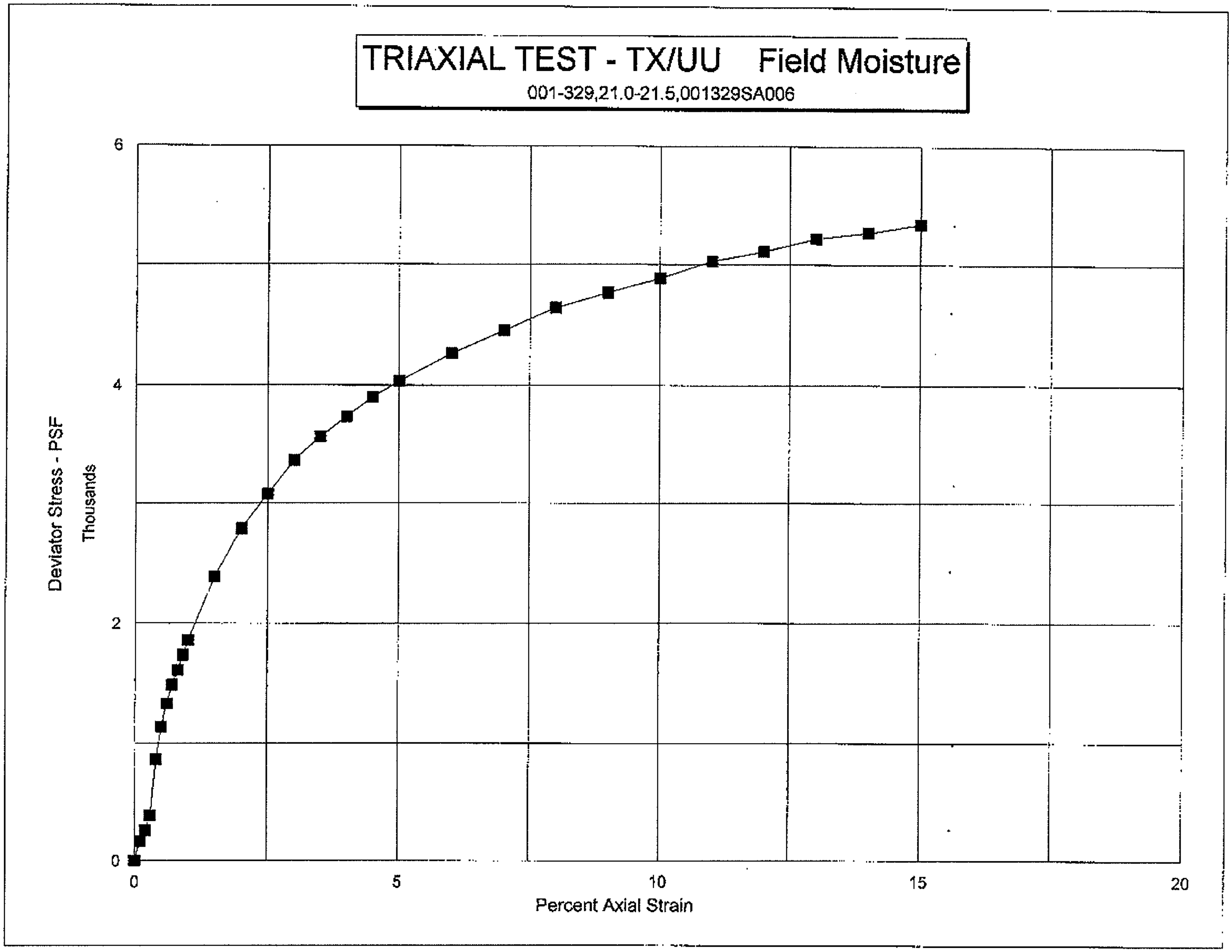
001-329,10-12',001329SA003 Pt. C



TRIAXIAL TEST - TX/UU Field Moisture

001-329,16.5-18.5' (18.0-18.5'),001329SA004


TRIAXIAL TEST - TX/UU Field Moisture
001-329,20.0-20.5',001329SA005
Deviator Stress - PSF
Thousands
15
10
5
0
0
5
10
15
20
Percent Axial Strain



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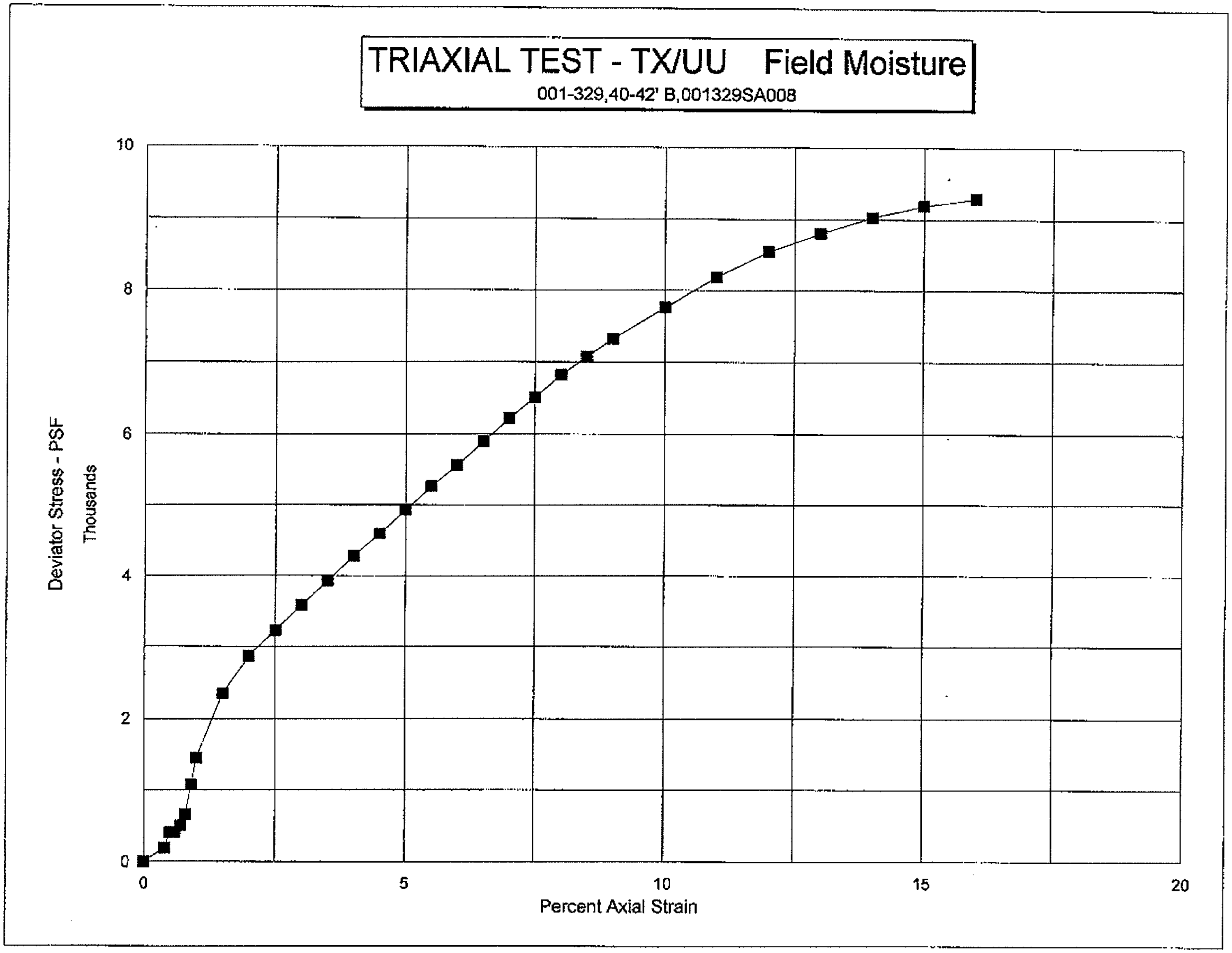
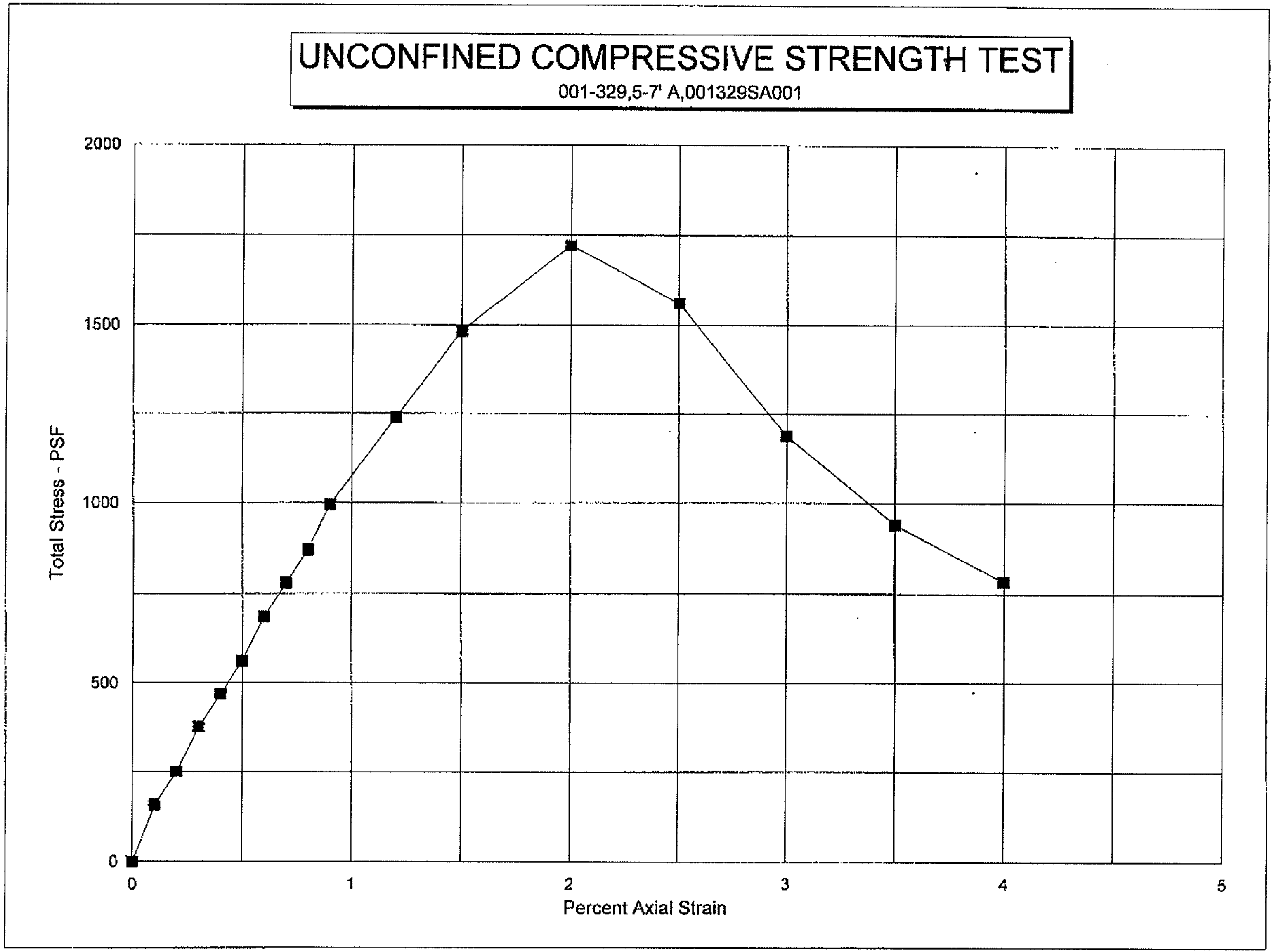
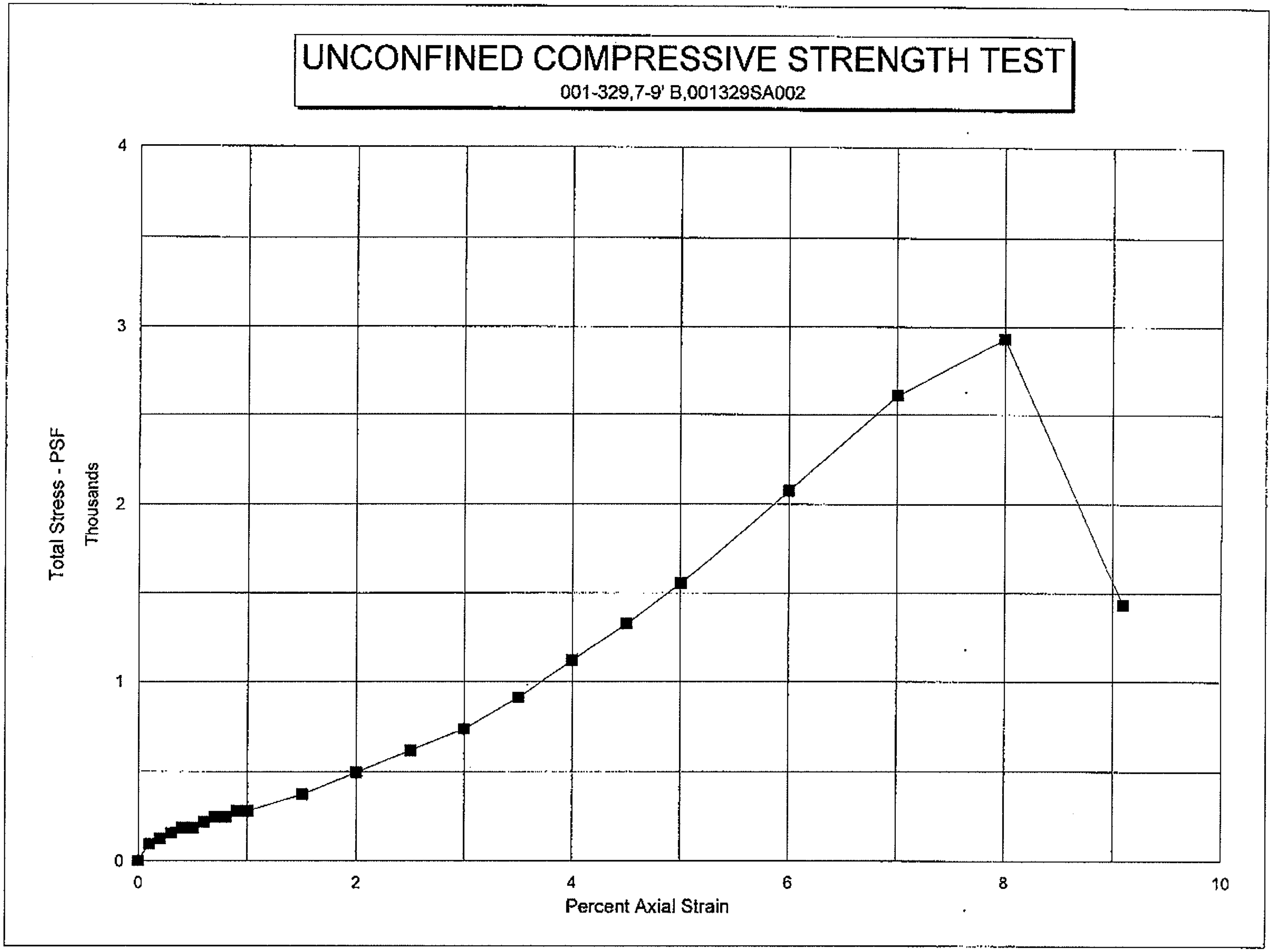
001-329,21.0-21.5,001329SA006


