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RESULTS OF DNAPL CHARACTERIZATION AND REMEDIATION STUDY, Revision 1

Sauget Area 1
Sauget and Cahokia, Illinois

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EXECUTIVE SUMMARY

Background Information

Environmental investigations were conducted at Sauget Area 1 in 1999-2000, as required by an Administrative Order of Consent (AOC) dated January 21, 1999. Investigation results and evaluation of remedial alternatives were presented in the Engineering Evaluation/Cost Analysis and Remedial Investigation/Feasibility Study (EE/CA and RI/FS), which was submitted to USEPA in March 2001 and revised in June 2001.

In a letter dated January 9, 2003, USEPA required that a DNAPL characterization and remediation study be conducted at Sauget Area 1. The January 9, 2003 letter stated that the DNAPL study should focus on:

- *"The characterization and distribution of DNAPL within the middle and deep hydrogeologic units, the assessment of DNAPL migration under current and future site conditions, and the risk of uncontrolled DNAPL mobilization.*

- *The extent and properties of DNAPL (e.g. density, viscosity, and interfacial tension); as well as the timing of the DNAPL release; topography, property, and heterogeneity of geologic units on which the DNAPL may accumulate; the existence of ongoing DNAPL releases; and transport characteristics of the bedrock.*

- *The evaluation of the DNAPL remedial options and the evaluation of the benefits and costs associated with source removal technologies (thermal technologies such as steam injection and chemically-enhanced extraction such as the use of surfactants or co-solvents)."*

The Sauget Area 1 DNAPL characterization and remediation study was conducted during the period May to December 2004, in accordance with a Work Plan dated April 1, 2004. To address USEPA comments, additional work was conducted during the period September to December 2005, in accordance with a supplemental work plan dated August 2, 2005.

Site investigation activities included the following: i) NAPL surveys and NAPL recovery tests in May 2004, October 2004, and September 2005; ii) a 3-D seismic reflection survey to map the topography of the bedrock surface; iii) soil sampling and piezometer installation at 19 locations; iv) bench-scale DNAPL treatability tests and review of DNAPL source depletion alternatives; and v) additional investigations at and near well BR-I.

Key Findings of DNAPL Characterization Study

Results of NAPL Surveys and Recovery Tests: During a May 2004 NAPL survey of 57 previously existing wells and piezometers, an accumulation of LNAPL was found at one shallow well, EE-11, and some evidence of DNAPL was observed at two bedrock wells, BR-G and BR-I.

A sample of LNAPL was recovered from EE-11 and submitted for laboratory testing. No DNAPL was recovered during the recovery tests conducted at BR-G and BR-I.

The October 2004 NAPL survey of 18 newly installed piezometers and four previously existing wells (EE-11, BR-G, BR-H, and BR-I) indicated that some evidence of LNAPL was observed at EE-11, and some evidence of DNAPL was observed at BR-G and A1-8. No LNAPL was recovered from EE-11, and no DNAPL was recovered from BR-G. An accumulation of pooled DNAPL was found at bedrock well BR-I, and a sample of DNAPL recovered from BR-I was submitted for laboratory testing.

During the September 2005 NAPL survey, some evidence of LNAPL was observed at EE-11, and some evidence of DNAPL was observed at BR-G. An accumulation of pooled DNAPL was present at bedrock well BR-I. No LNAPL was recovered from EE-11, and no DNAPL was recovered from BR-G. DNAPL was recovered from BR-I on three separate occasions in September and October 2005, and DNAPL was also found in a new piezometer, A1-19, which was installed 15 feet from BR-I in October 2005.

The surveys showed that pooled NAPL is not widespread throughout Sauget Area 1. Pooled DNAPL at BR-I can be recovered by pumping, albeit at a low rate, and it is likely that some pooled DNAPL can be recovered at A1-19. Pumping of pooled DNAPL is not feasible at BR-G or A1-8, and further recovery of LNAPL from EE-11 is not feasible.

The most likely explanation for the presence of DNAPL in BR-I is that the open borehole at BR-I is acting as a sump for accumulation of DNAPL that enters from the overlying alluvial aquifer and/or the upper few feet of weathered bedrock. It is possible that some DNAPL could also be entering the open borehole by leakage through the seal between the PVC well casing and the bedrock that the casing is seated in.

Bedrock Topography and Bedrock Transport Characteristics: An interpreted topographic map of the bedrock surface underlying the alluvial aquifer was generated based on i) results of the 3-D seismic reflection survey; ii) bedrock depth information from three previously existing wells; and iii) bedrock depth information from the first ten bedrock piezometers installed in September-October 2004. An interpreted map of the bedrock surface (see Figure 6) was used to locate topographic lows in the bedrock surface where pooled DNAPL could potentially accumulate. Due to noisy and badly scattered seismic reflection data at Site G, the predicted bedrock surface elevations at Site G were considered less reliable overall than the predicted elevations at Sites H and I. Three cross sections (Figures 7, 8, and 9) were prepared using measured bedrock depths from the borings in order to illustrate the stratigraphy underlying Sauget Area 1.

An evaluation of bedrock transport characteristics (see Appendix J) suggests that the upper few feet of the bedrock, which is weathered and fractured, is more likely to be a pathway for groundwater flow than the underlying competent bedrock.

Soil Sampling and Testing Results: Soil sampling and piezometer installation were conducted at a total of 19 locations. As called for in the Work Plan, the drill sites included: i) locations

within the boundaries of the fill areas for Sites G, H, I, and L; ii) locations for investigation of possible topographic lows, based on results of the seismic reflection survey; and iii) locations outside the boundaries of the fill areas. A total of seven of the 19 piezometers were installed at predicted topographic lows in the bedrock surface, based on results of the seismic reflection survey.

A variety of data was collected to evaluate the possible extent of NAPL within the fill materials and aquifer matrix. The data collection methods included: i) observations and testing of soil cores in the field; ii) laboratory testing of soil samples for VOCs, SVOCs, and TOC; and iii) laboratory testing of undisturbed cores for pore fluid saturations, NAPL mobility, and physical properties. Based on visual observations of NAPL presence in soil cores or a positive indicator from a Sudan IV vial test kit, there was evidence for the possible presence of NAPL in one or more sampling intervals from 13 of the 19 soil borings (see Table 6).

Determination of the Volume of Fill Materials and Aquifer Matrix Containing DNAPL: The method that was found to be most suitable for estimating the volume of fill materials and aquifer matrix containing DNAPL (the "DNAPL Volume") was to use a combination of field indicators of NAPL presence in the cores and laboratory data for total VOCs and total SVOCs.

The total estimated DNAPL Volume was 1,700,000 yd^3 within a total area of approximately 15 acres. Using an alternate approach for the volume calculation, the estimated total DNAPL volume was approximately 1,200,000 yd^3.

DNAPL Treatabilty Tests and Review of Source Depletion Alternatives

Three source depletion technologies (surfactant-enhanced solubilization, thermal treatment, and chemical oxidation) were evaluated as part of the Sauget Area 1 DNAPL characterization and remediation study. Treatability tests were developed and conducted as part of this evaluation. The evaluation of each of these technologies was presented in terms of performance, cost, and engineering considerations. In addition to these evaluations, a comprehensive dissolution test was conducted at the bench-scale to provide data on mass flux and time required to deplete the source.

Results of the surfactant treatability test that was conducted using the DNAPL sample from well BR-I indicated that no consistent enhancement in solubilization was noted for any of the compounds of interest. This result suggests that surfactant-enhanced solubilization is not an appropriate technology selection for Sauget Area 1. It is expected that chemical oxidation would not be an effective source depletion technology at Sauget Area 1. This finding is based on i) results of a chemical oxidation treatability test conducted at the nearby Solutia Inc. W.G. Krummrich Plant, which has a DNAPL generally similar to that at Sauget Area 1; and ii) concern that continued treatment may be necessary to prevent rebound of COC concentrations after treatment.

Thermal treatment using a combination of Dynamic Underground Stripping and Hydrous Pyrolosis Oxidation (DUS/HPO), which does not require dewatering of the saturated zone, could

result in significant (but not complete) DNAPL recovery at Sauget Area 1. There would be significant technical challenges to applying this technology. Use of the DUS/HPO technology would require generation of large volumes of steam to heat the aquifer, a series of extraction wells for recovery of volatilized constituents, and a series of wells for hydraulic control and for recovery of constituent mass, as free phase DNAPL and in the aqueous phase. In addition, there are three significant site-specific technical challenges to applying this technology at Sauget Area 1:

1) The size of the Sauget Area 1 application area would be large;

2) Using the DUS/HPO technology, a significant mass of contaminants could be mobilized as free product. At Sauget Area 1, there is a single ~100 thick saturated zone. Mobilizing large volumes of DNAPL through this thick treatment zone could be very difficult to control without risk of lateral DNAPL migration.

3) The transmissivities of the middle and deep water-bearing units at Sauget Area 1 are relatively high, potentially increasing the cost and difficulty of the required hydraulic control component of the thermal treatment system.

In spite of these issues, thermal treatment will be carried forward in the remedial alternatives evaluation because this technology has potential for greater DNAPL mass removal compared to surfactant-enhanced solubilization or chemical oxidation.

1.0 INTRODUCTION

Engineering Evaluation/Cost Analysis and Remedial Investigation/Feasibility Study: On January 21, 1999, an Administrative Order by Consent (AOC) was entered into regarding environmental actions to be completed at Sauget Area 1 in Sauget and Cahokia, Illinois. Sauget Area 1 includes five fill areas near Dead Creek known as Sites G, H, I, L, and N. Sauget Area 1 also includes five segments of Dead Creek identified as Creek Segments B through F and one former borrow pit (Site M). The locations of these areas are shown on Figure 1.

One of the requirements of the AOC for Sauget Area 1 was to prepare and implement an Engineering Evaluation/Cost Analysis (EE/CA) to address soil, sediment, leachate, surface water, and air. The AOC also required a focused Remedial Investigation/Feasibility Study (RI/FS) to address groundwater. A Support Sampling Plan was approved by USEPA on September 9, 1999 for implementation of the actions required by the AOC and to provide the data needed for completion of both the EE/CA and the RI/FS.

From September 1999 to April 2000, sampling and testing activities were conducted to investigate impacts to environmental media resulting from disposal/deposition of materials in Sauget Area 1 and to assess the associated risk to human health and the environment. A draft

EE/CA and RI/FS report was submitted to USEPA on March 9, 2001. In response to Agency comments, a revised EE/CA and RI/FS report was submitted on June 8, 2001.

The EE/CA and RI/FS report (Roux Associates, June 2001) included the following: extensive background information about Sauget Area 1; site investigation procedures and results; a description of the source, nature and extent of contamination; and evaluation of remedial alternatives for the fill areas and for affected groundwater. The report briefly discussed draft versions of a baseline human health risk assessment and baseline ecological risk assessment that were submitted to USEPA in January 2001.

Removal of Sediments and Underlying Soils from Dead Creek: On May 31, 2000, USEPA issued a Unilateral Administrative Order (UAO) requiring the removal of sediments from Creek Segments B, C, D, and E, and from Site M. The UAO was amended in 2001 to include a portion of Creek Segment F and a basin area located at a lift station. The sediment removal action and post-removal sampling were conducted as required by the UAO. The removed sediments were placed in an on-site containment cell located on Judith Lane. Currently the on-site containment cell holds approximately 46,000 cubic yards of excavated sediments.

DNAPL Investigation: In a letter dated January 9, 2003, USEPA required a separate DNAPL characterization and remediation study for Sauget Area 1. USEPA had determined that this additional work was necessary to accomplish the objectives of the EE/CA and RI/FS report. The January 9, 2003 letter, which included an attachment with USEPA's comments and recommendations regarding the DNAPL study, stated that the DNAPL study should focus on:

- *"The characterization and distribution of DNAPL within the middle and deep hydrogeologic units, the assessment of DNAPL migration under current and future site conditions, and the risk of uncontrolled DNAPL mobilization.*

- *The extent and properties of DNAPL (e.g. density, viscosity, and interfacial tension); as well as the timing of the DNAPL release; topography, property, and heterogeneity of geologic units on which the DNAPL may accumulate; the existence of ongoing DNAPL releases; and transport characteristics of the bedrock.*

- *The evaluation of the DNAPL remedial options and the evaluation of the benefits and costs associated with source removal technologies (thermal technologies such as steam injection and chemically-enhanced extraction such as the use of surfactants or co-solvents)."*

A draft Work Plan for the DNAPL study was submitted to USEPA on February 28, 2003. Revised versions of the DNAPL Work Plan were submitted on May 13, 2003, and August 14, 2003, in response to comments from USEPA. Additional comments were received in October and November 2003. USEPA conditionally approved the DNAPL Work Plan at a meeting on December 16, 2003. The final DNAPL Work Plan was submitted on April 19, 2004.

The Work Plan focused on Sites G, H, I, and L, and included the following tasks:

- Task 1 – Project Startup, Review of Existing Data, and Contractor Scheduling.
- Task 2 – NAPL Survey and Recovery Tests at Existing Wells.
- Task 3 – Geophysical Survey to Map Topography of Bedrock Surface.
- Task 4 – Soil Sampling and Installation of Piezometers.
- Task 5 – NAPL Recovery Tests and Analysis of NAPL Samples.
- Task 6 – Bench-Scale Treatability Tests.
- Task 7 – Review of DNAPL Source Depletion Alternatives.
- Task 8 – Remedial Alternatives Evaluation.
- Task 9 – Project Report.

The Sauget Area 1 DNAPL study was conducted during the period May to December 2004, and a report was submitted on January 21, 2005. USEPA issued comments on the report on March 25, 2005, and the PRPs responded to those comments in a document submitted on May 27, 2005. After further discussions with USEPA, the PRPs submitted a supplemental work plan to USEPA on August 2, 2005, which the USEPA subsequently approved. The supplemental work plan included the following tasks:

- Task 1 – Coordination and Scheduling.
- Task 2 – NAPL Survey and NAPL Recovery Tests.
- Task 3 – Well Swabbing and Downhole Geophysics Survey at Well BR-I.
- Task 4 – Installation of One Additional Piezometer near BR-I
- Task 5 – Two Follow-up DNAPL Surveys of BR-I and the New Piezometer
- Task 6 – Plugging and Abandonment of BR-I *(optional task - not performed)*
- Task 7 – Revision of DNAPL Report

The additional DNAPL characterization activities were performed during the period September to December 2005.

Section 2.0 of this report provides site background information used to guide the data collection process during the DNAPL characterization study. Section 3.0 describes DNAPL characterization activities, and Section 4.0 outlines results of the DNAPL characterization study. Section 5.0 describes results of calculations and bench-scale treatability tests used to assess applicability and potential effectiveness of thermal, surfactant-based, and chemical oxidation technologies for addressing DNAPL impacts at Sauget Area 1.