TRIAXIAL TEST - TX/UU Field Moisture
001-329,40-42' B,001329SA008
Deviator Stress - PSF
Thousands
0
2
4
6
8
10
0
5
10
15
20
Percent Axial Strain

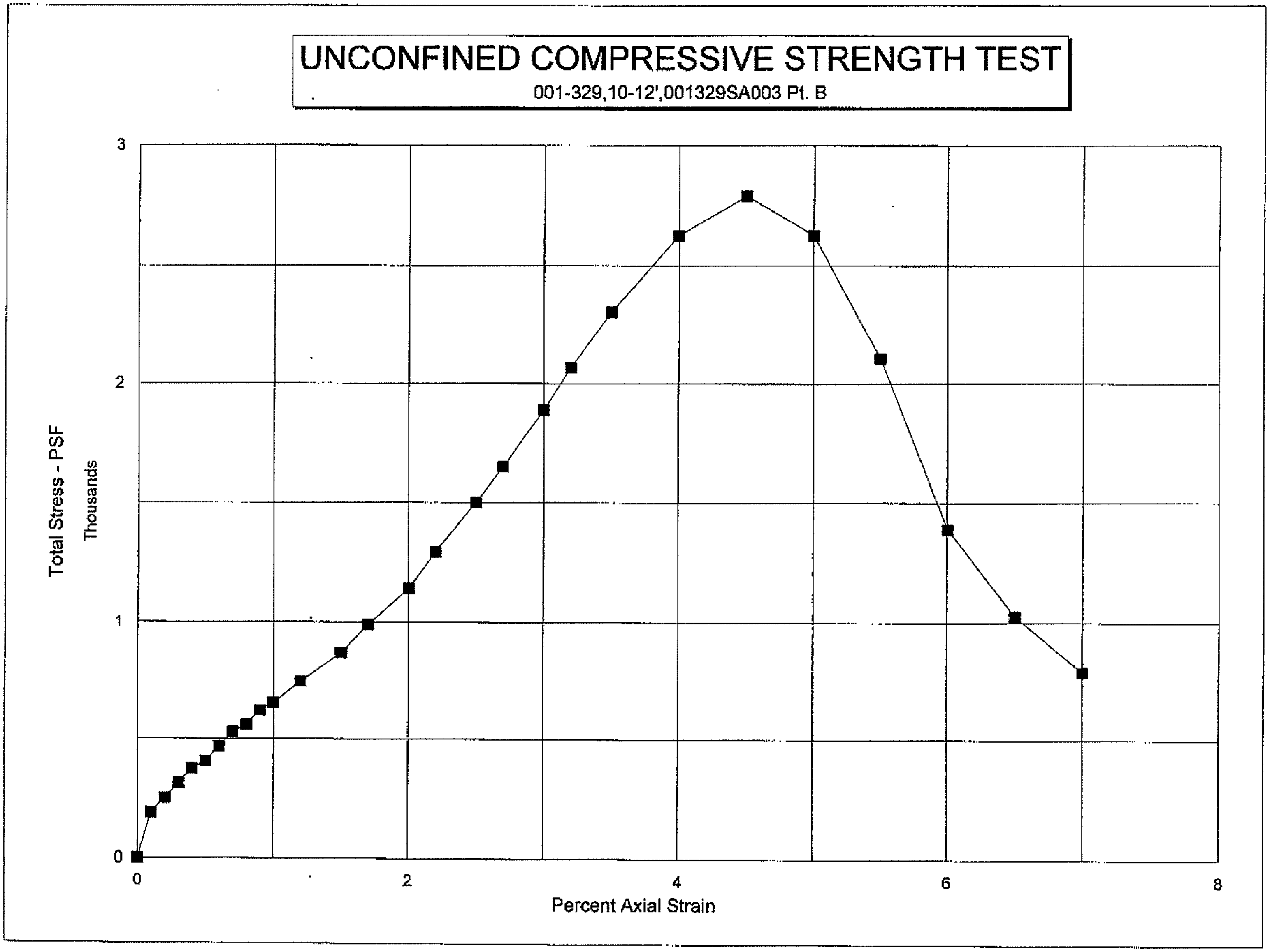

UNCONFINED COMPRESSIVE STRENGTH TEST

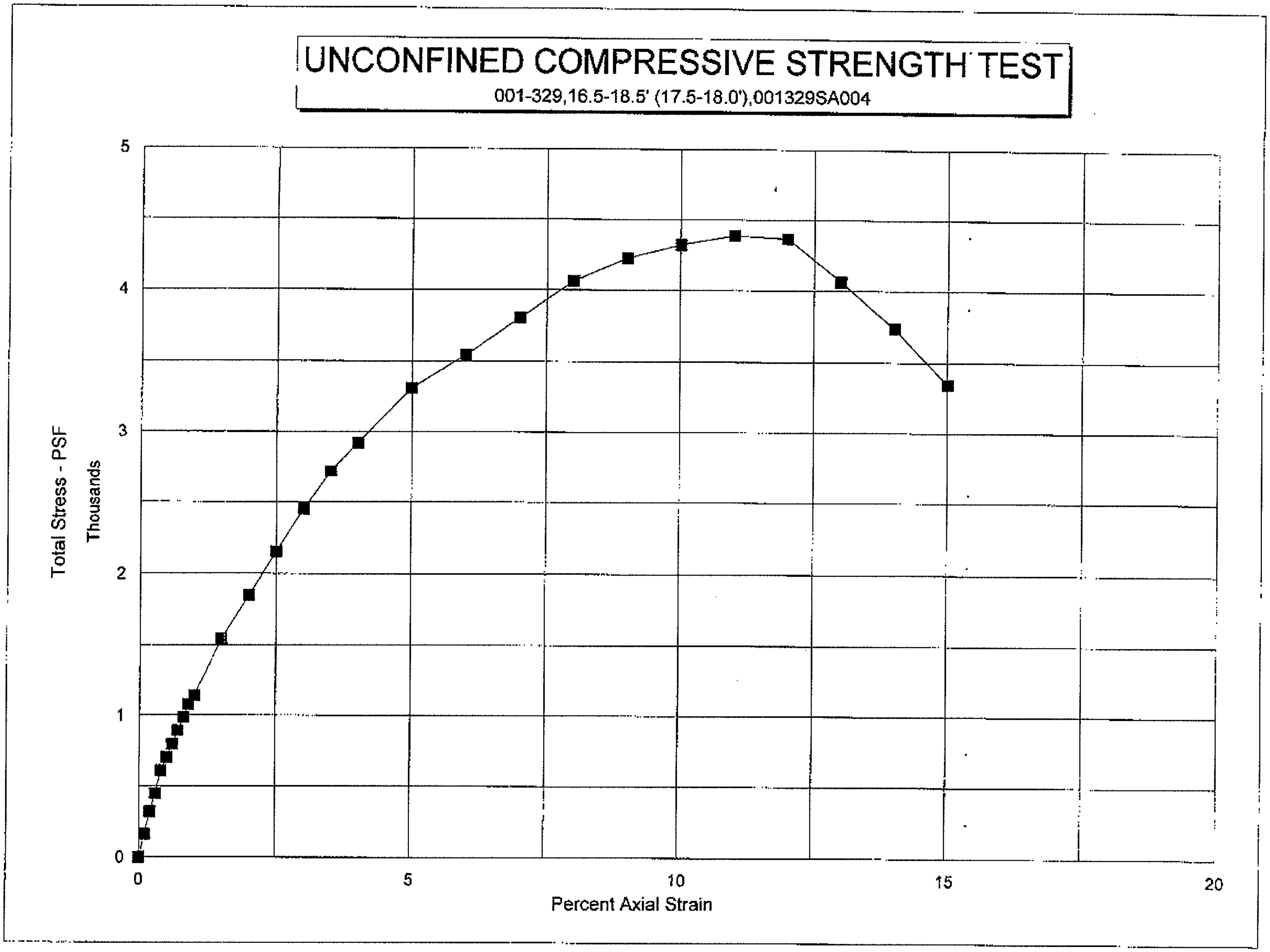
001-329,5-7' A,001329SA001



UNCONFINED COMPRESSIVE STRENGTH TEST

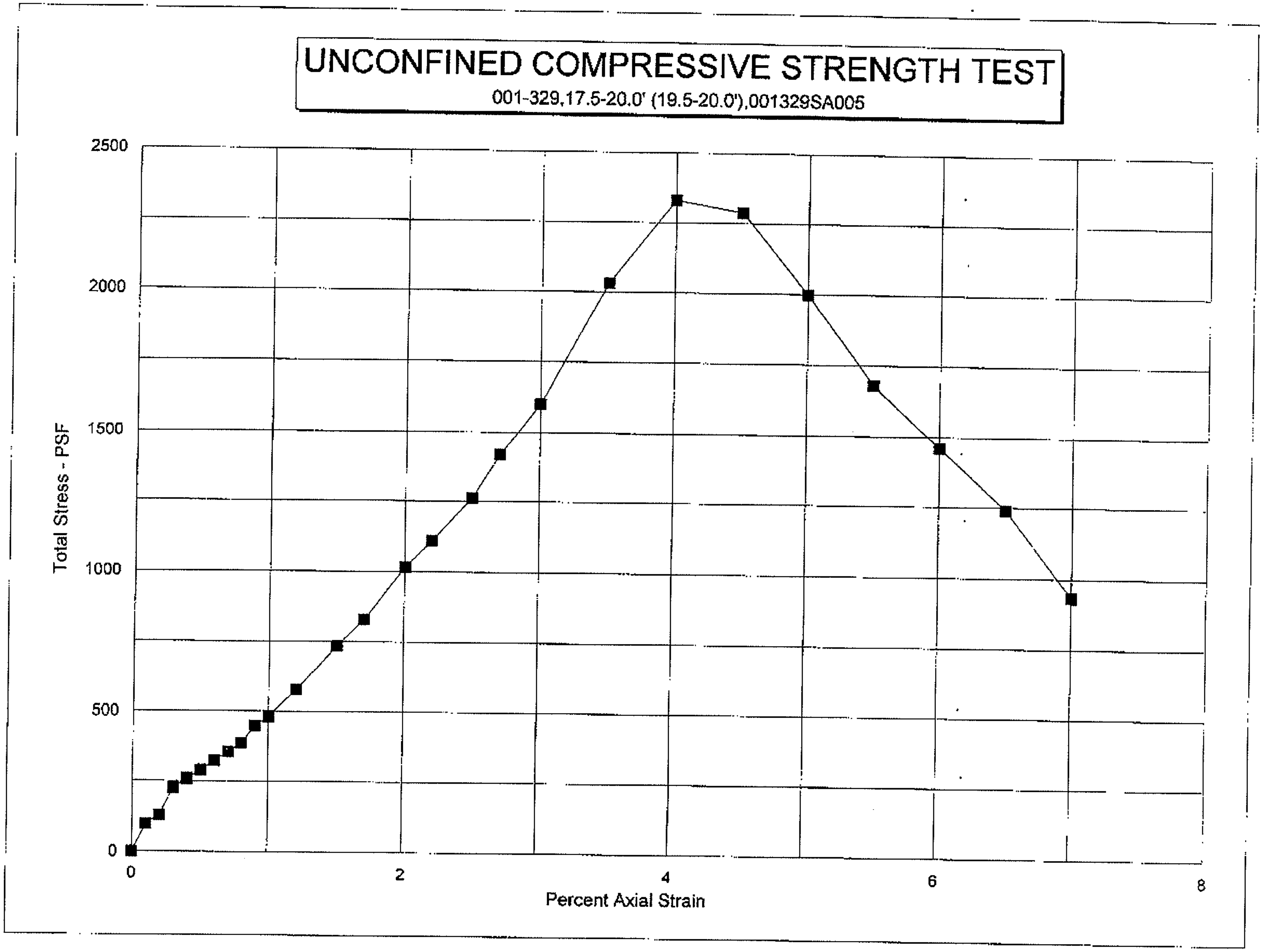
001-329,7-9' B,001329SA002


UNCONFINED COMPRESSIVE STRENGTH TEST
001-329,10-12',001329SA003 Pt. B
Total Stress - PSF
Thousands
3
2
1
0
0
2
4
6
8
Percent Axial Strain



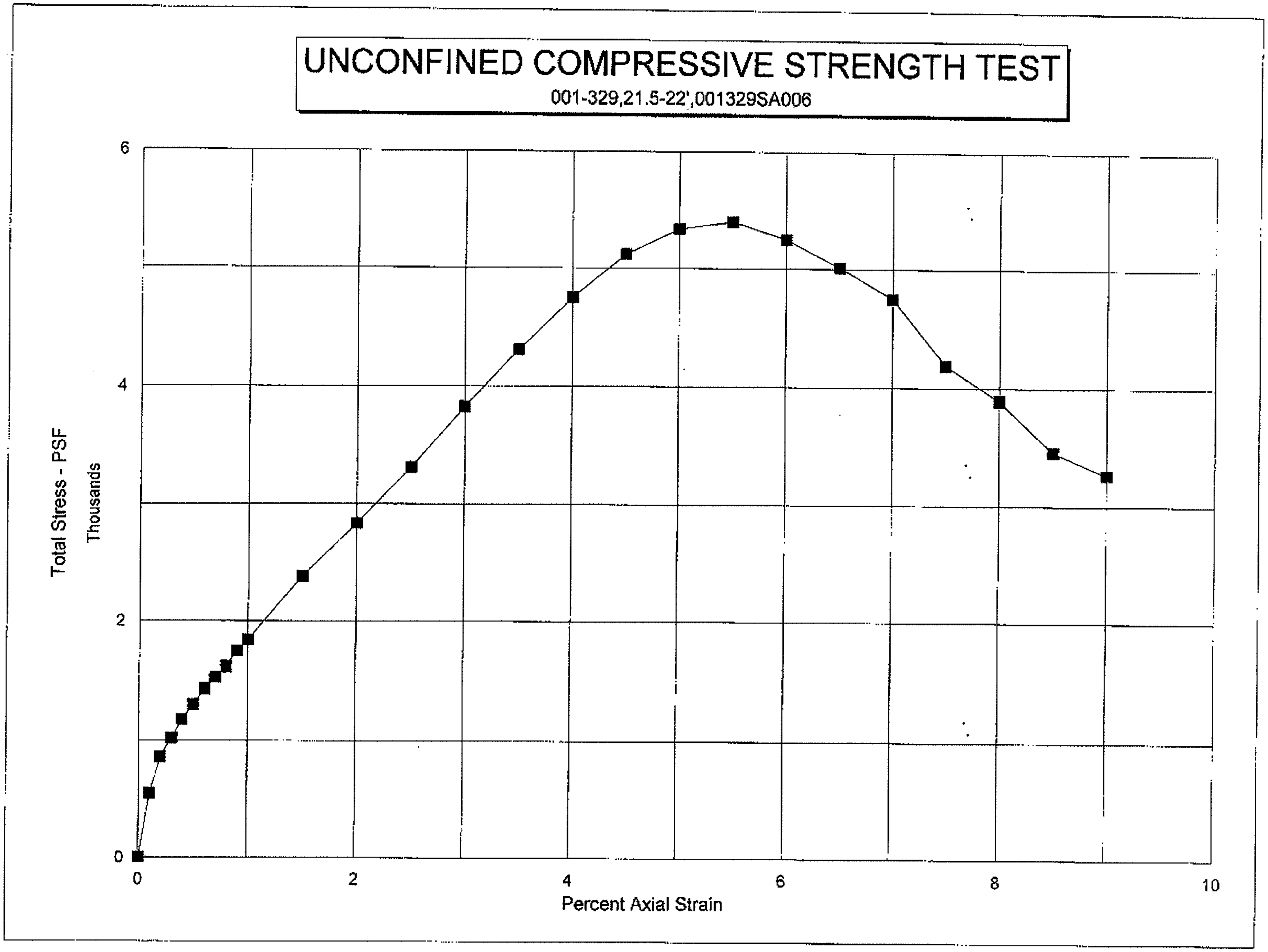
UNCONFINED COMPRESSIVE STRENGTH TEST

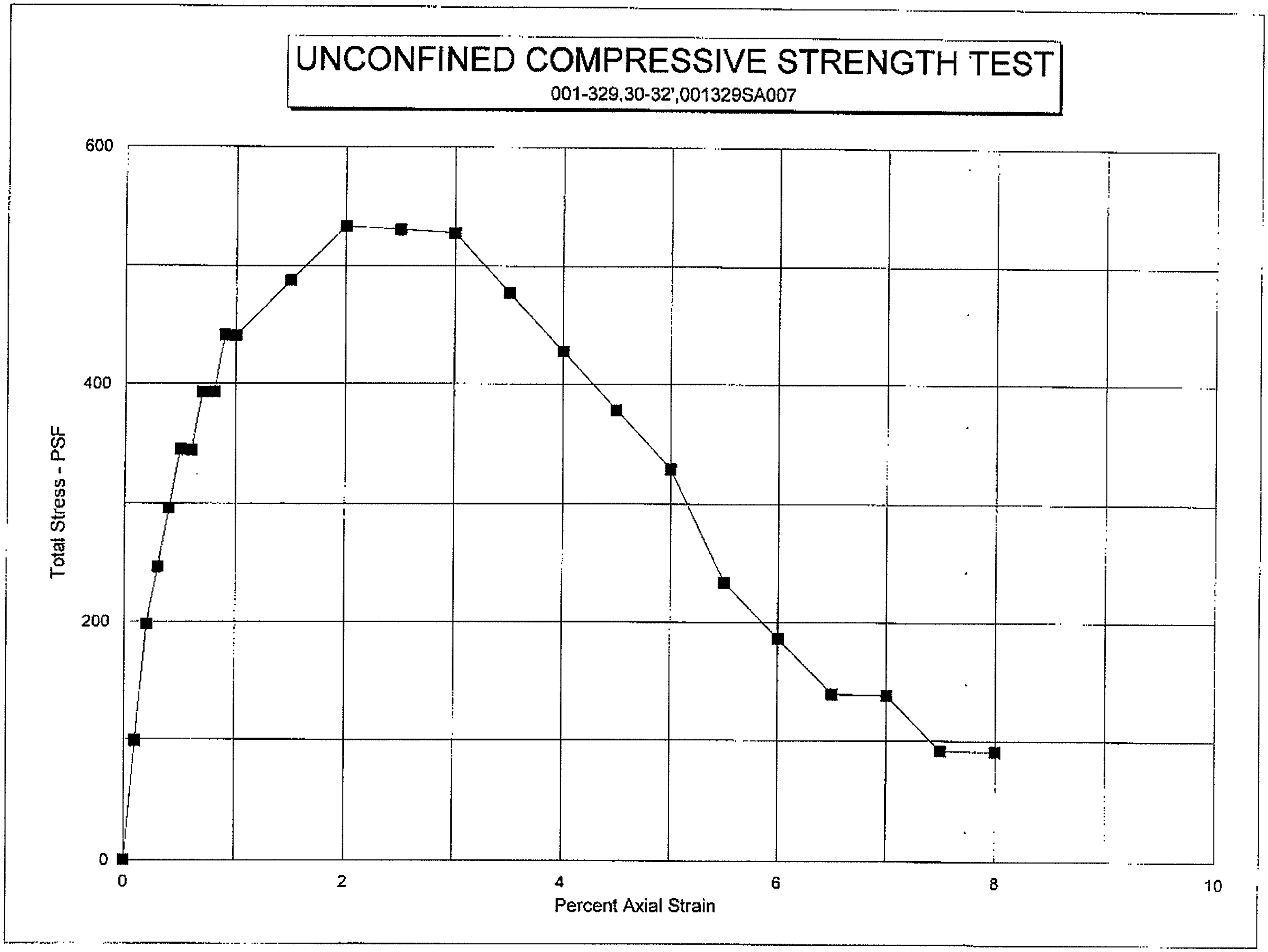
001-329,16.5-18.5' (17.5-18.0'),001329SA004