2.0 SITE BACKGROUND INFORMATION

Objectives of DNAPL Study: The DNAPL Characterization and Remediation Study was focused on collecting the information needed for i) estimation of the volume of DNAPL-affected material; ii) assessment of the ability to remove DNAPL from the aquifer matrix by treatment; iii) estimation of the removal efficiencies of various treatment technologies; and iv) determination of the presence of pooled DNAPL. These data were used to determine if aggressive source treatment will make any meaningful difference in the time required to achieve ARARs and, if so, the cost of such treatment.

Evaluation of DNAPL Thickness Data Presented on Table 4-0c: Table 4-0c listed reported DNAPL thickness measurements in wells and piezometers at Sauget Area 1. All of the wells and piezometers on Table 4-0c were screened in the shallow and middle hydrogeologic units of the alluvial aquifer. Table 4-0c was prepared in 2001 by the U.S. Army Corps of Engineers based on their tabulation of field notes from a Sauget Area 1 well survey that was conducted by a Solutia contractor on September 28-30, 1999.

In response to agency comments on the draft Sauget Area 1 DNAPL Work Plan, the data on Table 4-0c were incorporated into the Work Plan, and the scope of the Work Plan was refined based on the inferred presence of widespread pooled DNAPL at Sauget Area 1.

A technical memorandum with an evaluation of the data listed on Table 4-0c was submitted to USEPA for review in conjunction with the "Summary Report with Proposed Locations for Soil Borings/Piezometers" dated August 13, 2004. On September 16, 2004, USEPA issued a letter that included comments on the memorandum. The memorandum has been revised to incorporate the USEPA comments and is included as Appendix A of this report. The key finding of the revised technical memorandum is as follows:

> *"Based on review of all available information, it is our opinion that the only reliable data in the September 1999 field notes regarding NAPL occurrence is the visual observation of free product (now known to be LNAPL) at well EE-11. We believe that pooled DNAPL was <u>not</u> widely present during September 1999 within the wells and piezometers screened in the shallow and middle hydrogeologic units of the alluvial aquifer."*

Evaluation of Groundwater Analytical Data: Groundwater analytical data can be a useful indicator of possible DNAPL occurrence. In the Summary Report dated August 13, 2004, GSI reviewed groundwater analytical results from 1999-2000 that were presented in the EE/CA and RI/FS report (Roux Associates, 2001) to identify potential locations for DNAPL occurrence at and near Sites G, H, I, and L.

Based on data in the EE/CA and RI/FS report, chlorobenzene and 1,4-dichlorobenzene are the site constituents that have the highest reported concentrations in groundwater at the downgradient boundary of the Site I fill area. The concentrations of chlorobenzene and 1,4-dichlorobenzene in groundwater exceeded 1% of the respective pure phase solubility at several

locations beneath the Site G, H, and I fill areas, and to the west of the Site I fill area (see Figures B-1 through B-4 in Appendix B).

The presence of COCs at concentrations in excess of 1% of pure-phase solubility is an indicator for potential occurrence of residual and/or pooled DNAPL. Elevated concentrations of chlorobenzene and 1,4-dichlorobenzene in groundwater to the west of Site I are probably due to dissolution of residual DNAPL within the aquifer matrix underlying the Site I fill area.

Note that the data on Figures B-1 through B-4 were not used as the criteria for defining the extent of DNAPL in this report. Section 4.4 of this report discusses a more robust method for DNAPL delineation using data from the soil borings/piezometers that were drilled and installed during the DNAPL characterization study.

3.0 DESCRIPTION OF DNAPL CHARACTERIZATION ACTIVITIES

3.1 NAPL Surveys, NAPL Recovery Tests, and Downhole Geophysical Survey

NAPL surveys were conducted in May 2004, October 2004, and September 2005. The May 2004 survey included 57 previously existing wells and piezometers at Sauget Area 1. The October 2004 and September 2005 surveys included A1-1 through A-18 and four previously existing wells, BR-G, BR-H, BR-I, and EE-11. The October 2005 and December 2005 surveys included one new piezometer, A1-19, and well BR-I. NAPL recovery tests were conducted at locations where there was evidence of LNAPL or DNAPL.

NAPL Survey Procedures: Several techniques were used during the surveys to check for possible accumulations of LNAPL or DNAPL. An electronic interface probe was used to measure the depth to water and to check for the presence and thickness of LNAPL and DNAPL. A disposable clear bailer was lowered to the water level in each well to check for the possible presence of accumulated LNAPL. A visual check for pooled DNAPL was performed by lowering a weighted cotton string to the bottom of the well, then retrieving the string to inspect for evidence of staining. Finally a disposable clear bailer was lowered to the bottom of each well to check for the presence of pooled DNAPL. New string, bailer, and bailer cord were used for each well, and soiled string, bailers, and cord generated during the survey were placed in a designated container for management as investigation-derived waste.

NAPL Recovery Test Procedures: Based on results of the NAPL surveys, LNAPL recovery tests were performed at well EE-11 and DNAPL recovery tests were performed at wells BR-G and BR-I. The LNAPL recovery test performed in May 2004 at EE-11 was conducted using a peristaltic pump with downhole tubing, and the recovery test in October 2004 at EE-11 was performed using a clear bailer. The DNAPL recovery tests at BR-G and BR-I were performed using Waterra pumps, which are inertial lift pumps consisting of downhole tubing and a foot valve. DNAPL was also recovered at BR-I in October 2005 using the air-lift pumping method.

The recovery tests were conducted using alternating periods of pumping and resting. Each NAPL recovery test was terminated when at least one of the following conditions was met: i) the recovery test had been on-going for at least 8 hours; ii) a total of at least 100 gallons of fluids had been recovered from a well; or iii) no measurable NAPL had been recovered from a well during at least two consecutive pumping and rest cycles following the initial pumping period. The volume of NAPL and volume of water recovered during each test were recorded in the field notes. Containers of NAPL were collected for laboratory analysis of physical and chemical properties and for possible use in bench-scale treatability testing. Field measurements of NAPL density, viscosity, and temperature were conducted at each well where NAPL was recovered. Qualitative observations of NAPL wettability were made while pouring the NAPL into separate beakers containing glass beads, sand, and rock fragments.

Laboratory Testing of NAPL Samples: A sample of LNAPL was recovered from well EE-11 in May 2004, and a sample of DNAPL was recovered from well BR-I in October 2004. From each sample, one liter of NAPL and one liter of water were submitted for laboratory analysis of fluid properties at PTS Laboratories. These samples were tested using ASTM D445 and ASTM D1481, which include measurement of: i) dynamic viscosity and fluid density at three temperatures; ii) surface tension for each fluid; and iii) interfacial tension for oil/water, oil/air, and water/air. Vials of the LNAPL and DNAPL were submitted to Severn Trent Laboratories for laboratory analysis of VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin, and metals.

Additional containers of NAPL were submitted to SPL, Inc. for distillation testing by ASTM D86 and to Triton Analytics for a High Temperature Simulated Distillation (HTSD) test. The HTSD test is a GC technique that separates individual hydrocarbon components in the order of their boiling points, giving a percent mass yield as a function of boiling point. The HTSD test can be used to determine the carbon number distribution up to C120.

A groundwater sample collected during the recovery test at well BR-G in October 2004 was submitted to Severn Trent Laboratories for analysis of VOCs and SVOCs. This sample was submitted for laboratory testing because no DNAPL could be recovered at BR-G. Results of the NAPL surveys and NAPL recovery tests are summarized in Sections 4.1 and 4.2 of this report. Appendix C includes complete analytical results for the LNAPL sample from EE-11, the DNAPL sample from BR-I, and the groundwater sample from BR-G.

Downhole Geophysical Logging at BR-I: The supplemental DNAPL work scope submitted in August 2005 (GSI, 2005) called for a downhole geophysical survey at BR-I to obtain more information about the condition of BR-I and a better understanding of the origin of the DNAPL found in BR-I. Several days prior to the downhole survey, a local drilling contractor brushed the interior of the well casing and open borehole using wire brushes and then pumped the well using the air-lift method. Clean heated water was added to the well several time during the later stages of air-lift pumping to help flush out the lower portion of the well, with a total of 75 gallons of clean water added. The logging contractor performed the following surveys in BR-I on October 5, 2005: optical televiewer, acoustic televiewer, three-arm caliper, fluid temperature/conductivity, and video.

3.2 Seismic Reflection Survey and Selection of Drilling Locations

The DNAPL Work Plan dated April 1, 2004 called for soil sampling and piezometer installation at up to 18 locations at and near Sites G, H, I, and L. The Work Plan called for the following: i) up to twelve soil sampling and piezometer locations within the boundaries of the fill areas; ii) three locations for investigation of possible topographic lows, based on results of the seismic reflection survey; and iii) three locations outside the boundaries of the fill areas, to evaluate the potential extent of DNAPL outside fill areas.

The initial site-wide NAPL survey of existing wells and piezometers was completed in May 2004. Following discussions with USEPA in early June 2004, a decision was made to defer the drilling program until the seismic reflection data could be acquired and interpreted. In July 2004 USEPA requested that a data report be prepared with proposed drilling locations and the rationale for the proposed locations.

Seismic Data Acquisition: As called for in the DNAPL Work Plan, a three-dimensional seismic reflection survey was conducted to map the topography of the bedrock surface and to identify topographic lows where pooled DNAPL could potentially accumulate. The survey covered an L-shaped area approximately 44 acres in size encompassing Sauget Area 1 Sites G, H, I, and L. The survey was performed under the direction of Resolution Resources, Inc. of Warrenton, Virginia. Bird Seismic Services of Globe, Arizona, collected the 3-D seismic data.

Prior to acquisition of the seismic data, a land survey was conducted using GPS equipment to establish the geophone positions for the seismic survey grid. The seismic survey was conducted using a network of geophones and cables, a data acquisition and recording instrument, and an energy source. At most locations in the study area, the energy source was a truck-mounted accelerated weight drop apparatus. At locations where truck access was not possible, a 20-lb sledgehammer was used as the energy source. To adequately image the bedrock surface, the lines of geophones were at 55 ft intervals. Downhole “check shot” surveys were conducted in bedrock wells BR-G, BR-H, and BR-I to generate seismic travel time to depth relationships.

Seismic Data Processing and Initial Interpretation: Data processing and analysis began after data acquisition had been completed. Excel Geophysical Services of Greenwood Village, Colorado, conducted the data processing. The project geophysicist, Dr. Ed Blott (ExplorTech LLC, Centennial, Colorado), provided oversight, quality control, and interpretation of the data set. The seismic reflection data were processed in various stages using a UNIX workstation and Promax 3D seismic processing software. Processing steps included the following: editing field data, creating a geometry file, common mid-point sorting, mute, velocity analysis, normal moveout corrections, static corrections, common mid-point stacking, digital filtering, automatic gain compensation, and 3D migration.

To meet project requirements, the data processing and interpretation were conducted on an accelerated schedule. The geophysicist completed a preliminary interpreted bedrock surface elevation map on August 18, 2004.

Summary Report and Startup of Drilling Activities: As requested, a report was prepared with proposed drilling locations and the rationale for the proposed locations (see "Summary Report with Proposed Locations for Soil Borings/Piezometers," August 13, 2004). The proposed drilling locations were depicted on the interpreted bedrock surface elevation map that was completed by the geophysical contractor on August 18, 2004.

The proposed drilling locations were revised based on discussions with USEPA at a meeting on August 24, 2004, and an updated map of proposed boring locations was submitted to USEPA on September 2, 2004. Drilling activities began on September 9, 2004. On September 16, 2004, USEPA issued a letter that included comments on the Summary Report dated August 13, 2004. The Summary Report was revised to incorporate these comments and was reissued to USEPA on September 30, 2004. The revised report included a discussion of the prioritization of the soil boring/piezometer locations.

Throughout the course of the drilling program, USEPA and oversight contractor staff provided input regarding final selection of drilling proposed locations and the order in which the locations were drilled. A representative of the USEPA oversight contractor was on-site each day during the soil boring and piezometer installation program and approved each staked drilling location.

Revision of Seismic Interpretation Based on Drilling Data: Measured depths to bedrock and surveyed ground elevations for the first ten bedrock piezometers were provided to the geophysical contractor for development of a revised bedrock surface interpretation. These data improved the accuracy of the velocity model that was used for conversion of seismic reflection times to depths. The revised bedrock surface elevation map that was completed by the geophysicist on October 6, 2004 (see Figure 6) was submitted to USEPA with proposed locations for the remaining soil borings and piezometers. The revised bedrock surface interpretation was then discussed in a conference call with USEPA, and drilling and installation of the remaining soil borings/piezometers were completed by October 13, 2004.

Rationale for the Drilling Locations: The drilling program conducted in September-October 2004 included soil sampling and piezometer installation at a total of eighteen locations, which were drilled in the following order: A1-3, 2, 16, 11, 8, 18, 4, 7, 10, 9, 17, 12, 6, 1, 5, 13, 14, and 15. As previously noted, the DNAPL Work Plan called for the following: i) up to twelve soil sampling and piezometer locations within the boundaries of the fill areas; ii) three locations for investigation of possible topographic lows, based on results of the seismic reflection survey; and iii) three locations outside the boundaries of the fill areas, to evaluate the potential extent of DNAPL outside fill areas.

The locations of the eighteen soil borings and piezometers drilled and installed at Sauget Area 1 in September-October 2004 were in conformance with the scope of the drilling program outlined in the DNAPL Work Plan. The supplemental DNAPL work scope submitted in August 2005 (GSI, 2005) called for an additional piezometer to be installed next to well BR-I. This piezometer, A1-19, was installed in October 2005.

The horizontal distribution of the 19 drilling locations can be summarized as follows:

	Shallow Soil Boring Plus a Piezometer	Soil Boring to Bedrock Plus a Piezometer	Number of Locations
Site I Fill Area	-	A1-6, 7, 8, 10, and 11	5
West of Site I	-	A1-9 and 12	2
Site G Fill Area	-	A1-13, 14, and 16	3
West of Site G	-	A1-18	1
North of Site G	A1-17	A1-15	2
Site H Fill Area	-	A1-1, 2, and 3	3
West of Site H	-	A1-5	1
Site L Fill Area	-	A1-4	1
Near Well BR-I (Site I Fill Area)	-	A1-19 (October 2005)	1
		Total:	**19**

Seven piezometers (A1-2, 6, 8, 11, 13, 14, and 16) were installed at predicted topographic low spots in the bedrock surface, based on the bedrock surface interpretation generated by the geophysical contractor. One well (A1-17) was installed to verify that the LNAPL found at well EE-11 did not extend beyond the limits of the Site G fill area. The number of soil borings and piezometers for each fill area was based on the size of the fill area and the potential magnitude of DNAPL impact. Accordingly, more soil borings and piezometers were installed at Site I, compared with Site L, because Site I has a larger surface area and has more potential for DNAPL impacts.