UNCONFINED COMPRESSIVE STRENGTH TEST

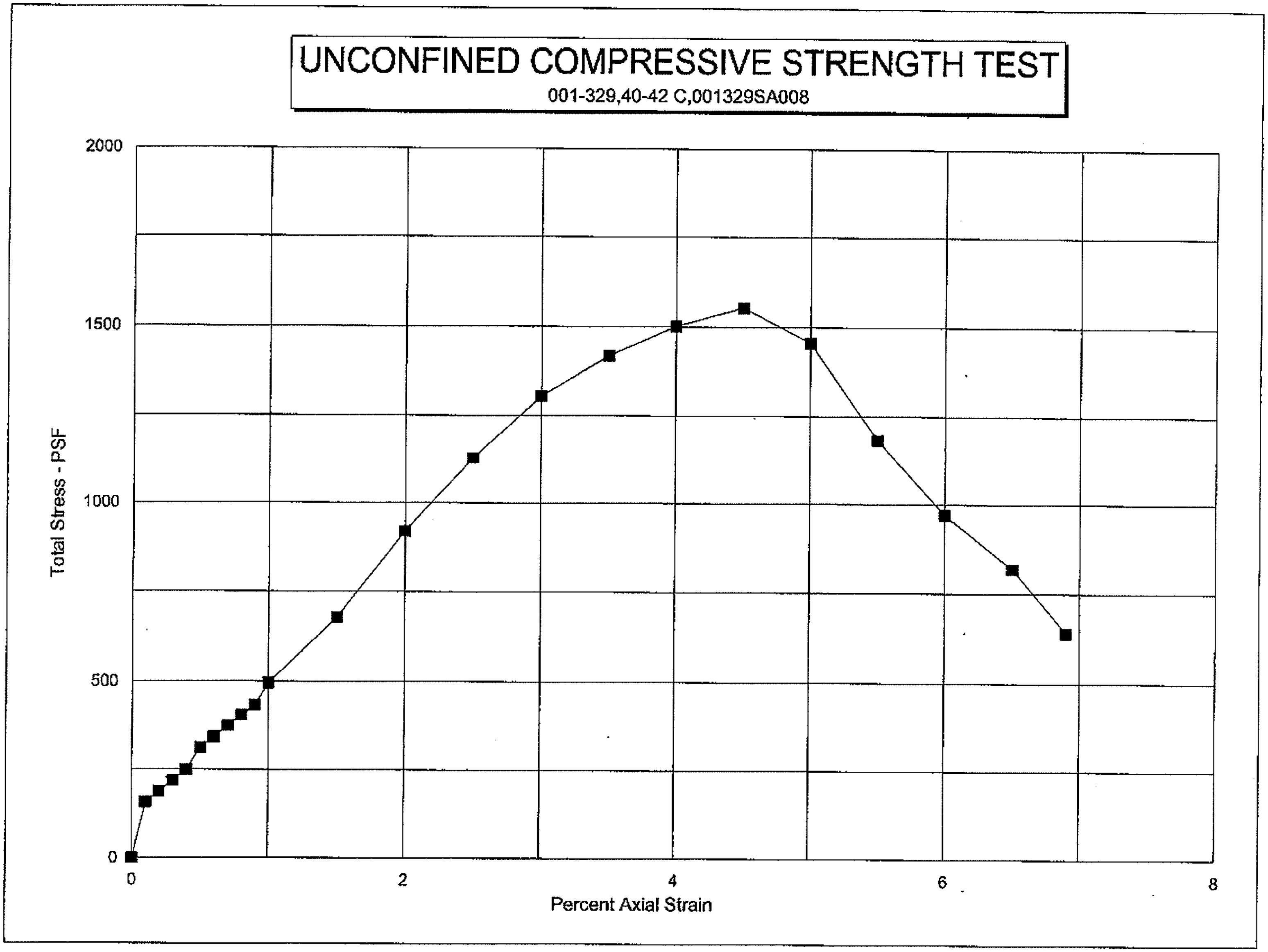
001-329,17.5-20.0' (19.5-20.0'),001329SA005


UNCONFINED COMPRESSIVE STRENGTH TEST
001-329,21.5-22',001329SA006
Total Stress - PSF
Thousands
0
2
4
6
0
2
4
6
8
10
Percent Axial Strain



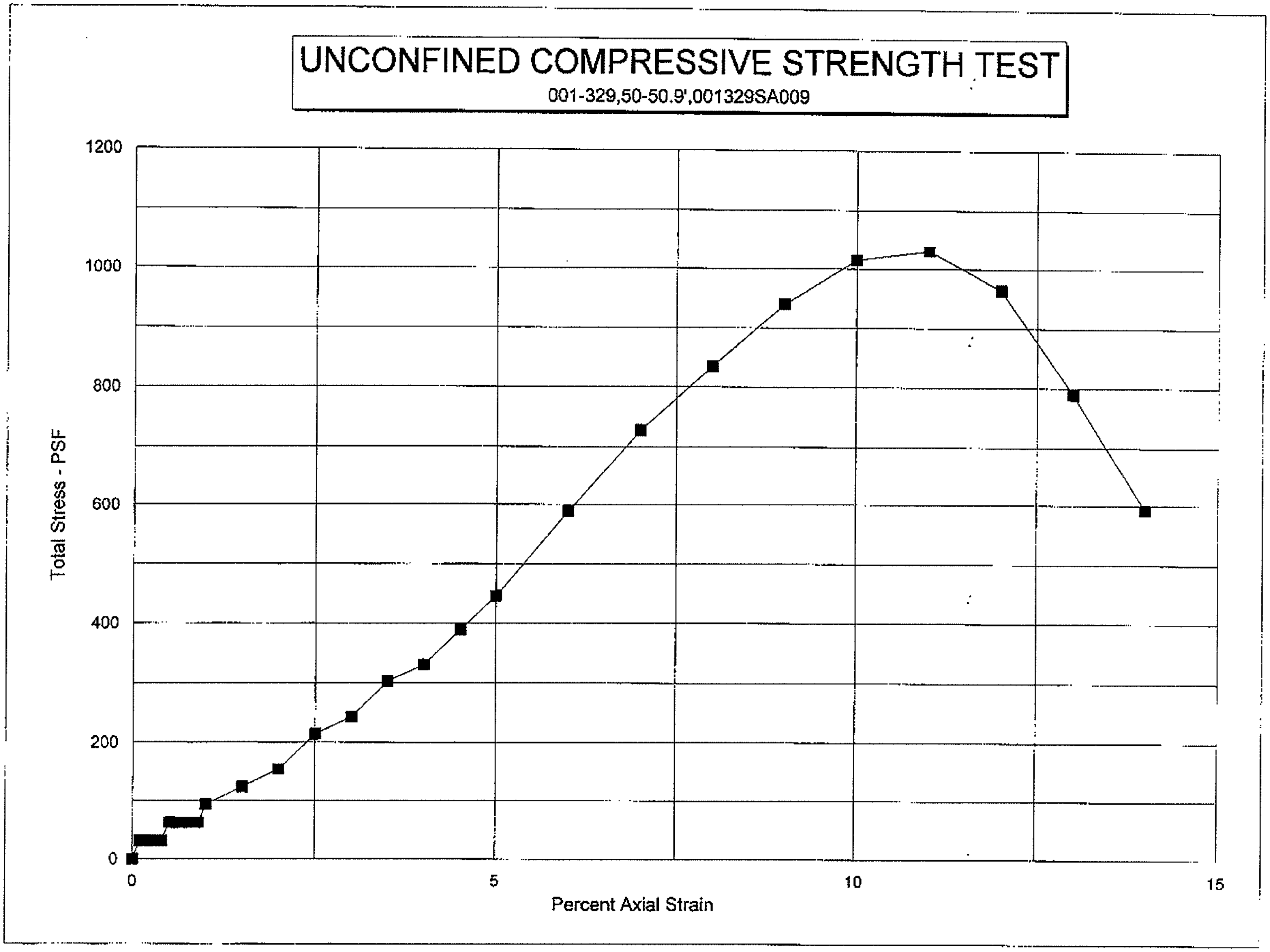
UNCONFINED COMPRESSIVE STRENGTH TEST

001-329,30-32',001329SA007



UNCONFINED COMPRESSIVE STRENGTH TEST

001-329,40-42 C,001329SA008


UNCONFINED COMPRESSIVE STRENGTH TEST
001-329,50-50.9',001329SA009
Total Stress - PSF
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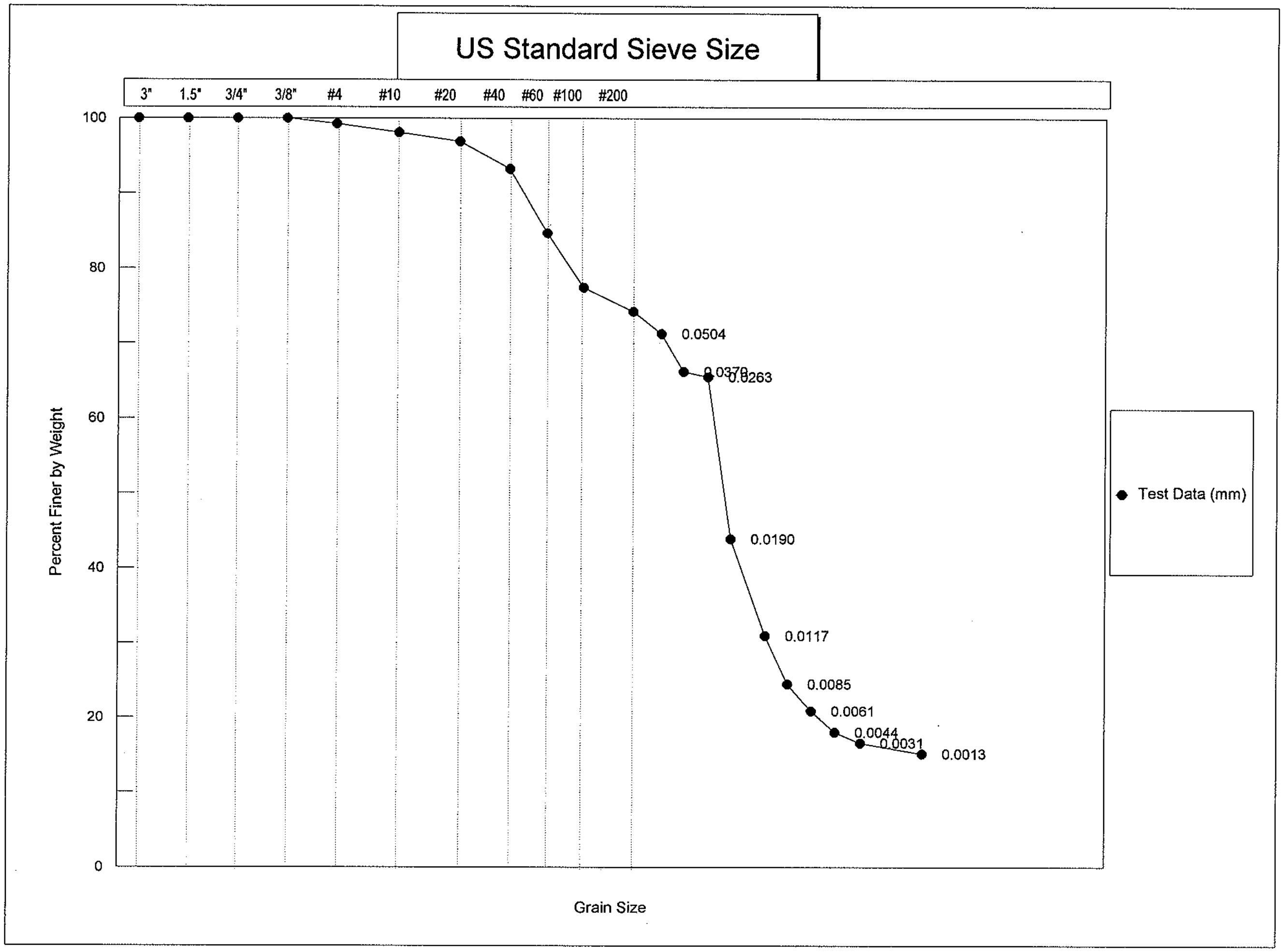
1000
800
600
400
200
0
0
5
10
15
Percent Axial Strain



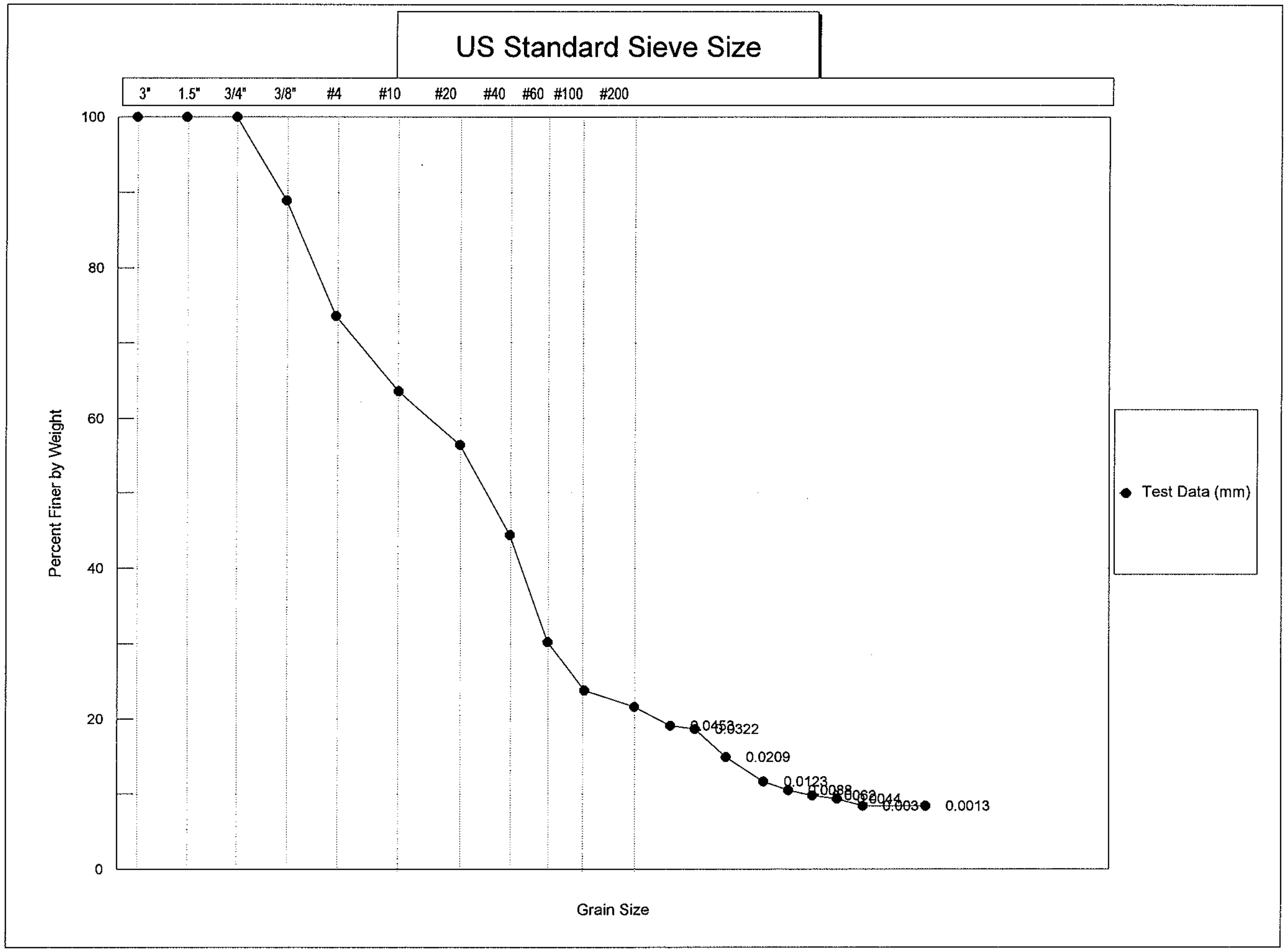
| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

Client: LATA Kentucky
Job Number: 2855-01
Boring No.: 001-306
Depth: 10-13'
Sample No.: 001306GRNSZ1
Classification: **Classification Not Performed**



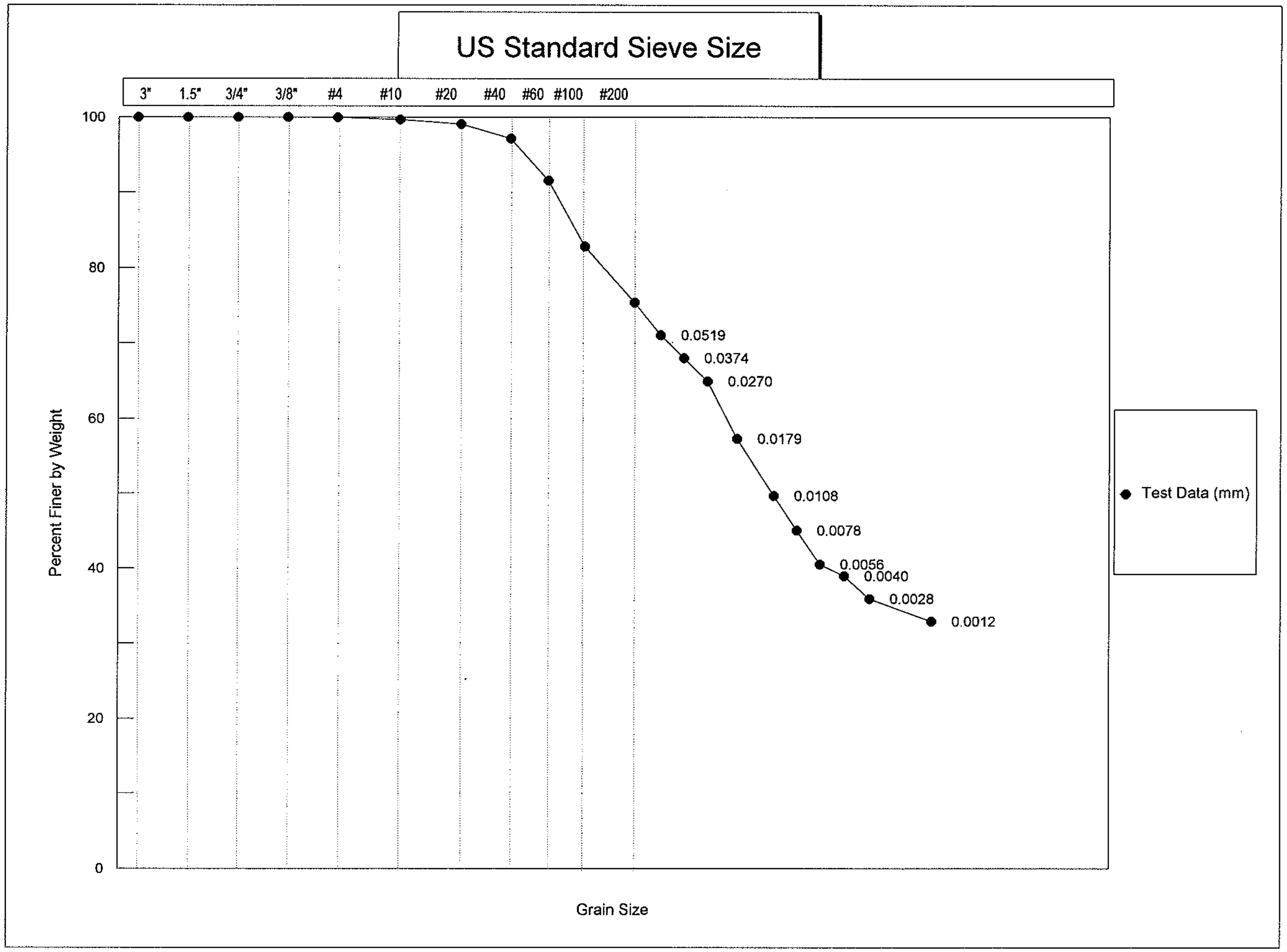
| | | | | | | |
|---|---|---|---|---|---|---|
| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

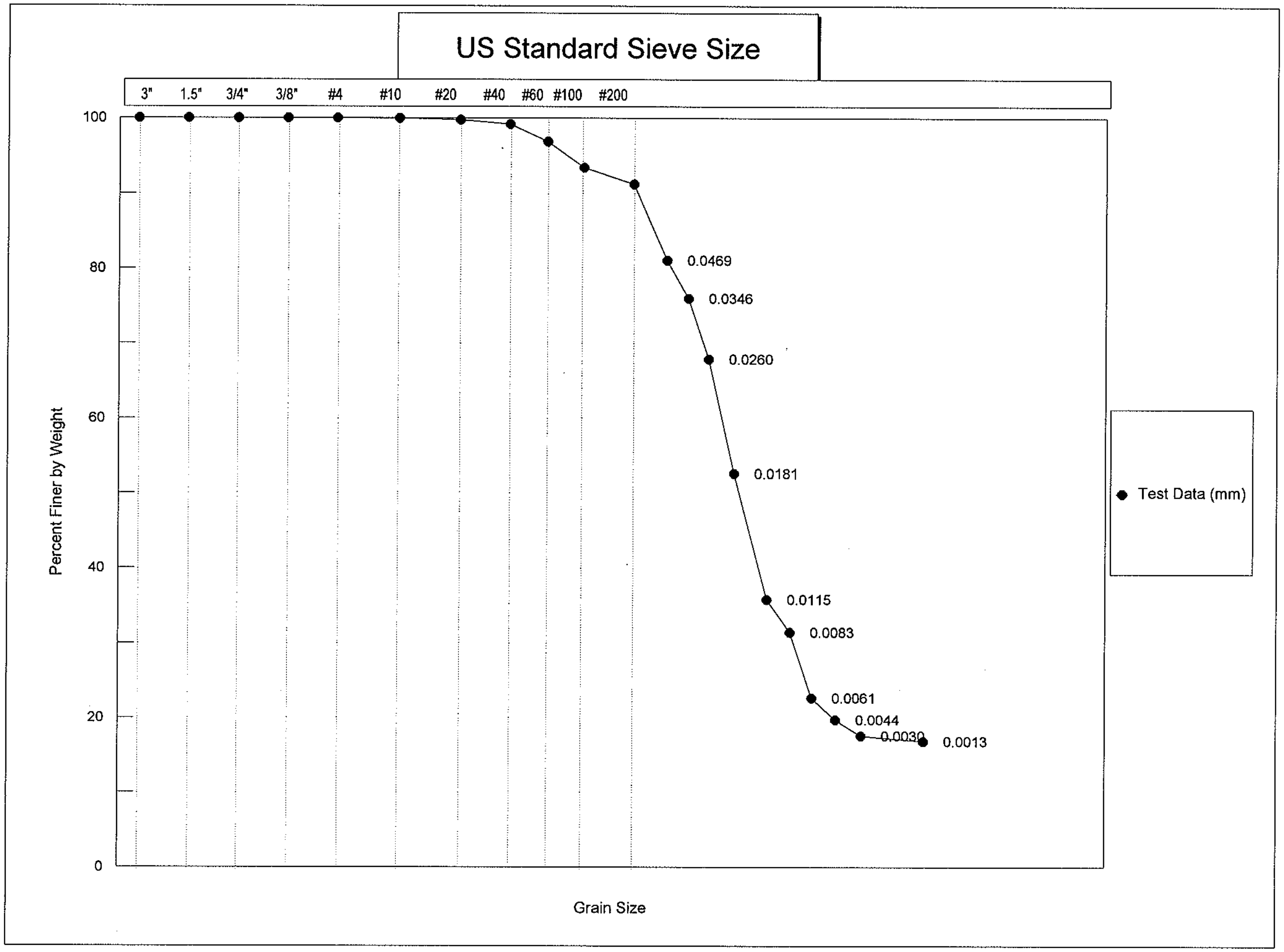
Client: LATA Kentucky
Boring No.: 001-306
Sample No.: 001306GRNSZ2
Job Number: 2855-01
Depth: 15-20'
Classification: **Classification Not Performed**



| COBBLES | GRAVEL |  | SAND |  |  | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
|  | COARSE | FINE | CRS | MEDIUM | FINE |  |  |

| COBBLES TO BOULDERS | PEBBLE GRAVEL |  |  |  | SAND |  |  | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
|  | COARSE | MED | FINE | GRAN | COARSE | MED | FINE |  |  |  |