3.3 Procedures for Drilling, Soil Sampling, and Laboratory Analysis

The drilling program was performed using sonic drilling equipment. Drilling, soil sampling, and piezometer installation were conducted in accordance with procedures outlined in the Work Plan.

Drilling and Soil Sample Handling Methods: Continuous soil coring was conducted at each drilling location. Each boring was continuously cored through the fill materials, the alluvial deposits, and five or more feet into bedrock. Although soil samples were generally collected using the sonic core barrel, a split-spoon sampling device was used wherever an undisturbed soil core was needed.

The 10-ft long sonic core barrel was used to collect soil cores for lithologic description, NAPL screening, and selection of samples for laboratory analysis of chemical constituents. During drilling, the 4-inch diameter core barrel was advanced to collect continuous soil cores. A 6-inch diameter steel over-ride casing was advanced over the inner drill rods and core barrel to stabilize the borehole and minimize cross-contamination between intervals. In addition, a 7-inch diameter over-ride casing was used to isolate fill and waste materials at borings located within the boundaries of Sites G, H, I, and L.

After each 10-ft long core barrel was retracted from the borehole, the core was extruded into two 5-ft long heavy-ply polyethylene sleeves for examination and screening. The field crew immediately collected soil samples from each 2.5-ft interval for possible laboratory analysis. Samples for VOC analysis were collected using Terra-Core sampling devices. The sample aliquots were extruded from the Terra-Core devices into separate pre-weighed vials containing methanol preservative and sodium bisulfate preservative. Samples for SVOCs and TOC analyses were placed directly into glass jars. All soil samples were retained on ice until completion of soil core examination and NAPL screening, at which time certain samples were selected for laboratory testing.

Soil Core Examination and Screening: Each soil core was examined and screened for NAPL using the following procedures: 1) visual inspection of the core surface for NAPL staining or droplets; 2) inspection for staining along a strip of flexible reactive liner material (i.e., a NAPL FLUTe strip) placed along the core surface; 3) measurement of headspace vapor concentrations using a photoionization detector (PID) to evaluate bagged samples taken from each 2.5-ft interval of the 10-ft long core; and 4) use of vial test kits containing Sudan IV dye to look for direct evidence of NAPL within the soil. Each core was also examined to determine soil type, using the Unified Soil Classification System (USCS), and the cores were digitally photographed. Soil cuttings and fluids generated during drilling were placed in designated containers for management as investigation-derived wastes.

Selection of Soil Samples for Laboratory Analysis: One soil sample from each 10-foot depth interval below ground surface (0-10 ft, 10-20 ft, etc.) was retained for laboratory analysis of chemical constituents. Duplicate soil samples were submitted to the laboratory at a ratio of one per ten soil samples, and matrix spike/matrix spike duplicate pairs were submitted at a ratio of one set per twenty soil samples.

The criteria used for selection of the samples for laboratory testing were as follows. If field indications of NAPL were noted in a 10-ft length of soil core based on visual inspection or other evidence (i.e., vial test kits and/or FLUTe strips), then the soil sample selected for laboratory analysis was from the interval that had the most obvious indications of NAPL. If there were no field indications of NAPL in a 10-ft length of core, the soil sample for laboratory analysis was from the interval exhibiting the maximum other evidence of organic constituents, based on a combination of odor, appearance, and/or organic vapor headspace testing results. In addition, a total of three “clean” soil samples (i.e., with little or no evidence of NAPL) were retained from each boring for analysis of fraction organic carbon.

Laboratory Analysis of Soil Samples for Chemical Constituents and Organic Carbon: The selected samples were shipped on ice to Severn Trent Laboratories (STL) in Savannah, Georgia. STL tested the selected soil samples from each 10-foot interval for VOCs by EPA Method 8260, for SVOCs by EPA Method 8270, and for TOC by EPA Method 9060 (the "Lloyd Kahn" method). STL tested the three "clean" soil samples retained from each boring for fraction organic carbon using EPA 9060. Tabulated analytical results are presented in Appendix D.

Collection and Testing of Undisturbed Cores: Several undisturbed cores were collected from each boring using a split-spoon sampling tool. These cores were carefully transferred from the sampling tool to a plastic core tray, covered with a sheet of Saran-wrap, and placed on dry ice. The frozen cores were submitted for possible testing at PTS Laboratories in Santa Fe Springs, California. Selected cores were tested using ASTM and API methods to determine physical properties (i.e., porosity, bulk density, and grain size classification). Some cores were evaluated for pore fluid saturations using the Dean-Stark test procedure (API RP 40), which includes determination of initial and residual pore fluid saturations, total porosity, dry bulk density, and visual indications of produced fluids. Selected cores were tested for DNAPL mobility using a modified centrifuge test procedure (ASTM D425M). Core testing results are provided in Appendix E.

3.4 Installation and Development of Piezometers

Each soil boring was completed as a piezometer. The bedrock piezometers were screened both above and below the bedrock surface and constructed of 2-inch diameter stainless steel casing with 15 feet of stainless steel wire-wound screen. The shallow piezometer (A1-17) was installed to a depth of 25 feet bgs with 15 feet of stainless steel wire-wound screen. Boring log/as-built diagrams for the nineteen piezometers are in Appendix F.

After the screen and casing were installed in the borehole, the sandpack, bentonite seal, and grout seal were placed as the six-inch diameter over-ride casing was retracted from the borehole. The piezometers were developed using a submersible electric pump and/or a trash pump. Water generated during development was placed in designated containers for management as investigation-derived waste.

After development was completed, the depth to water and total depth of each piezometer were measured, and the piezometers were checked for the possible presence of NAPL using an interface probe, weighted cotton string, and clear bailer. To allow for possible accumulation of NAPL, each new piezometer was left undisturbed for a period of at least one week prior to conducting a NAPL survey.

3.5 Data Validation

Severn Trent Labs (STL) delivered sample results from the DNAPL characterization study in 21 Sample Delivery Groups (SDGs). The SDGs were USEPA Level IV packages with Contract Laboratory Program (CLP) flagging. Electronic Data Deliverables (EDDs) were also provided.

STL performed an initial validation of the data. ECS Environmental Chemistry Services, Inc., of Houston, Texas, then conducted at independent Level IV review of 100% of the data. The validation and review procedures were consistent with the QAPP and with USEPA guidelines for the validation of laboratory data (USEPA, 2001 and 2002). Qualifiers were assigned to results when appropriate. Results were found to be acceptable for their intended use for all data. The text of the data validation report is included in Appendix I.

4.0 RESULTS OF DNAPL CHARACTERIZATION STUDY

4.1 Results of NAPL Surveys and Recovery Tests

The following paragraphs summarize overall results of the NAPL surveys conducted in 2004 and 2005, observations and recovery test results at wells where surveys indicated evidence of NAPL, and physical properties and chemical composition of NAPL samples recovered at EE-11 and BR-I.

4.1.1 Overall Results of NAPL Surveys in 2004 and 2005

In May 2004, GSI performed NAPL survey measurements at 57 previously existing wells and piezometers (see Table 1 and Figure 2). A total of 54 were screened in the shallow hydrogeologic unit (SHU) or middle hydrogeologic unit (MHU) of the alluvial aquifer, and the remaining three were bedrock wells BR-G, BR-H, and BR-I. An accumulation of LNAPL was found at shallow well EE-11, and evidence of pooled DNAPL was found at bedrock wells BR-G and BR-I. Recovery tests were conducted at EE-11, BR-G, and BR-I.

In October 2004, GSI performed NAPL survey measurements at 22 wells and piezometers, including A1-1 through A1-18 and EE-11, BR-G, BR-H, and BR-I (Table 2 and Figure 3). Evidence of LNAPL was observed in EE-11, and some evidence of pooled DNAPL was observed at BR-G and A1-8. An accumulation of pooled DNAPL was observed at BR-I. Recovery tests were conducted at EE-11, BR-G, and BR-I.

In July 2005, URS measured fluid levels in selected wells and piezometers at Sauget Area 1 as part of a regional water level survey of wells in Sauget. Measurements and observations indicated evidence of DNAPL at BR-G and BR-I.

In September 2005, GSI conducted another NAPL survey at the 22 wells surveyed in October 2004 (see Table 3 and Figure 4). Evidence of LNAPL was noted in well EE-11, some evidence of pooled DNAPL was observed at BR-G, and an accumulation of pooled DNAPL was found in well BR-I. Recovery tests were conducted in September 2005 at EE-11, BR-G, and BR-I.

In October 2005, GSI performed air-lift pumping at BR-I to obtain further information regarding the rate of DNAPL recovery and the time required for fluid levels to return to a static condition. After completion of air-lift pumping, water level elevation and DNAPL measurements were

recorded at BR-I and at the nearby piezometer, A1-19 (see Table 5). Pooled DNAPL was found to be present in BR-I and A1-19.

4.1.2 Observations and Measurements at EE-11

In May 2004, EE-11 contained a dark brown LNAPL that appeared to be a petroleum hydrocarbon, based on color and odor. The well contained as much as 8 to 9 feet of accumulated LNAPL. Approximately one gallon of LNAPL was removed during a recovery test on May 19, 2004. Well EE-11 is a low yield well and became dry after only a relatively short period of pumping. Fluid levels in EE-11 were re-measured on May 20, 2004, and at that time EE-11 had a layer of LNAPL approximately 0.2 feet thick. A total of approximately 1/4 cup of LNAPL (0.02 gallons) was removed from EE-11 on May 20. A sample of LNAPL recovered from EE-11 was retained for chemical analysis and physical properties testing. Testing results are documented in Appendix C and discussed below in Section 4.1.6.

In October 2004, EE-11 showed some evidence of the presence of a small amount of LNAPL. Brown staining was noted on the interface probe and on the outer surface of a bailer lowered just below the water table. Tiny droplets of NAPL were observed inside the bailer. An LNAPL recovery test was attempted at EE-11 using a clear bailer. Only water was recovered, and there was no LNAPL visible in the produced fluids. The initial accumulation of LNAPL observed at EE-11 in May 2004 was apparently depleted by the recovery tests conducted in May 2004.

In September 2005, EE-11 had some evidence of the presence of a small amount of LNAPL. Brown staining was noted on the interface probe and on the outer surface of a bailer lowered just below the water table. In an effort to remove LNAPL, well EE-11 was pumped using a peristaltic pump on September 29, 2005. An estimated volume of 1.5 quarts (0.38 gallons) of water mixed with globules of NAPL was recovered.

Based on the above observations, further recovery of LNAPL by pumping at EE-11 does not appear to be feasible.

4.1.3 Observations and Measurements at A1-8

This well was installed in September 2004. When it was surveyed in October 2004, A1-8 had some evidence of the presence of a small amount of DNAPL. A bailer lowered to the bottom of A1-8 contained mostly water, but also included dark brown droplets of DNAPL inside the bottom end of the bailer. A recovery test was not performed at A1-8, due to the limited evidence of DNAPL observed at this piezometer during the well survey. When A1-8 was measured again in September 2005, there was no evidence of DNAPL. Based on these observations, we conclude that pooled DNAPL is not present in A1-8.

4.1.4 Observations and Measurements at BR-G

In May 2004, BR-G had some evidence of the presence of a small amount of DNAPL. There was no interface probe response to indicate the presence of DNAPL, but dark brown spots and

minor discontinuous brown staining were noted on the bottom 4 feet of a weighted cotton string lowered to the bottom of the well. A bailer lowered to the bottom of the well was found to have a light sheen or droplets on the bailer surface when it was retrieved, but no NAPL was present within the bailer. A DNAPL recovery test was attempted on May 20, 2004, and approximately 5 gallons of fluids were pumped from the bottom of the well using a Waterra inertial lift pump with an electric-powered actuator. Only water was recovered; no NAPL was visible in the produced fluids.

In October 2004, there was no interface probe response to indicate the presence of DNAPL, but a sheen was noted on the bottom 3.5 feet of a weighted cotton string lowered to the bottom of the well. A bailer lowered to the bottom of the well contained mostly water, but there were tiny droplets of NAPL within the bottom two inches of the bailer. A DNAPL recovery test was attempted on October 30, 2004, and approximately 40 gallons of fluids were pumped from the bottom of the well using a Waterra inertial lift pump with an electric-powered actuator. Only water was recovered; no NAPL was visible in the produced fluids. Small droplets of DNAPL were visible in the bottom few feet of the Waterra tubing when the tubing was removed from the well at the end of the recovery test.

In July 2005, URS measured fluid levels at BR-G as part of a survey of static water levels in the Sauget region. There was no interface probe response to indicate the presence of DNAPL, but a “greenish black product” was noted on the bottom 1 to 2 feet of the interface probe.

In September 2005, the interface probe did not indicate the presence of DNAPL, but staining was noted on the bottom 3.5 feet of a weighted cotton string lowered to the bottom of the well. A bailer lowered to the bottom of the well came back with 3.25 feet of staining, and there was DNAPL at the bottom of the bailer. A DNAPL recovery test was attempted on September 29, 2005, and approximately 65 gallons of fluids were pumped from the bottom of the well using a Waterra inertial lift pump with a gasoline-powered actuator. Only water was recovered; no NAPL was visible in the produced fluids. Small droplets of DNAPL were visible on the inside surface of the Waterra tubing when the tubing was removed from the well at the end of the recovery test.

These results suggest that some DNAPL is present in BR-G. Based on results of the recovery tests performed at BR-G in May 2004, October 2004, and September 2005, recovery of DNAPL at BR-G by pumping does not appear to be feasible.

4.1.5 Observations and Measurements at BR-I and A1-19

Pooled DNAPL has been found in bedrock well BR-I and in an adjacent piezometer, A1-19 (see data on Tables 4 and 5). This section discusses the following topics: i) depth to bedrock and well construction based on boring log data, wireline coring records, and downhole geophysical surveys; ii) summary of DNAPL observations and measurements at these two wells; and iii) evaluation of DNAPL recoverability and the likely origin of DNAPL in BR-I.

Bedrock and Well Construction Information

- Top of Bedrock at BR-I and A1-19: Limestone and dolomite bedrock that is weathered and/or fractured (i.e., rock quality designation of poor) begins at a depth of approximately 111 ft bgs (see Figure 5). Bedrock is relatively unweathered (i.e., rock quality designation of excellent) from 126.5 ft to 146.9 ft bgs, although some fractures are present in this depth interval. (See the Colog report in Appendix I and a technical memo in Appendix J.)

- Well Construction of BR-I and A1-19: A1-19 has 15 ft of 2-inch diameter stainless steel well screen positioned across the interface between the alluvial aquifer and underlying bedrock (see Figure 5), and has a total depth of approximately 117 ft bgs. BR-I has a 4-inch diameter PVC casing set into bedrock to a depth of approximately 124.75 ft bgs and an open borehole in the bedrock extending to a depth of approximately 146.9 ft bgs.

- Condition of the PVC Casing in BR-I: Colog's interpretation of the acoustic televiewer and caliper surveys indicates no evidence of damage to the bottom of the PVC casing (see Appendix I). However, pooled DNAPL in BR-I may have been in direct contact with the lower portion of the PVC casing, and some chemical degradation of the PVC casing could have occurred over time.

DNAPL Observations and Measurements

- Depth to DNAPL at BR-I - May 2004 to September 2005: Inferred depth to DNAPL ranged from 137 ft bgs to 140 ft bgs, based on observations during the May 2004, October 2004, July 2005, and September 2005 measurement events (see Table 4). However, on three of the four measurement events, the interface probe did not give a solid tone indicating DNAPL, and estimated DNAPL thickness was based on the length of staining observed on a weighted string lowered to the bottom of the well.

- DNAPL Recovery Tests at BR-I – May 2004 to September 2005: During the May 2004 test, 8 gallons of fluids were produced, but no DNAPL was recovered, possibly because the pump intake was not at the well TD. (The pump intake may have encountered refusal just below the bottom of the PVC casing, where the well diameter narrows to approximately 2.5 inches.) During the October 2004 test, approximately 50 gallons of fluids were produced, comprising an estimated 15 gallons of DNAPL and 35 gallons of water. During the September 2005 test, approximately 100 gallons of fluids were produced, but the volume of DNAPL produced was not determined with certainty. The estimated DNAPL volume of 15 gallons recovered in the October 2004 test suggests a theoretical depth to DNAPL of approximately 106 ft bgs in BR-I prior to that test (see calculations and assumptions on Table 4).

- Brushing, Air-lift Pumping, and Downhole Geophysical Survey at BR-I: On September 30, 2005, the interior of BR-I was brushed with a wire brush and then the well was

pumped using air-lift pumping equipment. Clean water was heated and added to the well several times during the later stages of pumping to help flush out the lower portion of the well. An estimated volume of 13 gallons of DNAPL was recovered, based on the thickness later measured in a drum of recovered fluids (see Table 4). The downhole geophysical surveys were performed October 5, 2005 (see Colog report in Appendix I). The optical televiewer showed a DNAPL interface at 114.5 ft bgs, and fluid conductivity decreased sharply at the same depth. If the top of DNAPL was at 114.5 ft bgs, this suggests that a volume of approximately 11.7 gallons of DNAPL was present in BR-I (see calculations and assumptions on Table 4).

- Measurements at BR-I and A1-19 – October 20-21, 2005: Several inches of pooled DNAPL were measured in A1-19. Inferred depth to DNAPL was approximately 119 ft bgs at BR-I, and approximately 8 gallons of DNAPL were subsequently recovered using air-lift pumping (Table 4). A DNAPL volume of 8 gallons suggests a theoretical depth to DNAPL of approximately 120 ft bgs in BR-I (see calculations and assumptions on Table 4), which is close to the inferred depth to DNAPL (119 ft bgs) from measurements taken prior to the recovery test.

- Sustainable Well Yield and Recovery of Water Levels to Static Conditions: A1-19 was pumped at a rate of up to 5 gpm during well development, and higher flow rates could likely be achieved since this well is screened in medium-coarse sand, gravel, and weathered bedrock. In contrast, recovery test results confirm that BR-I is a low-yield well. After fluids stored within the 4-inch PVC diameter casing at BR-I were pumped out, the measured well yield was approximately 0.05 gpm with drawdown of approximately 100 feet below static water level (Table 4). Water levels in A1-19 recovered to static level relatively rapidly after pumping of A1-19 was terminated, but water levels in BR-I took more than 20 days to return to static level after pumping of BR-I was terminated (see Table 5).

- Additional DNAPL Observations and Measurements October 24–November 10, 2005: Inferred depth to DNAPL in BR-I was approximately 105-106 ft bgs (or 107-108 ft below top of casing) on October 27, 2005, approximately one week after the recovery test (Table 5). Measurements taken on November 1 and 10, 2005, confirmed this inferred depth to DNAPL. The inferred depth to DNAPL in A1-19 changed from approximately 116.5 ft bgs (i.e., < 6 inches thick) to approximately 113 ft bgs (or 115 ft btoc) between October 20 and November 10, 2005 (see Table 5).

- Performance of DNAPL Pumping Methods used in Recovery Tests: The May 2004 and October 2004 recovery tests were conducted using a Waterra pump and an electric-powered actuator. Observed flowrates were very low, and it was later determined that the total depth of BR-I is close to the effective depth limit for pumping using an electric actuator. A more powerful gasoline powered actuator was used for the September 2005 recovery test, and air-lift pumping was used at BR-I on two occasions in October 2005. The air-lift method may have been more effective than the Waterra method at removing

DNAPL from the lowermost portion of BR-I. However, well yield was low during each recovery test at BR-I.

DNAPL Recoverability and Origin of DNAPL in BR-I

- DNAPL Recoverability at BR-I and A1-19: Pooled DNAPL can be recovered from BR-I by pumping, albeit at a relatively slow rate, and it is likely that DNAPL can be recovered at A1-19. During recovery tests at BR-I, DNAPL was recovered using Waterra equipment and air-lift pumping equipment, but these two methods require on-site personnel and would not be cost effective for long-term recovery of DNAPL. Another type of pump could be used for recovery of DNAPL from the 2.5-inch diameter open borehole at BR-I and/or the 2-inch diameter stainless steel well at A1-19. DNAPL recovery may be more productive at BR-I that at A1-19, because BR-I has an open borehole in the bedrock that acts as a sump for accumulation of pooled DNAPL.

- Origin of DNAPL in BR-I: The upper few feet of the bedrock is weathered. Pooled DNAPL is present in A1-19, which is located 15 feet from BR-I and is screened across the interface between the alluvial aquifer and the weathered bedrock (see Figure 5). The upper end of the open borehole at BR-I begins only a few feet below the apparent base of weathered bedrock. Although some acoustic features (i.e., fractures) were observed in the open borehole of BR-I, recovery tests indicate that the well yield of BR-I is low, at approximately 0.05 gpm. Based on these findings, the most likely explanation for the presence of DNAPL in BR-I is that the open borehole at BR-I is acting as a sump for accumulation of DNAPL that enters from the overlying alluvial aquifer and/or the upper few feet of weathered bedrock. Although the acoustic televiewer and caliper logs for BR-I did not show evidence of damage to the interior of the PVC casing, it is possible that some DNAPL could be entering the open borehole by leakage through the seal between the PVC well casing and the bedrock that the casing is seated in.

4.1.6 Physical Properties and Chemical Composition of NAPL Samples

NAPL samples were recovered from EE-11 and BR-I. Field observations and laboratory test results are summarized below and documented in more detail in Appendix C.

EE-11: The sample from EE-11 was collected in May 2004 and was an LNAPL. Results of testing at PTS Labs indicated that the sample had a specific gravity of 0.89 and a viscosity of 26.4 centistokes at 70°F. NAPL/water interfacial tension was 15.4 dynes/cm at 79°F. Severn Trent Labs analyzed the sample for a broad range of target analytes, including VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, and metals. Taken together, the target analytes that were identified by Severn Trent Labs comprised less than one percent of the sample by weight.

As reported by SPL, initial boiling point of the sample was 517°F, and final boiling point was 700°F, at which point the sample experienced decomposition. Triton Analytics conducted a

High-Temperature Simulated Distillation (HTSD) test and reported that the boiling characteristics of the sample showed that a significant portion of material was in the carbon number range consistent with diesel fuel (i.e. about C_{10} to C_{23}). There was also a second boiling region of material present in the C_{23} carbon number range, which is more characteristic of a vacuum gas or heavier oil.

BR-I: The sample from BR-I was collected in October 2004 and was a DNAPL. Results of testing at PTS Labs indicated that the sample had a specific gravity of 1.44 and viscosity of 5.92 centistokes at 70°F. NAPL/water interfacial tension was 15.0 dynes/cm at 71°F. Severn Trent Labs analyzed the sample for a broad range of target analytes, including VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, and metals. Taken together, the target analytes comprised approximately 18 percent of the sample by weight. The predominant identified constituent was 1,2,4-trichlorobenzene, which comprised 14% of the sample by weight. Hexachlorobenzene and 1,4-dichlorobenzene comprised 1.0% and 0.8% of the sample by weight, respectively. As reported by SPL, initial boiling point of the sample was close to 432°F, and final boiling point was 530°F. Based on results of an HTSD test, Triton Analytics reported that the sample was likely to be a synthetic product and appeared to have a significant component that was either not hydrocarbon or was insoluble in CS_2.

A1-19: Pooled DNAPL in A1-19 has not been sampled for laboratory analysis. This well is located approximately 15 feet from BR-I, and the chemical composition of the DNAPL in A1-19 is expected to be very similar to the chemical composition of the DNAPL in BR-I. This is supported by soil analytical data from A1-19 for an aquifer matrix sample collected at 100-102.5 ft bgs, a depth that is close to the base of the alluvial aquifer. As shown on Table D-2, the predominant constituents detected in this aquifer matrix sample were 1,2,4-trichlorobenzene at 520 mg/kg, 1,4-dichlorobenzene at 560 mg/kg, and hexachlorobenzene at 180 mg/kg. These were the three major COCs identified in the DNAPL sample from BR-I.

4.2 Bedrock Topography and Bedrock Transport Analysis

4.2.1 Bedrock Topography

The 3-D seismic survey was conducted to locate topographic lows in the bedrock surface at Sauget Area 1 where DNAPL could potentially accumulate. A total of seven piezometers were installed at predicted topographic low spots in the bedrock surface. Four of these seven piezometers (A1-2, 8, 11, and 16) were sited based on the preliminary seismic interpretation that was completed on August 18, 2004, prior to the start of the drilling program. The other three piezometers that targeted topographic lows (A1-6, 13, and 14) were sited based on the revised seismic interpretation (see Figure 6) that was completed on October 6, 2004.

Figure 6 shows interpreted bedrock surface elevations in feet above mean sea level (MSL). As indicated by the color bar in the legend, blue colors indicate where lower bedrock surface elevations are predicted, and yellow and orange colors indicate where higher bedrock surface elevations are predicted. The revised seismic interpretation (Figure 7) incorporated bedrock depth information from three previously existing bedrock wells (BR-G, BR-H, and BR-I) and

observed bedrock depths from the first ten new bedrock piezometers installed in September-October 2004 (A1-3, 2, 16, 11, 8, 18, 4, 7, 10, and 9).

To illustrate the stratigraphy underlying Sauget Area 1, three cross sections (Figures 7, 8, and 9) were prepared using data from monitoring well boring logs. These cross sections show relevant surface features, fill area profiles, the alluvial aquifer, and the bedrock surface. Observed bedrock elevations were used for preparation of these cross sections, rather than the predicted bedrock elevations from the seismic interpretation.

At Sites H and I, bedrock elevations observed at the piezometer locations generally agreed with interpreted bedrock elevations from the seismic reflection survey. However, observed and interpreted elevations were not in good agreement at Site G.

The geophysical contractor reported that the seismic data at and near Site G were significantly more difficult to interpret than the data from the other areas. The data from the area at and near Site G were noisy and badly scattered, and the continuity and character of the reflectors were very changeable. Due to the noisy and badly scattered data at Site G, the predicted bedrock surface elevations are considered less reliable overall than the predicted elevations at Sites H and I.

Observed bedrock surface elevations at six bedrock piezometers installed at and near Site G (i.e., A1-5, 13, 14, 15, 16, and 18) ranged from approximately 295 ft MSL to 297.5 ft MSL. This suggests that bedrock could be relatively flat in the area at and near Site G, which is how the bedrock surface is depicted on the cross sections (see Figures 7 and 8). The large topographic variations at Site G that are shown on the revised seismic interpretation (Figure 6) do not appear to accurately represent the bedrock topography underlying Site G for the reasons discussed above.

Observed Bedrock Elevations at Sauget Area 1

Well	Ground Elevation (ft MSL)	Depth to Top of Bedrock (ft bgs)	Elevation of Bedrock Surface (ft MSL)
A1-01	408.4	106.5	301.9
A1-02	405.5	107	298.5
A1-03	409.7	110	299.7
A1-04	407.8	110	297.8
A1-05	406.5	109	297.5
A1-06	408.9	109	299.9
A1-07	410.9	111	299.9
A1-08	409.1	111	298.1
A1-09	407.7	111	296.7
A1-10	409.4	111	298.4
A1-11	410.9	116	294.9
A1-12	406.3	112	294.3
A1-13	406.4	110	296.4
A1-14	411.6	116.5	295.1

A1-15	407.1	111	296.1
A1-16	407.3	112	295.3
A1-17 (shallow)	407.2	Not applicable	Not applicable
A1-18	409.6	113	296.6

4.2.2 Bedrock Transport Analysis

An evaluation of bedrock transport characteristics (see Appendix J) suggests that the upper few feet of the bedrock, which is weathered and fractured, is more likely to be a pathway for groundwater flow than the underlying competent bedrock.

4.3 Soil Sampling and Testing Results

Soil sampling and testing results for VOCs, SVOCs, and TOC are presented on the tables in Appendix D. Figures 10 through 16 illustrate the horizontal and vertical distribution of the following constituents or constituent groups: total VOCs; total SVOCs; chlorobenzene; 1,4-dichlorobenzene; and 1,2,4-trichlorobenzene. Chlorobenzene and 1,4-dichlorobenzene are of interest based on their presence at elevated concentrations in groundwater downgradient of Site I (see maps in Attachment B). The 1,2,4-trichlobenzene is of interest based on its presence at an elevated concentration in the DNAPL sample from well BR-I.

Table 6 presents soil core inspection and testing results for each boring, including the reported values of total VOCs, total SVOCs, and TOC for soil samples tested. Based on visual observations of NAPL presence in soil cores or a positive indicator from a Sudan IV vial test kit, there was evidence for the presence of NAPL in one or more soil cores from 13 of the 19 soil borings (A1-1, 2, 3, 6, 7, 8, 9, 11, 13, 14, 16, 18), and 19.

Core testing results from PTS Laboratories are presented in Appendix E. The test results in Appendix E include: i) physical properties data (i.e., porosity, bulk density, and grain size classification); ii) fluid saturation measurements using the Dean-Stark test procedure; and iii) DNAPL mobility test results from a modified centrifuge test procedure. Core testing results indicate that most cores selected for testing had a mean grain size of fine to medium sand, based on particle size analysis. Based on Dean-Stark test results, pore fluid saturations for NAPL ranged from <0.1% to 30.4% of pore volume for the cores tested.