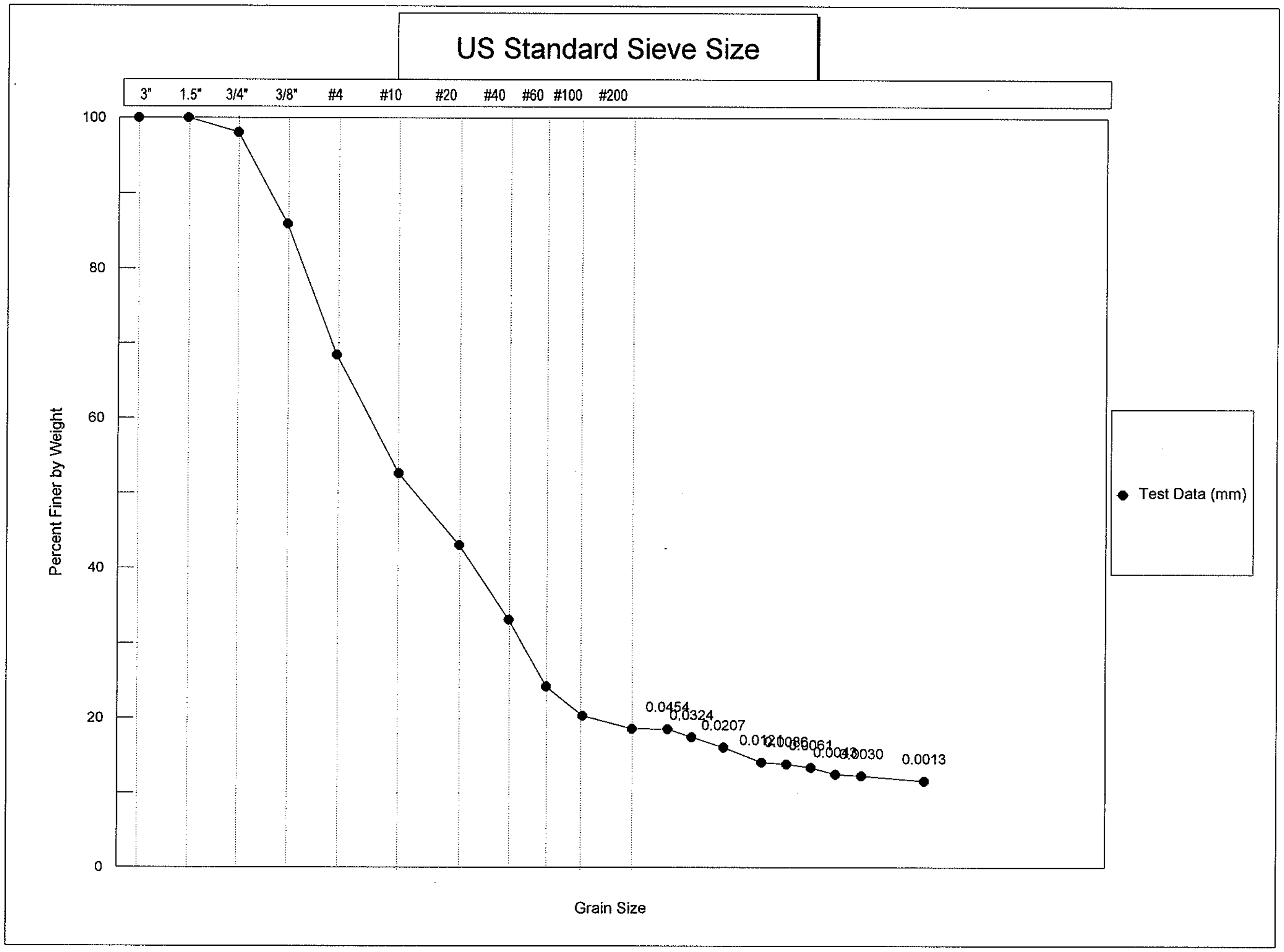
Client: LATA Kentucky
Boring No.: 001-306
Sample No.: 001306GRNSZ3
Job Number: 2855-01
Depth: 32.7-34.0'
Classification: **Classification Not Performed**



| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES<br>TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky
Job Number: 2855-01
Boring No.: 001-307
Depth: 12.5-14.6'
Sample No.: 001307GRNSZ1
Classification: **Classification Not Performed**

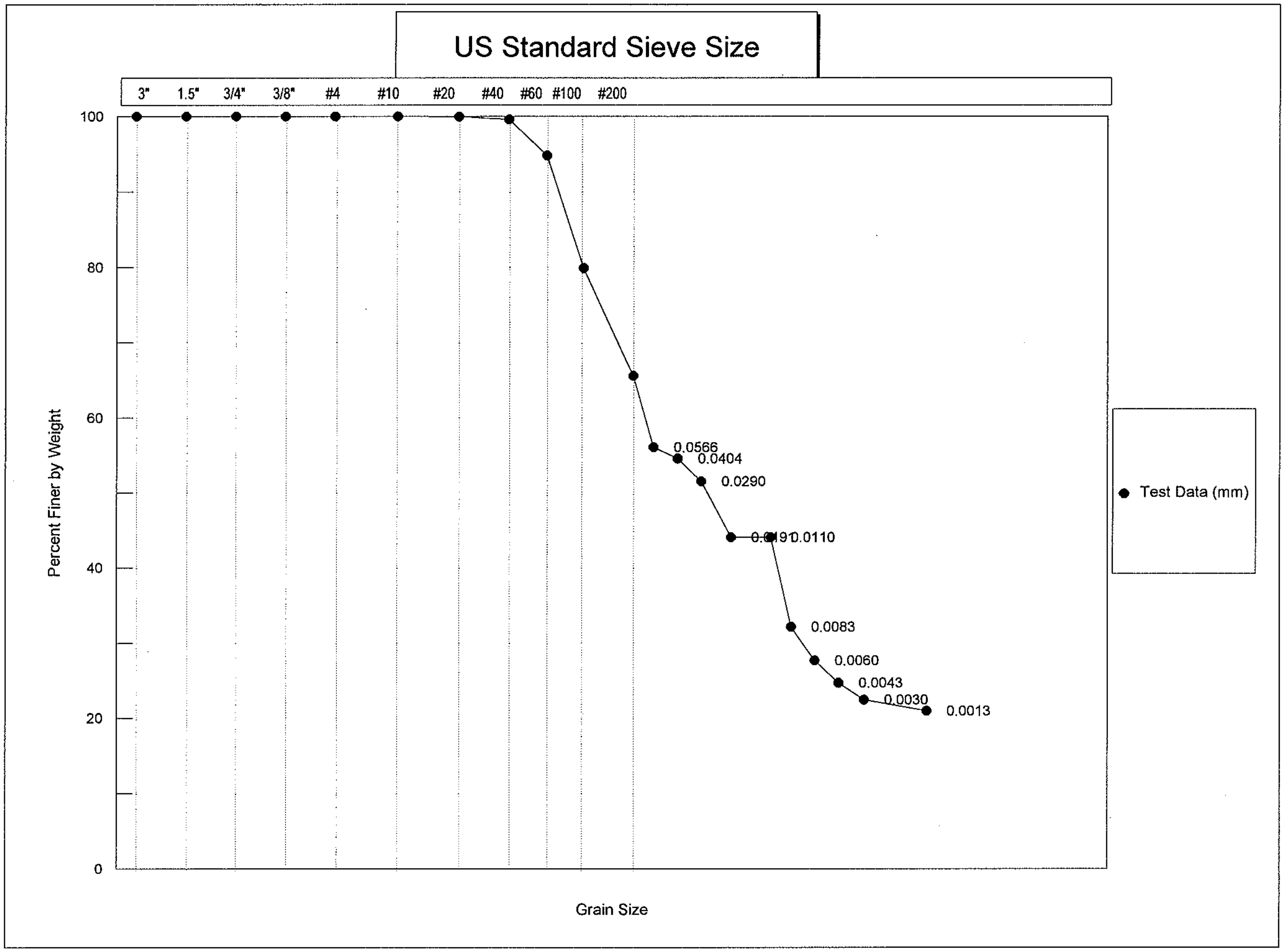


| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES<br>TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

| | | | | | |
|---|---|---|---|---|---|
| Client: | LATA Kentucky | Boring No.: | 001-307 | Sample No.: | 001307GRNSZ2 |
| Job Number: | 2855-01 | Depth: | 19.4-21.9' | | |

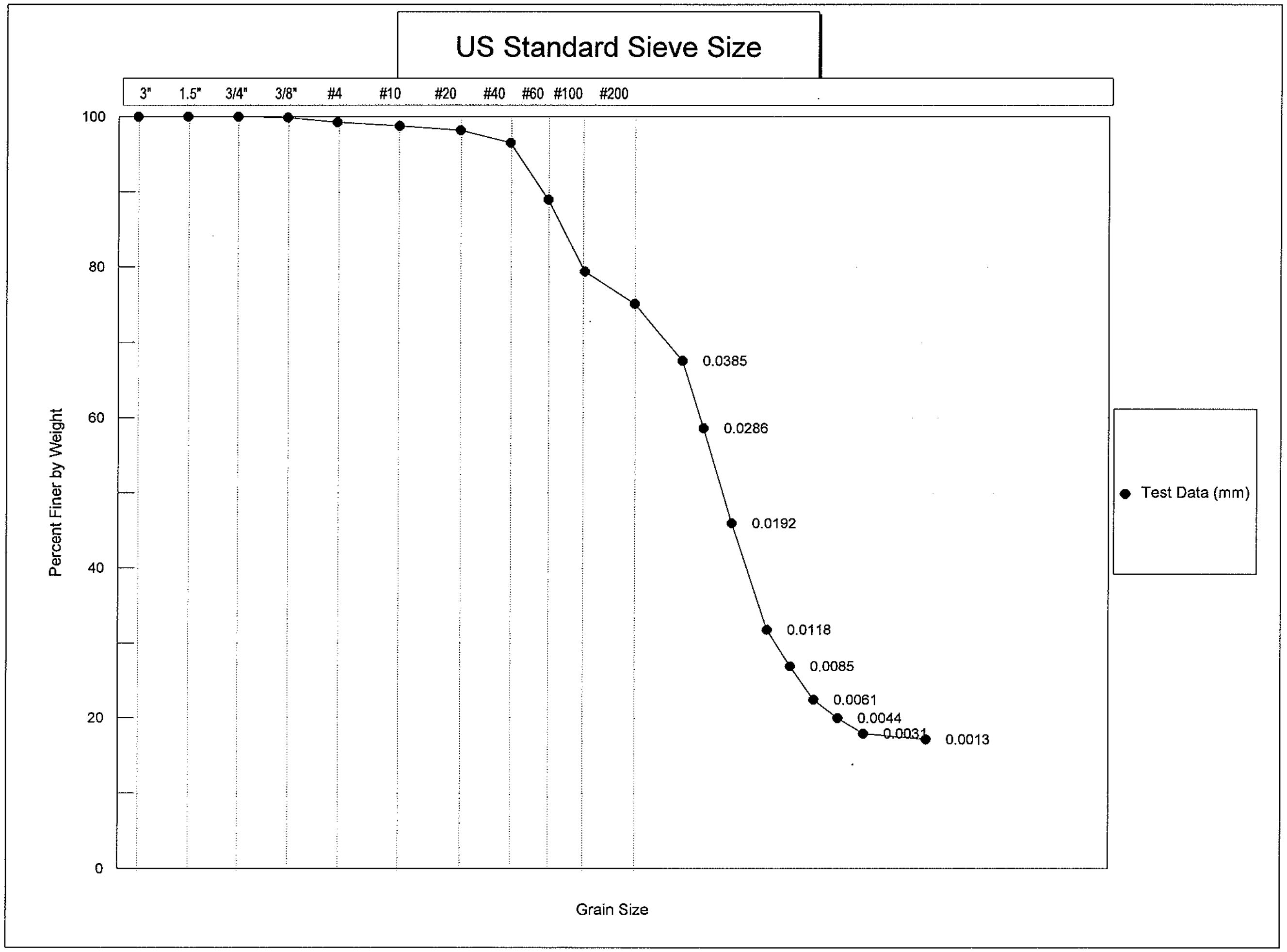
Classification: **Classification Not Performed**



| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

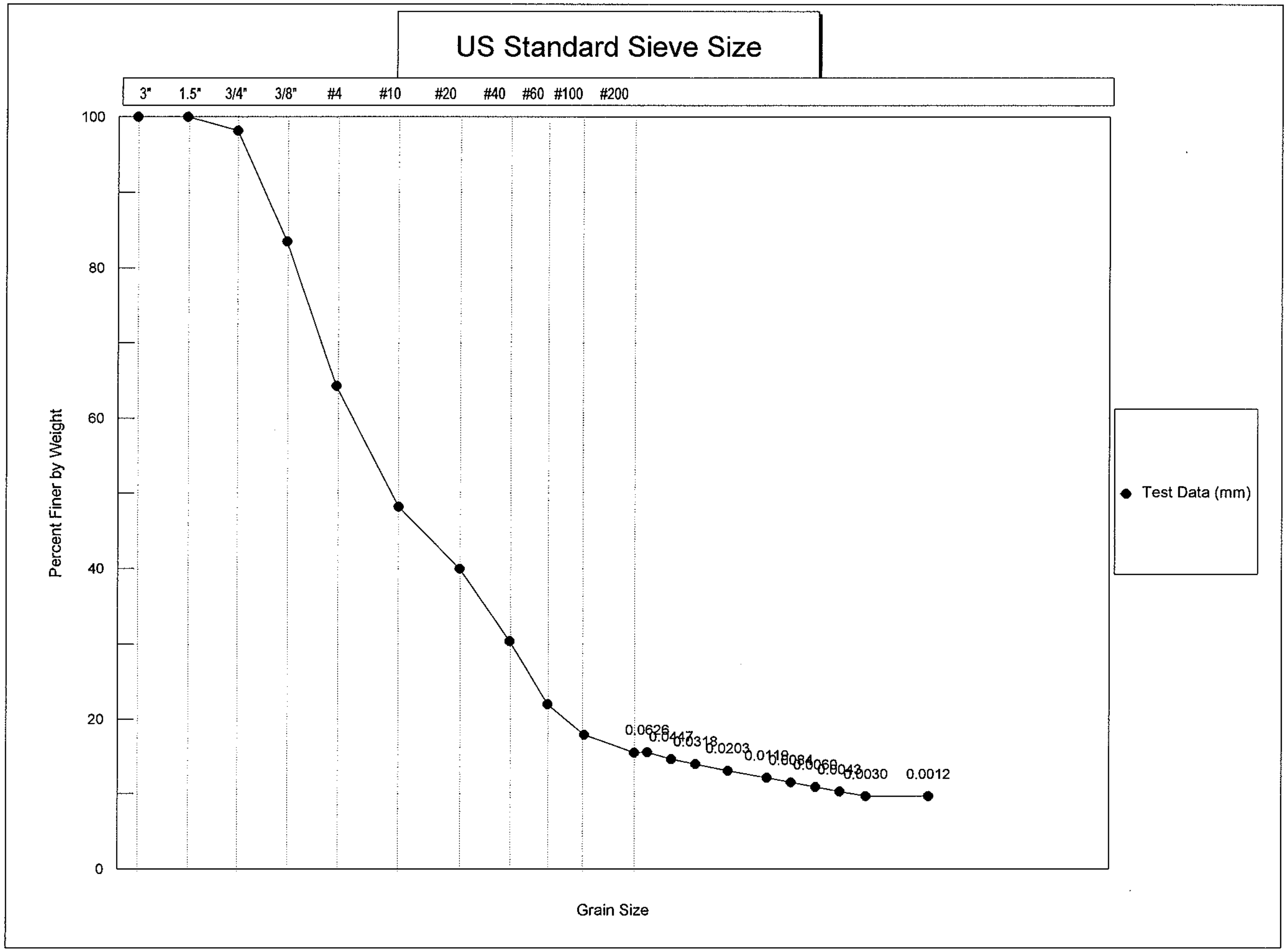
Client: LATA Kentucky
Boring No.: 001-307
Sample No.: 001307GRNSZ3
Job Number: 2855-01
Depth: 30.0-33.7'
Classification: **Classification Not Performed**



| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky
Boring No.: 001-316
Sample No.: 001316GRNSZ1
Job Number: 2855-01
Depth: 10-14'
Classification: **Classification Not Performed**



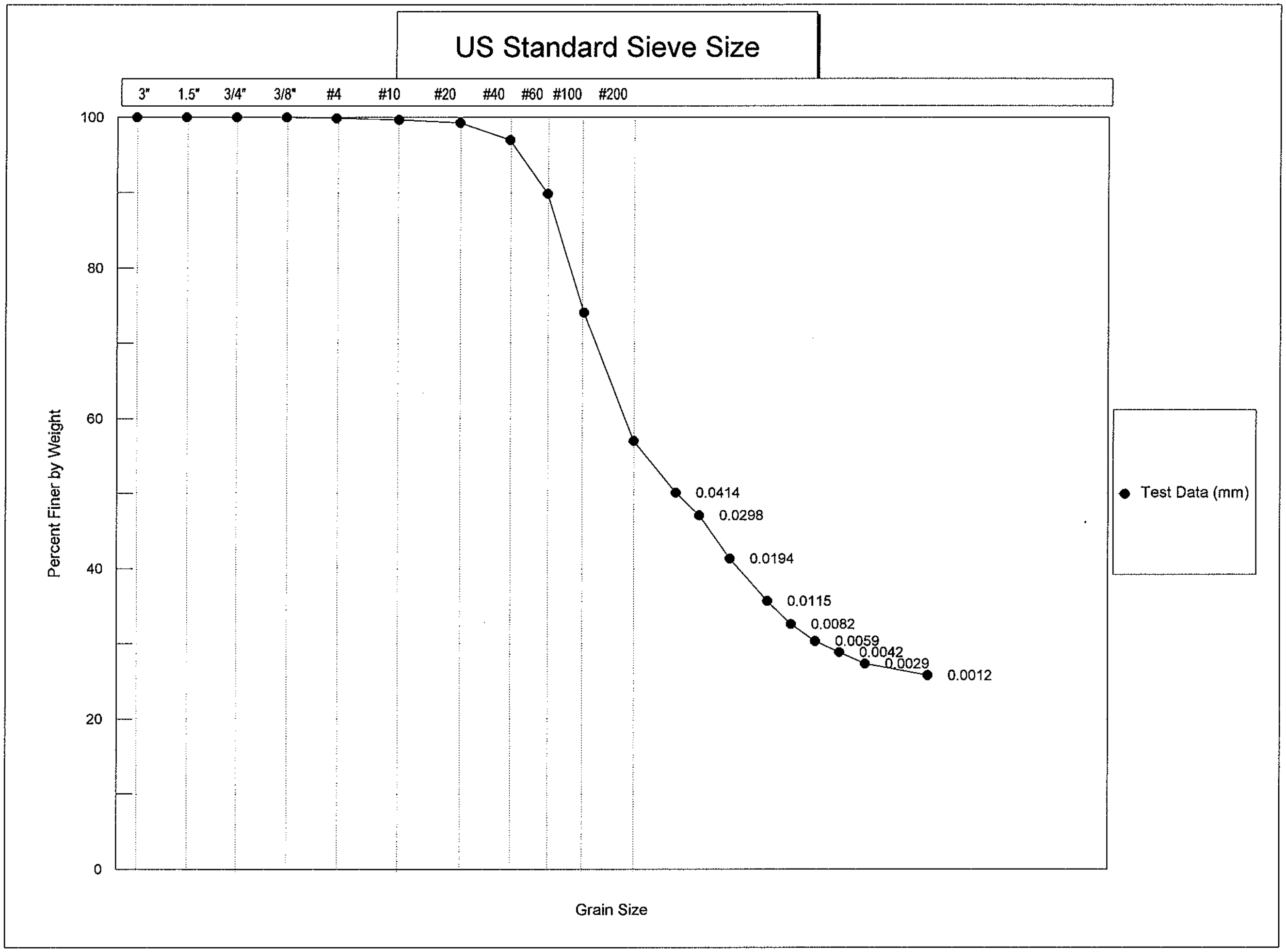
| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) |
|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | |

USCS

| COBBLES | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY |
|---|---|---|---|---|---|---|---|---|---|
| TO BOULDERS | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | |

WENTWORTH

Client: LATA Kentucky
Boring No.: 001-316
Sample No.: 001316GRNSZ2
Job Number: 2855-01
Depth: 20-23'
Classification: **Classification Not Performed**



| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY (mm) | USCS |
|---|---|---|---|---|---|---|---|
| | COARSE | FINE | CRS | MEDIUM | FINE | | |

| COBBLES<br>TO BOULDERS | PEBBLE GRAVEL | | | | SAND | | | SILT | CLAY | WENTWORTH |
|---|---|---|---|---|---|---|---|---|---|---|
| | COARSE | MED | FINE | GRAN | COARSE | MED | FINE | | | |

Client: LATA Kentucky
Job Number: 2855-01
Classification: **Classification Not Performed**

Boring No.: 001-316
Depth: 32-35'

Sample No.: 001316GRNS~~23~~Z3 Gkm 8/27/12

# APPENDIX D

# AIR DISPERSION ANALYSIS

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# D.1 AIR DISPERSION ANALYSIS

## D.1.1 INTRODUCTION

This appendix describes the air dispersion analysis of potential hazardous air pollutant (HAP) and/or toxic air pollutant (TAP) emissions from the implementation of the remedial action (RA) to be implemented at the Southwest Groundwater Plume source area at Paducah Gaseous Diffusion Plant (PGDP) at Solid Waste Management Unit (SWMU) 1. The property boundary concentrations for potential HAP and/or TAP emissions were estimated using BREEZE AERMOD Version 7.7.1. Report printouts and electronic model-ready input files are included in the attachment to this appendix.

### Air Dispersion Model Selection

The BREEZE AERMOD Version 7.7.1 program was used to conduct air dispersion modeling using the latest version (12345) of the American Meteorological Society Environmental Protection Agency Regulatory Model (AERMOD) to estimate maximum ground-level concentrations. AERMOD is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain.

### Modeling Receptor Grids

Ground-level concentrations were calculated within one Cartesian receptor grid and at receptors placed along the U.S. Department of Energy (DOE) property line (property line). The property line grid receptors were spaced at a maximum of approximately 50 meters apart. The Cartesian receptor grid extending out a minimum of 600 meters beyond the property line was spaced at 200-meter intervals in all directions. The Cartesian receptor grid was generated to ensure concentrations were decreasing away from the property line. All resultant maximum concentrations occur well within this distance.

### Terrain

AERMOD uses advanced terrain characterization to account for the effects of terrain features on plume dispersion and travel. AERMOD’s terrain pre-processor, AERMAP (latest version 11103), imports digital terrain data and computes a height scale for each receptor from National Elevation Dataset (NED) data files. A height scale is assigned to each individual receptor and is used by AERMOD to determine whether the plume will go over or around a hill.

The modeled receptor terrain elevations input into AERMAP are the highest elevations extracted from United States Geological Survey (USGS) 1:24,000 scale (7.5-minute series) NED data for the area surrounding PGDP. For each modeled receptor, the maximum possible elevation within a box centered on the receptor of concern and extending halfway to each adjacent modeled receptor was chosen. This is a conservative technique for estimating terrain elevations by ensuring that the highest terrain elevations are accounted for in the analysis. HAP/TAP emission concentrations were calculated at all receptors.

**Building Downwash Analysis**

The emission unit was evaluated in terms of its proximity to nearby structures. The purpose of this evaluation was to determine if stack discharge might become caught in the turbulent wakes of these structures leading to downwash of the plume. Wind blowing around a building creates zones of turbulence that are greater than if the building were absent. The current version of the AERMOD dispersion model treats building wake effects following the algorithms developed by Schulman and Scire.[1] This approach requires the use of wind direction-specific building dimensions for structures located within 5L of a stack, where L is the lesser of the height or projected width of a nearby structure. Stacks taller than the Good Engineering Practice (GEP) stack height, which is the structure height plus 1.5L are not subject to the effects of downwash in the AERMOD model. The emissions unit's stack height is greater than the GEP stack height. Therefore, there are no buildings which are considered nearby for the purposes of modeling and no further evaluation of cavity or wake effects is required.

## D.1.2 IDENTIFICATION OF AIR POLLUTANTS

The potential HAPs/TAPs that could be emitted by the RA (LDA soil mixing with steam and ZVI injection) have been identified based on soil characterization. The soil treatment area characterization is documented in *the 90% RDR and previous investigation reports for SWMU 1*. The potential HAPs/TAPs that could be emitted are trichloroethene (TCE), vinyl chloride, *trans*-1,2-dichloroethene (DCE), *cis*-1,2-DCE, and 1,1-DCE.

## D.1.3. ALLOWABLE OFF-SITE CONCENTRATIONS CALCULATIONS

The treated vapor/gases must comply with the contaminant concentration requirements of 401 *KAR* 63:020. This states that no owner or operator shall allow any affected facility to emit potentially hazardous matter or toxic substances in such quantities or duration as to be harmful to the health and welfare of humans, animals and plants.

### D.1.3.1 TCE and Vinyl Chloride Allowable Off-site Concentrations

The maximum allowable air concentration for TCE and Vinyl Chloride were estimated using the EPA Region 9 Regional Screening Levels (RSL), formerly referred to as Preliminary Remediation Goals (PRGs), which are available from the EPA's website at: http://www.epa.gov/region9/superfund//prg/index.html. The TCE and Vinyl Chloride values are based on the carcinogenic risk posed by lifetime[2] exposure to each HAP/TAP. The health effects of exposure to TCE and Vinyl Chloride are measured by a target risk of one in one million (1 x $10^{-6}$). The residential RSLs were used to develop an allowable off-site concentration limits.