In the centrifuge test procedure for evaluating DNAPL mobility, the core samples were spun for one hour at 1000xG. A total of 16 core samples were tested from seven different borings. Centrifuge test results indicate that a total of eight core samples (from borings A1-8, 13, and 14) produced DNAPL. One of the four core samples from A1-8 that was tested produced both DNAPL and LNAPL. Trace amounts of free product were produced by core samples from A1-2 and A1-3. No free product was produced by the four core samples from A1-4 (Site L) or by the core sample from A1-6. These results can be used to confirm the presence or absence of NAPL in the cores that were tested. However, it is considered likely that, where present, the

NAPL within these cores would in most instances be relatively immobile under normal gravitational conditions.

4.4 Determination of Volume of Fill Materials and Aquifer Matrix Containing DNAPL

4.4.1 Methods

Three methods were considered for estimating the volume of fill materials and aquifer matrix containing DNAPL (the "DNAPL Volume"). These methods are briefly summarized below.

Equilibrium Partitioning: The first method was to compare detected soil concentrations with concentrations that would be expected based on equilibrium partitioning. This method, which is detailed in the 1992 U.S. EPA publication 93554-07FS ("Estimating Potential for Occurrence of DNAPL at Superfund Sites"), uses a partitioning coefficient (K_d) to convert the effective solubility of contaminants to sorbed concentration. Analytical data for a sample of DNAPL collected from the site is required. Using this method, there is potential for DNAPL in a soil sample if constituents that are detected in the DNAPL sample are present in the soil sample at sorbed concentrations that exceed calculated equilibrium partitioning values.

The sample from BR-I was the only DNAPL sample that could be collected during this investigation. The LNAPL sample from well EE-11 was not considered suitable for use with the equilibrium partitioning method, because the identified constituents comprised only a very small fraction of the sample.

For the DNAPL sample collected at well BR-I, the portion that could be identified by the analytical methods comprised 20% of the sample on a mole fraction basis (see laboratory data in Appendix C). The primary constituent in the DNAPL sample was 1,2,4-trichlorobenzene, which comprised 16% of the sample on a mole fraction basis. Laboratory data for soil samples collected at Sauget Area 1 indicate that 1,2,4-trichlorobenzene is present in soil at elevated concentrations. However, dichlorobenzenes, chlorobenzene, chlorophenols, xylenes, and a variety of other VOCs and SVOCs are also present at elevated concentrations in soil samples (see data tables in Appendix D). This indicates that the Sauget Area 1 DNAPL source materials were very heterogeneous from a chemical perspective.

Because of insufficient knowledge of DNAPL mole fraction composition across the Sauget Area 1 sites, the equilibrium partitioning method is not considered a reliable method for determining the presence or absence of DNAPL in soil at Sauget Area 1.

Dean Stark Test Data: The second method for determining the extent of DNAPL was to compare pore fluid saturation results from PTS Laboratories with total VOC and total SVOC data from Severn Trent Laboratories. A total of 15 core samples from 7 different soil borings were evaluated for pore fluid saturations using the Dean-Stark test procedure (API RP 40), which includes determination of initial and residual pore fluid saturations, total porosity, dry bulk density, and visual indications of produced fluids (see results in Appendix E). These cores were collected from locations at each of the fill areas (Sites G, H, I, and L) and were from depths

within the fill materials and within the shallow, middle, and deep hydrogeologic units of the alluvial aquifer.

NAPL pore fluid saturations for the fifteen undisturbed core samples were plotted against concentrations of total VOCs plus total SVOCs for the soil samples closest in depth to the undisturbed cores. The overall correlation was poor ($r^2 < 0.5$), indicating that this method could not be applied accurately. The poor correlation could be a result of the heterogeneous nature of the DNAPL source materials at Sauget Area 1.

Soil Core Field Screening Results: The third method for determining the extent of DNAPL, and the one that was selected for to determining DNAPL Volume at Sauget Area 1, was to use a combination of visual indicators of NAPL presence and laboratory data for total VOCs and total SVOCs (see Table 6). Either the visual presence of NAPL in a core sample, or a positive indicator from the Sudan IV vial test kits, were used to determine the presence of NAPLs in a soil boring. However, some of the locations where NAPL was indicated had very low concentrations of total VOCs and total SVOCs, and thus would probably not represent significant on-going sources of constituents to site groundwater. Therefore a further classification was used, where NAPL in soil (as indicated based on field screening of cores) was classified as “low-strength” NAPL if both total VOC and total SVOC concentrations in soil were less than 1 mg/kg. This “low-strength” NAPL in soil was excluded from the DNAPL Volume. NAPL in soil (as indicated based on field screening of cores) was classified as “moderate to high-strength” NAPL and was included in the DNAPL Volume if either total VOC or total SVOC concentrations in soil were greater than or equal to 1 mg/kg.

4.4.2 Volume Estimates

DNAPL areas are shown on Figures 17, 18, and 19. Borings with “low-strength” NAPL were excluded from the DNAPL areas. For example, a sheen was observed on a shallow soil core at boring A1-1. As shown on Table 6, the concentrations of total VOCs and total SVOCs are less than 1 mg/kg for the approximate depth intervals where NAPL indications were observed in this boring. This “low-strength” NAPL at boring A1-1 probably does not represent a significant on-going source of potential impacts to site groundwater, and is therefore excluded from the DNAPL area for the fill and shallow hydrogeologic unit (see Figure 17). Borings with “moderate to high-strength” NAPL were included in the DNAPL areas (see borings A1-2, 3, 6, 8, 9, 13, 14, 16, 18, and 19 on Figure 17).

For the fill/shallow hydrogeologic unit (see Figure 17), two separate DNAPL areas were defined, with a total area of approximately 15 acres. Assuming a thickness of 30 ft, the DNAPL Volume for the fill and shallow hydrogeologic unit was estimated to be 750,000 yd^3. The middle hydrogeologic unit and deep hydrogeologic unit both had DNAPL areas of approximately 8 acres (see Figures 18 and 19), and a combined DNAPL Volume of 950,000 yd^3 (assuming thickness of 40 feet for the middle hydrogeologic unit and 35 feet for the deep hydrogeologic unit). The total DNAPL Volume is 1,700,000 yd^3 within a total area of 15 acres.

Total DNAPL volume of 1,700,000 yd^3 was estimated based on the assumption that the entire thickness of the shallow, middle, or deep hydrogeologic unit is affected by DNAPL if any interval within the unit shows evidence of DNAPL. Therefore, the value of 1,700,000 yd^3 represents an upper-bound estimate of the DNAPL volume based on the data collected during the DNAPL Study. However, this conservative estimate is appropriate for planning purposes when evaluating the feasibility of various DNAPL treatment technologies for the Sauget Area 1 Sites. It would be very difficult to effectively apply in-situ DNAPL treatment technologies such as surfactant-enhanced solubilization, thermal treatment, or chemical oxidation to target very specific intervals of DNAPL-impacted media in the subsurface.

As requested by USEPA, an alternative estimate of total DNAPL volume was calculated by applying the estimated thickness of DNAPL-affected soil and aquifer matrix observed in each boring to a designated area surrounding each boring (see Figures 20, 21, and 22), and then summing the resulting volumes across the site for the shallow, middle, and deep hydrogeologic units. For the fill and shallow hydrogeologic unit, the estimated thickness of DNAPL-affected media ranges from 5 to 25 feet across a total area of approximately 15 acres, and the calculated DNAPL volume is approximately 420,000 yd^3. For the middle hydrogeologic unit, the estimated thickness of DNAPL-affected aquifer matrix ranges from 20 to 40 feet across a total area of 8 acres, and the calculated DNAPL volume is approximately 400,000 yd^3. For the deep hydrogeologic unit, the estimated thickness of DNAPL- affected aquifer matrix ranges from 10 to 45 feet across a total area of approximately 8 acres, and the calculated DNAPL volume is approximately 350,000 yd^3. Using this alternate approach, the total DNAPL volume for the shallow, middle, and deep hydrogeologic units is approximately 1,200,000 yd^3.

5.0 DNAPL TREATABILITY TESTS AND REVIEW OF DNAPL SOURCE DEPLETION ALTERNATIVES

Several source depletion technologies were evaluated as part of the DNAPL Characterization and Remediation Study for Sauget Area 1. Treatability tests were developed and conducted as part of this evaluation (see Appendix G). The results from these tests are intended to provide design information for evaluating the applicability and potential effectiveness of the technologies selected.

Various technologies have been developed for source depletion at DNAPL-impacted sites. As discussed in Task 7 of the the approved Sauget Area 1 DNAPL Work Plan, the technologies chosen for evaluation at Sauget Area 1 were surfactant-enhanced solubilization, thermal treatment, and chemical oxidation.

The evaluation of each of these technologies is presented in terms of performance, cost, and engineering considerations. In addition to these evaluations, a comprehensive dissolution test was conducted at the bench-scale to provide data on mass flux and time required to deplete the source.

5.1 Surfactant-Enhanced Solubilization

5.1.1 Performance

Surfactant flushing (with or without cosolvent) has been developed as an aggressive remediation technology for DNAPL contamination in the subsurface (Yin and Allen, 1999). The feasibility of this technology is based on the interaction between the surfactant and the contaminants in relation to the media in which they are present, typically water. Surfactants have the ability to alter the interfacial properties of fluids, with the end result of enhancing the amount of mass that can be present in an aqueous phase at equilibrium (Edwards et al., 1991). This transfer of the contaminant from the oil phase to the aqueous phase means the compound is more amenable to flushing or other remedial efforts. Similarly, surfactant amendments are intended to enhance mobilization *in situ* by lowering the interfacial tension between DNAPL and the surrounding aqueous phase. The interaction between each molecule of contaminant and the surfactant acts to dissipate capillary forces. However, it is generally difficult to separate the effects of enhanced solubilization and mobilization.

A bench-scale test was conducted using the DNAPL sample from well BR-I to determine the applicability of two different types of surfactants for enhancing solubility. Surfactants (Tween 80 and Aerosol MA-80I) were added at levels above their critical micelle concentrations to solutions containing DNAPL of known composition that was recovered from well BR-I. No consistent enhancement in solubilization was noted for any of the compounds of interest. The results from this treatability test (see Attachment G) suggest that surfactant-enhanced solubilization is not an appropriate technology selection for Sauget Area 1. Because increases in concentration following surfactant addition were not observed, no estimates can be made of the mass of surfactant needed to remove the constituents present at the site. While it is possible that surfactant amendments may have a more measurable impact on solubilization *in situ*, there is little indication that the compound profile is amenable to this technology.

Performance of this technology in promoting source depletion at a variety of other sites has been generally positive. A recent performance survey of source depletion technologies (McGuire, et al. in review) noted that at four sites where surfactant/cosolvents were used, reduction in parent compound concentrations ranged from 91 to 99%. However, only limited data for daughter product formation was available for this survey, so it is unknown whether the total concentration of chlorinated organics matched the pattern for the parent compound. All applications of this technology required less than 52 days of surfactant addition, and concentrations continued to decrease over time in the majority of wells, with rebound (increase relative to concentration immediately following treatment completion) noted in only 33% of the records. Therefore, it appears that the technology has been successfully demonstrated at a number of sites, and continued management following completion is minimal.

5.1.2 Cost

A recent review of costs of implementing source depletion technologies (McDade et al. 2005) noted that at six sites where surfactant/cosolvents were used, representative unit costs were

$118 - $1322 per cubic yard of treatment volume (this range represents the 25th to 75th percentile of cost from the six sites). This unit cost reflects both capital and operation and maintenance costs incurred per cubic yard of aquifer material, without regard to the amount of groundwater pumped during the remedial period.

Little correlation was observed between total treatment cost and the total treatment volume, but it is important to note that the largest site considered in this survey was roughly 7,000 yd^3. This volume is several orders of magnitude lower than the estimated DNAPL Volume at Sauget Area 1 (estimated DNAPL Volume of 1.7×10^6 yd^3, or over 200 times smaller), and it is not certain that the unit costs would remain independent of treatment volume at this level. In particular, the capital costs associated with injection and recovery wells would be expected to increase significantly for a larger implementation of this technology. In terms of supply cost, the bulk unit cost of Tween 80 is roughly $1/lb of surfactant. The uncertainty associated with the effectiveness of the tested surfactants has the potential to unfavorably multiply the supply costs of surfactant solubilization.

Based on the estimated DNAPL Volume of 1.7×10^6 yd^3 at Sauget Area 1 and the range of representative units costs of $118 to $1322 per cubic yard of treatment volume, costs for full-scale treatment of the entire DNAPL zone at Sauget Area 1 using surfactants could potentially range from $200 to $2200 million.

5.1.3 Engineering Considerations

As previously mentioned, this technology requires a significant level of hydraulic control to be effective. This necessitates a large network of injection and recovery wells, as well as extensive characterization of the subsurface flow patterns before and after the placement of wells. In addition, most field scale implementations and demonstrations of this technology have been conducted at depth intervals that are shallower than 15 m below ground surface. Constituents at Sauget Area 1 have been detected at intervals deeper than 30 m below ground surface.

Overall, surfactant/cosolvent addition is one of the most complex of the three technologies considered, both from a chemical and mechanical perspective. To the author's knowledge, full-scale application of this technology to treat a volume the size of the DNAPL Volume at Sauget Area 1 has not been attempted.

5.2 Thermal Treatment

5.2.1 Performance

Thermal treatment is a general term for a variety of approaches designed to destroy or mobilize constituent mass *in situ*. Most methods involve the injection of heat (often in the form of steam) to vaporize and strip volatile compounds. In such cases, vacuum wells are necessary to capture and recover the vapor phase constituents. Higher temperature applications can use thermal conduction to completely boil off all water within the treatment zone, followed by further heating (often > 700°C) to desorb and volatilize semi-volatile compounds. If higher

temperatures are employed, constituents can be completely oxidized or pyrolyzed. The recent performance survey of chlorinated solvent source depletion technologies (McGuire, et al., in review) evaluated six sites where thermal treatment was used, including the Visalia site in California. The median reduction in parent compound concentrations was 96%. No data for daughter product formation was available, though this technology is not expected to generate products unless incomplete oxidation occurs at high temperatures. Applications of this technology required 174 to 320 days. There was no evidence of rebound in concentration following completion, though data was limited to one well for this technology. Therefore, it appears that the technology has been successfully demonstrated at a number of sites, and continued management following completion is minimal.

It is not practical to dewater or completely boil off all water within the saturated zone at Sauget Area 1. For this reason, some thermal treatment methods are not feasible at Sauget Area 1. One thermal treatment approach that does not require dewatering of the saturated zone is a combination of Dynamic Underground Stripping and Hydrous Pyrolysis Oxidation (DUS/HPO). The DUS/HPO process involves the continuous injection of steam and oxygen to heat the aquifer to the boiling point of water and mobilize a portion of the contamination through volatilization and stripping. Recovery of volatilized constituents requires a series of extraction wells. Steam injection can be shut off eventually, allowing the condensing steam to react with remaining constituents (specifically low vapor pressure components). The high temperatures also stimulate oxidation and biological degradation of the constituents. Hydraulic control is used to recover a portion of the overall mass, including mobilized free product and aqueous phase constituents.

The DUS/HPO thermal treatment technology was used at the Visalia site in Visalia, California, to treat pentachlorophenol (PCP), creosote, and diesel (US DOE, 2000). The Visalia site is the best studied of all applications of thermal treatment, and it provides a reasonable basis for comparison in evaluating potential application of this technology at Sauget Area 1. At the Visalia site, thermal treatment was applied over a ~4 acre, ~600,000 cubic yards treatment zone. The constituent profile at Visalia included creosote-type compounds (minimum boiling point of 397°F) and PCP (boiling point of 588°F). During the twenty-five months of operation, approximately 50% of the contaminants were removed in the free phase, 16% as hydrocarbon vapors, 16% in the aqueous phase, and 17% were destroyed by hydrous pyrolysis in situ.

The principal constituents by mass fraction in the DNAPL sample from well BR-I were 1,2,4-trichlobenzene (14%); hexachlorobenzene (1%); and 1,4-dichlorobenzene (0.8%). These chemicals have minimum boiling points of 416°F, 630°F, and 346°F, respectively. Distillation test results using recovered DNAPL from well BR-I indicate that only 5% of the DNAPL has a boiling point at or below 432°F (see laboratory report in Section C.2 of Appendix C). The remaining 83% of the sample volume recovered had a boiling point that fell within the relatively narrow range of 432 to 530°F.

The DNAPL constituents within the fill materials and alluvial aquifer at Sauget Area 1 have relatively high boiling points, which indicates that volatilization is not likely to be the predominant source removal mechanism during thermal treatment using the DUS/HPO technology. Instead

the predominant mass removal mechanism is likely to be pumping of free product, based on results from the Visalia site. Heating of the fill materials and aquifer matrix would reduce interfacial tension and viscosity of residual DNAPL, thereby increasing the potential for the DNAPL to move through the fill and aquifer matrix and be removed by pumping from recovery wells.

The boiling point range for the Sauget Area 1 DNAPL is similar to the boiling point range for the Visalia site, which had creosote type compounds with a minimum boiling point 397°F and PCP with a boiling point of 588°F. Based on the performance of the Visalia system, significant (but not complete) DNAPL recovery could be expected from DUS/HPO treatment at Sauget Area 1.

5.2.2 Cost

A recent review of costs of implementing source depletion technologies (McDade et al. 2005) noted that at six sites where thermal treatment was used, representative unit costs were $48 - $129 per cubic yard of treatment volume (this range represents the 25th to 75th percentile of cost from the six sites). A relatively strong correlation was observed between total treatment cost and the total treatment volume, with the largest site (Visalia) consisting of 600,000 yd^3 of volume. This is the same order of magnitude as the estimated DNAPL Volume at Sauget Area 1, and it means that Sauget Area 1 cost projections can be made for thermal treatment more confidently than for other technologies (i.e., surfactant-enhanced solubilization or chemical oxidation), where treatment of large volumes (hundreds of thousands of cubic yards) has not been attempted.

Energy costs (in terms of the addition of heat) tend to drive total expenses at thermal treatment sites (US DOE, 2000). Because the boiling points of the DNAPLs are similar, energy costs for DUS/HPO at Sauget Area 1 are likely to be the same magnitude as at the Visalia site. Based on the estimated DNAPL Volume of 1.7x10^6 yd^3 at Sauget Area 1, a cost of $80-$220 million could be anticipated if DUS/HPO technology was implemented to remove DNAPL at Sauget Area 1.

5.2.3 Engineering Considerations

Use of the DUS/HPO technology would require generation of large volumes of steam to heat the aquifer, a series of extraction wells for recovery of volatilized constituents, and a series of wells for hydraulic control and for recovery of constituent mass, both as free phase DNAPL and in the aqueous phase. In addition, there are three significant site-specific engineering considerations for applying this technology at Sauget Area 1:

1) The size of the Sauget Area 1 application area would be very large (i.e, two times larger than the application area at the Visalia site);

2) Using the DUS/HPO technology, a significant mass of contaminants could be mobilized as free product. At Sauget Area 1, there is a single ~100 thick saturated zone. Mobilizing large volumes of DNAPL through this thick treatment zone could be very difficult to control without risk of lateral DNAPL migration.

3) The transmissivities of the middle and deep water-bearing units at Sauget Area 1 are relatively high, which could potentially increase the cost and difficulty of the required hydraulic control component of the thermal treatment system.

5.3 Chemical Oxidation

5.3.1 Performance

Chemical oxidation acts to deplete source mass via a chemical reaction between a strong oxidant with a reduced constituent with the goal of directly converting the compound to CO_2. This chemical attack is direct and can be applied as an *in situ* remedial strategy, thus reducing the costs associated with downgradient treatment and/or excavation. Mass destruction occurs through a thermodynamically favorable chemical oxidation in which the contaminant accepts electrons generated from the reduction of the added oxidant. The remaining by-products (water, salts, precipitate) are generally harmless. Common chemicals used for this purpose include hydrogen peroxide (H_2O_2), chloride dioxide (ClO_2), and potassium permanganate ($KMnO_4$). Potassium permanganate has been used for removing drinking water pollutants for several decades, and it has been applied in field demonstrations for removing DNAPL at the Borden site (Schnarr et al., 1998) and at the Portsmouth Gaseous Diffusion Plant in Ohio (U.S. DOE). On this basis, potassium permanganate was the chemical oxidant that was selected for further evaluation at Sauget Area 1.

Compounds identified in the Sauget Area 1 DNAPL include trichlorobenzene, dichlorobenzene, and chlorobenzene. The amount of permanganate needed to completely oxidize these compounds was determined from reaction stoichiometries. On a mass basis, this corresponds to ratios of 7.0 mg of $KMnO_4$ required per mg of trichlorobenzene, 9.3 mg of $KMnO_4$ required per mg of dichlorobenzene, and 13.1 mg of $KMnO_4$ required per mg of chlorobenzene.

Using a DNAPL recovered from another site in Sauget Area (the Solutia Inc. W.G. Krummrich Plant), a bench-scale chemical oxidation treatability test using permanganate was not successful in converting all VOCs to CO_2. The tests yielded ratios ranging from 15.7 to 148.3 g of permanganate needed per g of VOC oxidized, in part because the oxidation reaction was kinetically limited and non-selective. Because the Krummrich DNAPL is generally similar in composition to that recovered at Sauget Area 1 (chlorinated benzenes), it is not expected that chemical oxidation would be an effective source depletion technology at Sauget Area 1.

In the recent performance survey of source depletion technologies (McGuire, et al., in review), the median reduction in parent compound concentrations was 88% at twelve sites studied (23 individual wells), and the reduction in total COCs (parents plus daughter products) was 72%. However, two out of seven sites where a long-term (greater than one year) temporal record was available after treatment show complete rebound in concentrations. There was no evidence that chemical oxidation enhanced or maintained natural attenuation in comparison to other technologies.

The median value for the treatment duration of this technology was 212 days. Therefore, while this technology has been successfully demonstrated at a number of sites, there is concern that continued treatment may be necessary to prevent rebound. Specifically, the amount of oxidant added to the subsurface must be high enough to meet demand (including natural organic matter) and sustained over a long enough period to minimize the potential for rebound.

5.3.2 Cost

A recent review of costs of implementing source depletion technologies (McDade et al, 2005) noted that at 13 sites where chemical oxidation was used, representative unit costs were $47 - $194 per cubic yard of treatment volume (this range represents the 25th to 75th percentile of cost from the 13 sites). This unit cost reflects both capital costs and operation and maintenance costs incurred per cubic yard of aquifer material, without regard to the amount of groundwater pumped during the remedial period. No correlation was observed between total treatment cost and the total treatment volume. All total costs for treatment fell within the range of $0.1 to $1.3 million, with the largest site roughly 26,000 yd^3. This is 65 times lower than the DNAPL Volume at Sauget Area 1, and it is not certain that the unit costs would remain independent of treatment volume at this level. In particular, the capital costs associated with injection and recovery wells would be expected to increase significantly for a larger implementation of this technology. The bulk unit cost of potassium permanganate is roughly $2/lb, meaning that any uncertainties in oxidant demand has to potential to unfavorably multiply the supply costs.

Based on the estimated DNAPL Volume of 1.7x10^6 yd^3 at Sauget Area 1, an estimated cost of $80 - $330 million could be anticipated using chemical oxidation.

5.3.3 Engineering Considerations

Effective oxidant delivery requires significant hydraulic control in the subsurface. Recirculation can be considered to re-use unreacted oxidant, but this increases costs related to well placement. In addition, the formation of solid precipitate during the oxidation process can necessitate the use of a downstream removal mechanism prior to reinjection. If recirculation is not used, off-site migration of oxidant is possible.

Soil analysis at Sauget Area 1 has demonstrated that organic carbon content (as measured by total organic carbon) exceeds 0.1% in many intervals, and the oxidant demand will increase accordingly in these regions. The amenability of the unidentified fraction of the recovered DNAPL from well BR-I (approximately 80% by mole fraction) to chemical oxidation is unknown, and addressing this portion may require higher oxidant loadings. At these higher loadings, well and matrix clogging become more important factors. For all applications of this technology, oxidant delivery must be carefully monitored and varied when necessary to ensure adequate performance and reliability. The incidence of rebound at a number of field sites suggests that long-term monitoring following the initial treatment is necessary.

5.4 Dissolution

Dissolution of contaminants into the aqueous phase was considered as a baseline condition for remediation of the DNAPL source area. Estimates of persistence of contamination and time scales required for clean-up can be generated, and this provides a comparison case for natural attenuation and pump-and-treat remediation strategies. As described in the treatability test report (see Appendix G), dissolution tests were conducted using soil collected during the recent drilling program at Sauget Area 1. Site soil was added to bench-scale columns to model flow-through conditions in an aquifer. Dissolution was quantified in terms of the mass of constituents recovered per pore volume pumped through the column, or the number of pore volumes required to reach clean-up goals. Soil from the following borings and depth intervals was used: A1-8 (22.5-25 ft); A1-8 (70-72.5 ft); and A1-14 (25-27.5 ft).

Over the course of 50 pore volumes, passive dissolution resulted in depletion of total contaminant mass, but only minimal changes in total COC concentration were observed, suggesting that dissolution rates reached steady-state within a short period following the initiation of pumping. After 50 pore volumes, the total COC concentrations had decreased but within a range of only 10 to 30%. The flat concentration profile over time is consistent with studies that indicate that concentration changes in soil matrices containing NAPL are dependent on mass removal, and that significant changes in concentration are generally preceded by large changes in source mass (Newell and Adamson, 2004; Sale and McWhorter, 2001). In the case of the three soil samples used to create these columns, the total mass of COC present initially can be estimated using previous analyses of the core, and this mass can be compared to the cumulative mass in the effluent over time. After pumping 50 pore volumes, this percent removal of COCs ranged from 0.38 to 35%.

Analysis of the rate of concentration change versus pore volumes (see Appendix G) was performed, and indicated that at a minimum 740 pore volumes, and potentially 2800 would be required for natural dissolution to treat the DNAPL zone. This analysis ignored one dissolution test column with no measurable decrease in concentration after 50 pore volume flushes.

5.5 Results of Source Depletion Technology Evaluations

Section 5.0 evaluated three source depletion technologies: surfactant-enhanced solubilization, thermal treatment, and chemical oxidation. Thermal treatment will be carried forward for the remedial alternatives evaluation in the revised Engineering Evaluation / Cost Analysis (EE/CA), in spite of the engineering challenges and significant costs that would be associated with use of thermal treatment at Sauget Area 1. Thermal treatment has potential for greater DNAPL mass removal compared to surfactant-enhanced solubilization or chemical oxidation.

Based on a review of costs of implementing source depletion technologies (McDade, et. al, 2005), the largest treatment volumes in this survey for surfactant-enhanced solubilization and chemical oxidation were 7,000 cubic yards and 26,000 cubic yards, respectively. Thermal treatment has been applied at one site (Visalia) where the treatment volume was ~600,000

cubic yards, the same order of magnitude as the estimated DNAPL Volume of 1,700,000 cubic yards at Sauget Area 1.

6.0 REFERENCES

General References

Adrian Brown, 2001. Engineering Evaluation/Cost Analysis, Remedial Investigation/ Feasibility Study, Sauget Area 1, Volume 1, Revision 2, September 28, 2001.

CH2M Hill, 2005a. Review of *Results of DNAPL Characterization and Remediation Study* for Sauget Area 1, Sauget, Illinois. CH2M Hill, March 24, 2005.

CH2M Hill, 2005b. Review of *Response to March 2005 USEPA Comments on the DNAPL Report* for Sauget Area 1, Sauget, Illinois. CH2M Hill, July 12, 2005.

GSI, 2004. Workplan for DNAPL Characterization and Remediation Study, Sauget Area 1 Sites. Groundwater Services, Inc., April 1, 2004.

GSI, 2005a. Results of DNAPL Characterization and Remediation Study, Sauget Area 1 Sites. Groundwater Services, Inc., January 21, 2005.

GSI, 2005b. Response to March 2005 USEPA Comments on the DNAPL Characterization and Remediation Study, Sauget Area 1 Sites. Groundwater Services, Inc., May 27, 2005.

GSI, 2005c. Scope and Schedule for Supplemental DNAPL Investigation, Sauget Area 1 Sites. Groundwater Services, Inc., August 2, 2005.

Roux Associates, 2001. Engineering Evaluation/Cost Analysis, Remedial Investigation/ Feasibility Study, Sauget Area 1, Revision 1, June 8, 2001.

References Pertaining to DNAPL Treatability Tests

Abriola, L.M., K.D. Pennell, G.A. Pope, T.J. Dekker, and D.J. Luning-Prak, 1995. “Impact of Surfactant Flushing on the Solubilization and Mobilization of Dense Non-Aqueous Phase Liquids. Chapter 2 in *Surfactant-Enhanced Subsurface Remediation*, ACS Symposium Series, ACS, Washington, D.C.

Newell, C.J. and D.T. Adamson. “Planning-level source decay models to evaluate impact of source depletion on remediation timeframe”, Submitted to *Environmental Science and Technology*, October, 2004.

Edwards, D.A., R.G. Luthy, and Z. Liu, 1991. “Solubilization of polycyclic aromatic hydrocarbons in micellar nonionic surfactant solutions”, *Environ. Sci. Technol.*, Vol. 25, p. 127-133.