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[1] Earth Tech, Inc., *Addendum to the ISC3 User's Guide, The PRIME Plume Rise and Building Downwash Model*, Concord, MA.

[2] Lifetime exposure is assumed to be 70 years by convention for this air toxics risk assessment. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm. In such assessments, if exposure duration is less than 70 years, inhalation exposure estimates and/or allowable off-site concentrations limits may be adjusted accordingly. http://epa.gov/ttn/fera/risk_atra_vol2.html. For simplicity in this report, allowable off-site concentration limits were not adjusted although exposure duration is expected to be less than 70 years for this project.

The ambient air allowable off-site concentrations for TCE and Vinyl Chloride are 0.43 µg/m$^3$ and 0.16 µg/m$^3$, respectively. The allowable off-site concentration for TCE was selected from the most recent EPA publication of RSLs, which occurred in November 2012.

The allowable off-site concentrations of TCE and vinyl chloride were also calculated based on the U.S. Environmental Protection Agency (EPA) Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment. These values were obtained from the US EPA website, located at the following address: http://www.epa.gov/ttn/atw/toxsource/table1.pdf.

Both TCE and vinyl chloride are possible carcinogens. The cancer chronic inhalation value for each is used in calculating the maximum allowable concentration. The value for TCE is 4.1E-06 per µg/m$^3$ and the value for vinyl chloride is 0.0000088 per µg/m$^3$. The allowable risk is assumed to be 1 x 10$^{-6}$. The maximum allowable concentration is calculated by the following formula:

Allowable Risk = Estimate of continuous inhalation exposure X Inhalation Unit Risk Estimate

Or

Estimate of continuous inhalation exposure = Allowable Risk/Inhalation Unit Risk Estimate

For TCE the calculation would be as follows:

TCE Allowable concentration = 1 x 10$^{-6}$/4.1E-06 per µg/m$^3$

TCE Allowable concentration = 0.24 µg/m$^3$

Using the same approach for vinyl chloride, the allowable concentration would be 0.11 µg/m$^3$.

### D.1.3.2 DCE Allowable Off-site Concentrations

The maximum allowable air concentrations for dichloroethene (DCE) were also estimated using the EPA RSL. The health effects of exposure to DCE are measured by a hazardous index, with a hazard index of 1 being an indication of the nearest off-site receptor having detrimental health effects from exposure to DCE. The residential RSL was used to develop an allowable off-site concentration limit.

DCE is present in three chemical forms, as follows: 1,1-DCE; *cis*-1,2-DCE, and *trans*-1.2-DCE. The ambient air allowable off-site concentration for each chemical form is 1,1-DCE—210 µg/m$^3$; *cis*-1,2-DCE—37 µg/m$^3$; and *trans*-1,2-DCE—63 µg/m$^3$. The allowable off-site concentrations for 1,1-DCE and *trans*-1,2-DCE were selected from the most recent EPA publication of RSLs, which occurred in November 2012. The allowable off-site concentration value for *cis*-1,2-DCE was selected from the list of PRGs since EPA has not published a revised value for that chemical form since October 2004.

All of the allowable off-site concentrations for TCE, Vinyl Chloride and DCE are shown in Table D.1.

**Table D.1. Allowable Off-site Concentration Limits**

| Pollutant | Allowable Off-site Concentration (µg/m$^3$ ) | Reference Source |
|---|---|---|
| TCE | 0.24/0.43* | EAP Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment/ Regional Screening Levels, last updated November 2012 |
| Vinyl chloride | 0.11/0.16* | EAP Air Toxics Risk Assessment Reference Library, Volume 2, Facility Specific Assessment/ Regional Screening Levels, last updated November 2012 |
| 1,1-DCE | 210 | Regional Screening Levels, last updated November 2012 |
| *cis*-1,2-DCE | 37 | Preliminary Remediation Goals, last updated October 2004 |
| *trans*-1,2-DCE | 63 | Regional Screening Levels, last updated November 2012 |

*The first value is a result based on the EAP Air Toxics Risk Assessment Reference Library and the second value is based on Region 9 Screening Levels.

## D.1.4 ESTIMATED EMISSION RATES

### D.1.4.1 Emissions

During operation of the project, hazardous constituents in the subsurface will be volatilized underground and recovered by an off-gas extraction and vapor conditioning system. The system will capture the soil vapors, which will be treated and released through a stack. The current design uses three (3) vapor-phase granular activated carbon (VGAC) units to remove hazardous constituents from the off-gas prior to discharge to the atmosphere. The current design criteria for the treatment system is such that each VGAC will have a removal efficiency of a minimum of 90%, or 99.9% for 3 VGACs, for HAP/TAP.

In order to estimate the maximum off-site concentration the exhaust was assumed to contain the maximum concentration of each HAP. The following preliminary design parameters for the stack were used in the model to estimate the dispersion of the hazardous constituents:

- 6-inch diameter
- 15-ft high
- 600 to 1,500 scfm flow rate
- 90°F exhaust gas temperature
- The stack will be equipped with a raincap

The vertical component of the stack exit velocity is required to be used in the air dispersion modeling analysis. Because the proposed stack will be outfitted with a raincap, the modeled stack exit velocity was set to 0.001 meters per second.

The maximum emission rate in kilograms per day were estimated based on the following assumptions:

- The average mass concentration for each individual HAP/TAP for each boring, representing a worst-case scenario based on Remedial Design Support Investigation (RDSI) sampling results. For example, it was assumed that the average TCE concentration in boring 001-310 of 133,034 µg/kg was applied through the entire volume of each Large Diameter Auger (LDA) boring (representing approximately 111.7 cubic yards per boring) and the soil density was assumed to be 1.62 tons/yd$^3$. Based on these assumptions, a calculated TCE mass of approximately 21.8 kg per LDA boring was estimated.

- A boring installation rate of four (4) borings per 10 hour workday.

- Air control measures utilizing three (3) VGAC units result in HAP/TAP concentration reductions of at least 99.9% prior to atmospheric discharge.

- The estimated daily emission rates were converted to a gram-per-second emission rate using 24 hour averaging period.

The maximum emission rates during operation are listed in Table D.2 in both kilograms per day (kg/day) and grams per second (g/s).

**Table D.2. Estimated Emission Rates**

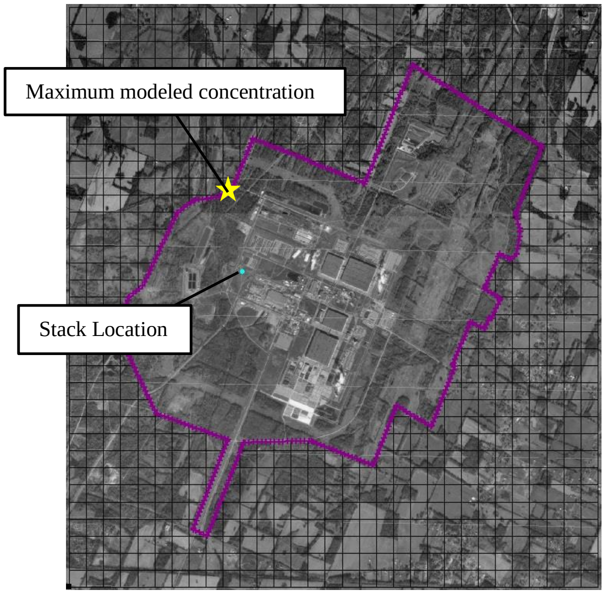
| **Pollutant** | **Stack Design Concentration** | | |
|---|---|---|---|
| | Uncontrolled | Uncontrolled | Controlled |
| | kg/day | g/s | g/s |
| TCE | 87 | 1.0 | 1.0x10$^{-3}$ |
| Vinyl chloride | 3.3x10$^{-3}$ | 3.8x10$^{-5}$ | 3.8x10$^{-8}$ |
| 1,1-DCE | 2.0x10$^{-3}$ | 2.3x10$^{-5}$ | 2.3x10$^{-8}$ |
| *cis*-1,2-DCE | 0.8 | 8.7x10$^{-3}$ | 8.7x10$^{-6}$ |
| *trans*-1,2-DCE | 6.6x10$^{-4}$ | 7.6x10$^{-6}$ | 7.6x10$^{-9}$ |

### D.1.4.3 Maximum Off-site Concentrations

The property boundary ambient concentration for each HAP/TAP was estimated using the air dispersion model BREEZE AERMOD Version 7.7.1.

Surface meteorology data from station number 3816 (Paducah, KY) and the nearest available upper air meteorology data from station 00013897 (Nashville, TN) were used. Dispersion analysis was performed using meteorological data from these stations for calendar years 2008, 2009, 2010, 2011 and 2012 (January 1, 2008 through December 31, 2012). The AERMOD-ready meteorological files were purchased from Trinity Consultants, Inc.

The air dispersion modeling analysis was performed assuming an emission rate of one gram per second. The resulting maximum modeled concentration, averaged over the entire year, was then multiplied by the aforementioned pollutant-specific controlled emission rate to estimate the off-site concentration for each pollutant. The results of the air dispersion modeling analysis suggest that the maximum annual average concentration occurs at a receptor (338132.20m, 4110280.70m) along the property boundary northwest of the proposed stack location, as illustrated below:



The estimated maximum annual average concentration for each pollutant is shown in Table D.3.

**Table D.3. Estimated Off-site Concentrations**

| Pollutant | Off-Site Concentration Limit | Annual Average Maximum Off-site Concentration |
|---|---|---|
| | µg/m$^3$ | µg/m$^3$ |
| TCE | 0.24/0.43* | $6.3\text{x}10^{-3}$ |
| Vinyl chloride | 0.11/0.16* | $2.4\text{x}10^{-7}$ |
| 1,1-DCE | 210 | $1.4\text{x}10^{-7}$ |
| *cis*-1,2-DCE | 37 | $5.5\text{x}10^{-5}$ |
| *trans*-1,2-DCE | 63 | $4.8\text{x}10^{-8}$ |

*The first value is a result based on the EAP Air Toxics Risk Assessment Reference Library and the second value is based on Region 9 Screening Levels.

The results of this air dispersion modeling analysis show the estimated maximum annual average concentration for each pollutant will be below the corresponding maximum allowable off-site concentration of respective pollutants. Additionally, the allowable off-site concentration limits for pollutants were developed using a lifetime (i.e., 70-year exposure period) per EPA's RSL User's Guide.[3] The duration of potential exposure associated with the operation of the VGAC will be less than 70 years. Therefore, emissions associated with this project are not expected to be harmful to the health and welfare of humans, animals, or plants.

### D.1.4.4 Sensitivity to Stack Concentration

The sensitivity of property boundary concentrations as a function of pollutant concentrations in the exhaust stream was analyzed. The maximum stack concentrations that resulted in the property boundary concentrations at the allowable limits were estimated using the air dispersion software. The exhaust flow

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[3] http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm

rate was conservatively assumed to be 600 scfm, the minimum flow rate from the VGAC units. To add an additional measure of conservatism, a factor of safety of 1.5 was applied to the Maximum Exhaust Pollutant Concentration. Table D.4 lists the maximum exhaust concentrations.

**Table D.4. Maximum Exhaust Pollutant Concentrations that Result in Property Boundary Concentrations at the Off-site Limit**

| **Pollutant** | **Off-site Limit** | **Maximum Exhaust Pollutant Concentration** | **Maximum Exhaust Pollutant Concentration (with Safety Factor)** |
|---|---|---|---|
| | μg/m$^3$ | ppmv | ppmv |
| TCE | 0.24/0.43* | 34 | 23 |
| Vinyl chloride | 0.11/0.16* | 72 | 48 |
| 1,1-DCE | 210 | 47 | 31 |
| *cis*-1,2-DCE | 37 | 47 | 31 |
| *trans*-1,2-DCE | 63 | 47 | 31 |

*The first value is a result based on the EAP Air Toxics Risk Assessment Reference Library and the second value is based on Region 9 Screening Levels.

Based on this analysis, it is concluded that the maximum exhaust concentrations described above may result in an exceedance of limits at the property boundary. The maximum exhaust pollutant concentrations, with the applied safety factor, represent the proposed operational limits or concentrations that may be utilized to trigger a work stoppage for evaluation of and correction to the applied off-gas treatment measures.

# ATTACHMENT

# AIR DISPERSION ANALYSIS REPORTS AND MODEL READY INPUT FILES

## CD—AERMOD INPUT AND OUTPUT FILES (see back cover).