GSI, 2001. Source Evaluation Study, Sauget Area 1. Groundwater Services, Inc., May 21, 2001.

McDade, J.M., T.M. McGuire, and C.J. Newell, 2004. "Cost of Source Depletion at Chlorinated Solvent Sites: Results from 34 Sites", Abstract submitted for the Battelle 8th International In Situ and On Site Biomediation Symposium, Baltimore, MD, June 2005.

McGuire, T.M. and J.B. Hughes, 2003. "Effects of Surfactants on the Dechlorination of Chlorinated Ethenes", Environmental Toxicology and Chemistry, Vol. 22, p. 2630-2638.

Pankow, J.F. and J.A. Cherry, 1996. *Dense Chlorinated Solvents and other DNAPLs in Groundwater*, Waterloo Press, Waterloo, Ontario.

Schnarr, M., C. Truax, G. Farquhar, E. Hood, T. Gonullu, and B. Stickney, 1998. "Laboratory and Controlled Field Experiments using Potassium Permanganate to Remediate Trichloroethylene and Perchloroethylene DNAPLs in Porous Media", Journal of Contaminant Hydrology, Vol. 29, p. 205-224.

Simpkin, T., T. Sale, B. Kueper, M. Pitts, and K. Wyatt, 1999. *Surfactants and Cosolvents for NAPL Remediation: A Technology Practices Manual*, Lewis Publishers, Boca Raton, FL.

U.S. Department of Energy, 2000. "Hydrous Pyrolysis Oxidation/Dynamic Underground Stripping", Innovative Technology Summary Report. DOE/EM-0504.

U.S. Environmental Protection Agency, 2004. *How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers*. EPA 510-R-04-002.

Wiedermeier, T.H., H.S. Rifai, C.J. Newell, and J.T. Wilson, 1999. *Natural Attenuation of Fuel Hydrocarbons and Chlorinated Solvents*, John Wiley and Sons, New York, NY.

Yin, Y. and H.E. Allen, 1999. "In Situ Chemical Treatment", Technology Evaluation Report prepared for Groundwater Remediation Technlogy Analysis Center, Pittsburgh, PA.

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TABLES

Table 1 Results of May 2004 NAPL Survey

Table 2 Results of October 2004 NAPL Survey

Table 3 Results of September 2005 NAPL Survey

Table 4 Summary of Measurements and Observations at BR-I

Table 5 Measurements After Termination of Recovery Test at BR-I

Table 6 Results of Soil Core Inspection and Testing

GROUNDWATER SERVICES, INC.

Table 1
Results of May 2004 NAPL Survey
Sauget Area 1
Sauget and Cahokia, Illinois

Well I.D.	Measured Depth to Water (ft below toc)	Measured Total Depth (ft below toc)	Measurements or Observations of LNAPL or DNAPL?
EE-01	13.23	34.96	No
EE-03	15.65	34.94	No
EE-04	17.04	19.94	No
EE-05	16.64	22.15	No
EE-11	(see Note 2)	23.12	**Yes - LNAPL (see Note 2)**
EE-20	15.95	30.45	No
EEG-101	17.56	19.93	No
EEG-102	13.90	22.05	No
EEG-106	**	**	**
EEG-107	15.55	32.04	No
EEG-108	11.32	23.97	No
EEG-109	**	**	**
EEG-110	13.61	25.33	No
EEG-112	13.15	22.30	No
P1-A-S	Dry	22.05	No
P1-A-M	23.65	40.21	No
P1-A-D	23.60	59.74	No
P1-B-S	20.24	21.19	No
P1-B-M	20.83	42.67	No
P1-B-D	20.72	62.71	No
P1-C-S	Dry	19.51	No
P1-C-M	21.00	42.30	No
P1-C-D	21.06	62.11	No
P2-A-S	16.89	20.94	No
P2-A-M	16.60	41.49	No
P2-A-D	16.92	62.59	No
P2-B-S	12.47	12.68	No
P2-B-M	12.45	42.60	No
P2-B-D	12.60	62.44	No
P2-C-S	12.42	15.83	No
P2-C-M	13.49	41.53	No
P2-C-D	13.84	61.13	No
P3-A-S	Dry	16.80	No
P3-A-M	17.20	42.05	No
P3-A-D	17.35	62.05	No
P3-B-S	15.04	16.10	No
P3-B-M	14.80	41.36	No
P3-B-D	15.20	57.10	No
P3-C-S	14.29	18.29	No
P3-C-M	16.12	41.58	No
P3-C-D	16.16	61.99	No
ST-G-S	Dry	12.43	No
ST-G-M	12.33	44.53	No
ST-G-D	12.60	79.99	No
ST-H-S	Dry	8.98	No
ST-H-M	8.40	42.73	No
ST-H-D	8.87	79.38	No

GROUNDWATER SERVICES, INC.

Table 1
Results of May 2004 NAPL Survey
Sauget Area 1
Sauget and Cahokia, Illinois

Well I.D.	Measured Depth to Water (ft below toc)	Measured Total Depth (ft below toc)	Measurements or Observations of LNAPL or DNAPL?
ST-I-S	14.00	15.07	No
ST-I-M	13.78	45.15	No
ST-I-D	13.63	79.09	No
ST-N-S	**	**	**
ST-N-M	8.37	41.69	No
ST-N-D	8.19	78.68	No
BR-G	16.45	135.08	**Yes - DNAPL (see Note 3)**
BR-H	15.14	117.68	No
BR-I	17.52	151.11	**Yes - DNAPL (see Note 4)**

Notes:
1) ** = Water level and or NAPL measurement could not be conducted due to bent well casing or subsurface obstruction.
2) Well EE-11 contained approximately 8 to 9 feet of LNAPL. Measured depth to top of LNAPL was 13.82 feet on May 17, 2004. A total of approximately one gallon of LNAPL was removed during a recovery test conducted on May 19, 2004.
3) There was no measurable thickness of DNAPL in BR-G. There was some evidence of the presence of a minor amount of DNAPL in BR-G, based on inspection of a cotton string and a clear bailer lowered to the bottom of the well. A DNAPL recovery test was attempted at this location. No DNAPL or DNAPL droplets were noted in the produced fluids.
4) DNAPL was found in well BR-I. See Table 4 for summary of DNAPL measurements and observations at BR-I.

GROUNDWATER SERVICES, INC.

Table 2
Results of October 2004 NAPL Survey
Sauget Area 1
Sauget and Cahokia, Illinois

Well I.D.	Measured Depth to Water (ft below toc)	Measured Total Depth (ft below toc)	Measurements or Observations of LNAPL or DNAPL?
EE-11	13.73	23.05	Yes - LNAPL (see Note 1)
A1-1	14.76	115.23	No
A1-2	13.41	115.10	No
A1-3	16.91	118.24	No
A1-4	15.61	117.57	No
A1-5	14.57	117.30	No
A1-6	15.93	118.41	No
A1-7	15.23	117.02	No
A1-8	17.02	117.62	Yes - DNAPL (see Note 2)
A1-9	12.73	116.72	No
A1-10	17.29	119.01	No
A1-11	18.73	123.81	No
A1-12	11.88	119.50	No
A1-13	14.70	117.73	No
A1-14	19.95	125.06	No
A1-15	12.15	116.23	No
A1-16	15.79	124.68	No
A1-17	15.83	27.98	No
A1-18	14.90	119.40	No
BR-G	15.72	135.03	Yes - DNAPL (see Note 3)
BR-H	14.64	119.30	No
BR-I	16.41	148.75	Yes - DNAPL (see Note 4)

Notes:
1) EE-11 showed some evidence of a small amount of LNAPL. Brown staining was noted on the interface probe and on the outer surface of a bailer lowered to just below the water table. Small droplets of NAPL were observed inside the bailer. LNAPL recovery was attempted using a clear bailer. Only water was recovered. There was no LNAPL in the produced fluids.
2) A1-08 showed limited evidence of a small amount of DNAPL, based on the presence of dark brown droplets of DNAPL seen in the bottom end of the bailer lowered to the base of the well.
3) At well BR-G, a sheen was noted on the bottom 3.5 ft of a weighted string lowered to the bottom of the well. A bailer lowered to the bottom of the well contained mostly water, but there were droplets of NAPL within the bottom 2 inches of the bailer. A DNAPL recovery test was attempted on October 30, 2004, and approx. 40 gallons of fluids were recovered. Only water was recovered. No NAPL was visible in produced fluids. Small droplets of NAPL were visible in the bottom few feet of the Waterra tubing when the tubing was removed from the well at the end of the test.
4) DNAPL was found in well BR-I. See Table 4 for summary of DNAPL measurements and observations at BR-I.
5) The measurements listed on this table were recorded by GSI field staff on October 26-27, 2004.

GROUNDWATER SERVICES, INC.

Table 3
Results of September 2005 NAPL Survey
Sauget Area 1
Sauget and Cahokia, Illinois

Well I.D.	Measured Depth to Water (ft below toc)	Measured Total Depth (ft below toc)	Measurements or Observations of LNAPL or DNAPL?
EE-11	14.72	23.05	Yes - LNAPL (see Note 1)
A1-1	15.76	115.02	No
A1-2	14.43	114.88	No
A1-3	17.91	118.55	No
A1-4	16.64	118.10	No
A1-5	15.60	117.05	No
A1-6	17.03	118.82	No
A1-7	16.26	117.52	No
A1-8	18.02	117.32	No
A1-9	13.84	116.65	No
A1-10	18.35	118.59	No
A1-11	19.84	123.65	No
A1-12	12.93	119.42	No
A1-13	15.64	117.68	No
A1-14	20.90	125.01	No
A1-15	13.14	116.01	No
A1-16	16.78	125.14	No
A1-17	16.99	27.98	No
A1-18	15.98	120.44	No
BR-G	17.01	133.47	Yes - DNAPL (see Note 2)
BR-H	15.69	118.58	No
BR-I	17.68	148.67	Yes - DNAPL (see Note 3)

Notes:
1) Well EE-11 had some evidence of the presence of a small amount of LNAPL. Approx. 1 inch of brown staining was noted on the interface probe. The outer surface of the bailer also had LNAPL staining. Approximately 1.5 quarts of water mixed with globules of NAPL was recovered on September 29, 2005 using a peristaltic pump.
2) At well BR-G, staining was noted on the bottom 3.5 ft of a weighted string lowered to the bottom of the well. A bailer lowered to the bottom of the well came back with 3.25 ft of staining, and there was DNAPL at the bottom of the bailer. A DNAPL recovery test was attempted on September 29, 2005, and approx. 65 gallons of fluids were recovered. Only water was recovered. No NAPL was visible in produced fluids. Small droplets of NAPL were visible on inside surface of Waterra tubing when tubing was removed from the well at the end of the test.
3) DNAPL was found in well BR-I. See Table 4 for summary of DNAPL measurements and observations at BR-I.
4) The measurements listed on this table were recorded by GSI field staff on September 20, 27, and 28, 2005.

GROUNDWATER SERVICES, INC.

Table 4
DNAPL Observations at BR-I, May 2004 to November 2005
Sauget Area 1, Sauget and Cahokia, Illinois

May 2004 (GSI) – NAPL Survey and Recovery Test
Interface probe: DTW 17.52 ft btoc. TD 151.11 ft btoc. Solid tone absent – no DNAPL indicated by probe. Weighted string: Dark brown spots and minor discontinuous staining on bottom 9 ft of string. Bailer to TD: Brown staining on bailer surface. Approx. 1/8 inch of DNAPL in bottom of bailer. Inferred depth to DNAPL (prior to recovery test): 142 ft btoc or **140 ft bgs.** Recovery test (Waterra, electric-powered actuator): Eight gallons of water recovered. No NAPL visible in produced fluids.
October 2004 (GSI) – NAPL Survey and Recovery Test
Interface probe: DTW 16.41 ft btoc. TD 148.75 ft btoc. Solid tone absent – no DNAPL indicated by probe. Weighted string: Dark brown spots on bottom 9 ft of string. Bailer to TD: Brown staining on bailer surface. No DNAPL in bottom of bailer. Inferred depth to DNAPL (prior to recovery test): 140 ft btoc or **138 ft bgs.** Recovery test (Waterra, electric-powered actuator): Approx. 50 gallons of fluids, including estimated 15 gallons of DNAPL, recovered during eight hours of pumping on October 28-29. Flow rate was very low near end of test.
July 2005 (URS) – Fluid Level Measurements during Regional Water Level Survey
Interface probe: DTW 14.55 ft btoc. Solid tone 139.11 ft btoc. TD 151.13 ft btoc. Apparent product, odor observed when probe was inspected. Inferred depth to DNAPL: 139 ft btoc or **137 ft bgs**.
September 27-29, 2005 (GSI) – NAPL Survey and Recovery Test
Interface probe: DTW 17.68 ft bgs. TD 148.67 ft btoc. Solid tone absent – no DNAPL indicated. However, bottom 9 ft of probe had NAPL film. Weighted string: NAPL staining on bottom 10.75 ft of string. Bailer to TD: Entire length of bailer stained on outside. Inferred depth to DNAPL (prior to recovery tests): 140 ft btoc or **138 ft bgs.** Recovery test (Waterra, gasoline-powered actuator): Test performed Sept. 27-29. Flowrate was low. When pumping was terminated at 0955 on Sept. 29, final DTW was 108.84 ft btoc. Total fluids recovery 100 gallons. The volume of DNAPL produced was not determined with certainty.
September 30, 2005 (GSI) – Well Brushing and Air-Lift Pumping
Well Brushing and air-lift pumping: Initial DTW was 67.56 ft btoc at 0810 on Sept. 30. The 2-inch diameter wire brush was oily when removed from well. Oily fluids were recovered during air-lift pumping. Clean heated water was added to well several times during pumping, with total volume of 75 gallons added. Final flowrate 0.06 gpm. Final DTW 122.03 ft btoc. Total fluids recovery 125 gallons, including an estimated 13 gallons of DNAPL (based on approx. 7.5 inches of DNAPL in a 22.5-inch diameter drum).
October 5, 2005 (GSI and Colog) – Downhole Geophysical Surveys
Optical televiewer: DTW visible at 27.5 ft bgs. DNAPL interface visible at 114.5 ft bgs. Fluid temperature/conductivity probe: Conductivity decreased sharply at 114.5 ft bgs. Inferred depth to DNAPL: **114.5 ft bgs.**

GROUNDWATER SERVICES, INC.

Table 4
DNAPL Observations at BR-I, May 2004 to November 2005
Sauget Area 1, Sauget and Cahokia, Illinois

October 21, 2005 (GSI) – NAPL Survey and Recovery Test
Interface probe: DTW 23.41 ft btoc. Solid tone 121.35 ft btoc. Staining visible on probe end when lowered to that depth.
Bailer to DNAPL interface: Bailer was lowered to 124 ft btoc, and staining was seen on inside/outside of bailer, except for top 3 inches of bailer.
Inferred depth to DNAPL (prior to recovery test): 121 ft btoc or **119 ft bgs.**
Recovery test (air-lift pumping): Recovered only water with pump intake at 105 ft and 115 ft btoc. Recovered mostly water with some globules of DNAPL with intake at 120 ft btoc. Recovered water then pure product when with intake at 125 ft btoc. Final intake depth 145 ft btoc. Flowrates decreased as test continued. Final measured flowrate 0.05 gpm. Total of 8 gallons of DNAPL collected in plastic buckets during recovery test.
October 21 – November 10 , 2005 (GSI and URS) – Measurements of Fluid Levels for 20 days after Recovery Test
Water level measurements: DTW was 99 ft btoc when first measured on October 21 approximately 1.5 hours after pumping of BR-I ended. Water levels rose slowly over the next 20 days but had still not recovered to static conditions as of November 10 (see Table 5).
DNAPL measurements and observations: On October 24, interface probe tone and staining indicated apparent thickness of < 6 inches of DNAPL. Probe measurements and observations on October 27, November 1, and November 10 indicated depth to DNAPL of approximately 107 ft btoc (see Table 5).
Inferred depth to DNAPL (October 27, November 1, and November 10): 107-108 ft btoc or **105-106 ft bgs.**

Calculations of Inferred Top of DNAPL or DNAPL Volume in BR-I
1) The 4-inch diameter Schedule 80 PVC casing at BR-I extends to a depth of 124.75 ft bgs, and has a reported diameter of 3.5 inches, according to the Colog survey). The open borehole below the PVC casing at BR-I has diameter of approximately 2.5 inches and is approximately 22 feet long.
Casing volume (gallons) = (0.25) * (PI) * (casing diameter, ft)^2 * (casing length, ft) * (7.48 gal / ft^3)
Using the above equation, the open borehole at BR-I (diameter of 2.5 inches, length of 22 ft) has a calculated volume of 5.5 gallons (or 0.25 gal/ft). On a per foot basis, the PVC casing at BR-I (diameter of 3.5 inches, length of one foot) has a calculated volume of 0.50 gal / ft of PVC casing.
2) Recovery Test, October 2004: An estimated 15 gallons of DNAPL were recovered. Using the above conversion factors, if 15 gallons of DNAPL were present, approximately 5.5 gallons would be in the open borehole, and the remaining 9.5 gallons would extend approximately 19 ft above the base of the PVC casing (i.e., 9.5 gallons / 0.50 gal/ft). The bottom of the PVC casing is at approximately 124.75 ft bgs, so top of DNAPL would theoretically be at approximately 106 ft bgs, (or 108 ft btoc).
3) Colog Survey, October 5, 2005: Apparent top of DNAPL was 114.5 ft bgs. This would suggest the presence of 5.5 gallons of DNAPL in the open borehole and 5.1 gallons of above the base of the PVC casing (i.e., (124.75 ft – 114.5 ft) * 0.5 gal/ft). Theoretical DNAPL volume would be 10.6 gallons.
4) Recovery Test, October 21, 2005: An estimated 8 gallons of DNAPL were recovered. If 8 gallons of DNAPL were present, approximately 5.5 gallons would be in the open borehole, and the remaining 2.5 gallons would extend approximately 5 ft above the base of the PVC casing (i.e., 2.5 gallons / 0.50 gal/ft). The bottom of the PVC casing is at approximately 124.75 ft bgs, so top of DNAPL would theoretically be at approximately 120 ft bgs (or 122 ft btoc).

Notes:

1) The top of the PVC casing at BR-I extends approximately 2.2 ft above ground surface.
2) The above calculations of inferred top of DNAPL or DNAPL volume are based on the assumption that substantially all of the DNAPL that is pumped out during a recovery test comes from storage within the open borehole or the PVC casing and that none of the pumped DNAPL comes from the surrounding rock.
3) DTW = depth to water. TD = total depth. btoc = below top of casing. bgs = below ground surface.

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TABLE 5
Measurements at BR-I and A1-19
October 21 - November 10, 2005
Sauget Area 1, Sauget and Cahokia, Illinois

Date	Time (hrs)	Depth to Water (ft btoc)		Depth to DNAPL (ft btoc)		Notes and Observations by Field Personnel
		BR-I	A1-19	BR-I	A1-19	
10/21/09	1535	-	17.24		<6 inch thick	Bottom 5 inches of interior of bailer stained with DNAPL.
(GSI)		-	-			
10/22/09	830	23.41	-	121.35		
(GSI)	915	-	(A1-19 pumped)	-	-	A1-19 was pumped from 0915 to 1145 for well development.
	1210	(BR-I pumped)	-	-	-	BR-I was pumped from 1210 to 1320 and from 1420 to 1500 for DNAPL recovery.
	1500	-	-	-	-	Pumping terminated at BR-I at 1500. No measurement was taken due to bad battery in probe.
	1630	99.0	-	-	-	First measurement taken after probe battery was replaced.
	1640	98.5	-	-	-	
	1705	97.7	-	-	-	
10/25/09	1015	46.60	-	-	-	
	1415	43.08	-	-	-	
	1800	40.33	-	-	-	
10/26/09	900	38.75	-	<6 inch thick		Interface probe only. Solid tone at the bottom and staining present on probe.
	905	-	17.51		<6 inch thick	Interface probe only. Solid tone at the bottom and staining present on probe.
	1300	38.10	-	-	-	
	1700	37.42	-	-	-	
	1705	-	17.50	-	-	
10/27/09	900	35.53	-	-	-	
	905	-	17.50	-	-	
	1300	34.89	-	-	-	
	1600	34.55	-	-	-	
	1605	-	17.49	-	-	
10/28/09	900	33.08	-	-	-	
	1100	33.06	-	107-108		Interface probe only. Solid tone and black staining present on the probe.
	1110	-	17.49		<6 inch thick	Interface probe only. Solid tone at the bottom and staining present on probe.
	1300	32.93	-	106.7		Interface probe showed 107-108 ft and bailer showed 106.7 ft below top casing.
	1600	32.85	-	-	-	
10/29/09	900	32.39	-	-	-	
	1600	32.20	-	-	-	
11/2/09	900	29.76	-	-	-	
	1315	29.69	-	106.8		Interface probe showed 107-108 ft and the staining on the probe showed 106.8 ft.
	1330	-	17.59		117.4	Interface probe showed 118 ft and the staining on the probe showed 117.40 ft.
11/3/09	1300	29.30	-	-	-	
	1315	-	17.59	-	-	
11/4/09	1300	28.91	-	-	-	
	1315	-	17.59	-	-	

GROUNDWATER SERVICES, INC.

TABLE 5
Measurements at BR-I and A1-19
October 21 - November 10, 2005
Sauget Area 1, Sauget and Cahokia, Illinois

Date	Time (hrs)	Depth to Water (ft btoc)		Depth to DNAPL (ft btoc)		Notes and Observations by Field Personnel
		BR-I	A1-19	BR-I	A1-19	
11/8/09	1300	28.60	-	-	-	
	1315	-	17.79	-	-	
11/9/09	1300	28.52	-	107		
	1315	-	17.79	-	-	
11/10/09	1300	28.45	-	-	-	
	1315	-	17.79	-	-	
11/11/09	1340	28.37	-	107		Interface probe showed 107 ft. The bailer did not go to the bottom but a sample was collected of the DNAPL. It was thick and dark black.
		-	-			
	1400	-	17.79		115	Interface probe showed 115 ft. The bailer and rope also showed 115 ft. The DNAPL sample in the bailer was thin, very fluid and black. Both the probe and the bailer showed the DNAPL floating 1 foot above the bottom.
		-	-			
		-	-			

Notes:

1) GSI field staff collected the measurements on 10/20 and 10/21/05. URS field staff collected all other measurements shown on this table.
2) Depth to water measurements in BR-I ranged from 14.6 ft to 17.7 ft btoc in the five survey events in 2004-2005 that occurred after BR-I had been left undisturbed for at least two months (i.e., the measurement events in May and October 2004 and in July and September 2005).
3) The casing stickup for BR-I is 2.2 ft above ground surface. The casing stickup for A1-19 is 2.0 ft above ground surface.

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-01	0-2.5	No	-	10	Negative	-	0.054	ND	90000
	2.5-5	No	-	8	Negative	Negative	-	-	-
	5-7.5	No Recovery							
	7.5-10								
	10-12.5	No	-	10	Negative	Negative	-	-	-
	12.5-15	No	-	31	Negative	Negative	0.42	-	-
	15-17.5	**Sheen**	Slight	-	Negative	Split Spoon Core Collected			
	17.5-20	No	Slight	8	Negative	**Black**	-	-	-
	20-22.5	No	Slight	10	Negative	-	-	-	10000
	22.5-25	No	No	12	Negative	Negative	-	-	-
	25-27.5	No	No	12	Negative	-	0.049	ND	740
	27.5-30	No	No	11	Negative	Negative	-	-	-
	30-32.5	No	No	9	Negative	-	-	-	-
	32.5-35	No	No	8	Negative	Negative	-	-	-
	35-37.5	No	No	10	Negative	-	0.019	ND	1100
	37.5-40	No	No	9	Negative	Negative	-		-
	40-42.5	No	No	11	Negative	-	0.01	ND	1800
	42.5-45	No	No	11	Negative	Negative	-	-	-
	45-47.5	No	No	9	Negative	-	-	-	-
	47.5-50	No	No	8	Negative	Negative	-	-	-
	50-52.5	No	No	11	Negative	-	0.0088	ND	500
	52.5-55	No	No	11	Negative	Negative	-	-	-
	55-57.5	No	No	8	Negative	-	-	-	-
	57.5-60	No	No	8	Negative	Negative	-	-	740
	60-62.5	No Recovery							
	62.5-65								
	65-67.5	No	No	10	Negative	-	-	-	-
	67.5-70	No	No	11	Negative	Negative	0.011	ND	900
	70-72.5	No	No	9	Negative	-			
	72.5-75	No	No	9	Negative	Negative	0.016	ND	860
	75-77.5	No	No	8	Negative	-	-	-	-
	77.5-80	No	No	9	Negative	Negative	-	-	-
	80-82.5	No	No	10	Negative	-	-	-	-
	82.5-85	No	No	10	Negative	Negative	0.015	ND	4500
	85-87.5	No	No	10	Negative	-	-	-	-
	87.5-90	No	No	11	Negative	Negative	-	-	-
	90-92.5	No	No	11	Negative	-	-	-	1400
	92.5-95	No	No	9	Negative	Negative	-	-	-
	95-97.5	No	No	9	Negative	-	-	-	-
	97.5-100	No	No	11	Negative	Negative	ND	ND	<1000
	100-102.5	No	No	11	Negative	-	-	-	-
	102.5-105	No	No	10	Negative	Negative	-	-	-
	105-107.5	No	No	12	Negative	-	ND	ND	400
	107.5-110	No Recovery							
	110-112.5								

See notes on page 19

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-02	0-2.5	No	No	0	Negative	-	-	-	-
	2.5-5	No	No	9	Negative	Negative	-	-	-
	5-7.5	No	Slight	41	Negative	-	-	-	-
	7.5-10	No	Yes	537	Negative	Negative	746	1100	39000
	10-12.5	No	Yes	345	Negative	-			
	12.5-15	No	Slight	276	Negative	Negative	298	2900	200000
	15-17.5	**Sheen**	Slight	44	Negative	-	-	-	-
	17.5-20	No	Slight	64	Negative	Negative	-	-	-
	20-22.5	No	Slight	32	Negative	Negative	-	-	860
	22.5-25	No	Slight	50	Negative	-	1.8	16	2800
	25-27.5	No	Slight	38	Negative	Negative	-	-	-
	27.5-30	No	No	49	Negative	-	-	-	-
	30-32.5	No	No	70	Negative	Negative	-	-	-
	32.5-35	No	No	59	Negative	-	0.74	ND	600
	35-37.5	No	Slight	30	Negative	-	-	-	-
	37.5-40	No	Yes	48	Negative	Negative	-	-	-
	40-42.5	No	Yes	8	Negative	-	-	-	-
	42.5-45	No	Slight	27	Negative	Negative	-	-	-
	45-47.5	No	Slight	18	Negative	-	-	-	-
	47.5-50	No	Slight	47	Negative	Negative	0.75	0.31	470
	50-52.5	No	Yes	471	Negative	-	13	68	880
	52.5-55	No	No	52	Negative	Negative	-	-	-
	55-57.5	Split Spoon Core Collected		21	Split Spoon Core Collected				
	57.5-60	No	Yes	233	Negative	**Red droplets**	-	-	-
	60-62.5	No	Yes	192	Negative	-	-	-	-
	62.5-65	No	Yes	-	Negative	**Pink coating**	29	31	440
	65-67.5	No	Yes	121	Negative	-	-	-	-
	67.5-70	No	Slight	114	Negative	**Pink coating**	-	-	-
	70-72.5	No	No	28	Negative	-	-	-	420
	72.5-75	No	No	33	Negative	Negative	-	-	-
	75-77.5	No	Slight	18	Negative	-	1.1	1.1	<1000
	77.5-80	No	Slight	14	Negative	Negative	-	-	-
	80-82.5	No	Slight	2	Negative	-	-	-	-
	82.5-85	No	Slight	13	Negative	**Dense layer**	0.94	9.3	3000
	85-87.5	No	No	13	Negative	-	-	-	-
	87.5-90	No	Slight	1	Negative	Negative	-	-	-
	90-92.5	No	Slight	1	Negative	-		0.14	<1000
	92.5-95	No	Slight	0	Negative	Negative	-	-	-
	95-97.5	No	No	0	Negative	-	-	-	-
	97.5-100	No	No	0	Negative	Negative	-	-	-
	100-102.5	No	No	0	Negative	-	-	-	-
	102.5-105	No	No	0	Negative	Negative	0.67		
	105-107.5	No	No	0	Negative	Negative	0.24	0.037	<1000

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-03	0-2.5	No	No	2	Negative	Negative	-	-	-
	2.5-5	No	No	0	Negative	-	-	-	-
	5-7.5	**Oily coating**	Yes	0	Negative	Negative	-	-	-
	7.5-8.5	**Oily coating**	Yes	236	Negative	-	-	-	-
	8.5-11	**Oily coating**	Yes	331	Negative	-	8.1	29	42000
	11-13.5	**Oily coating**	Faint	47	Negative	**Clear layer**	1.6	82	49000
	13.5-16	No	Faint	25	Negative	-	-	-	-
	16-18	No	No	8	Negative	Negative	-	-	-
	18-20	No	No	5	Negative	-	-	-	5400
	20-22.5	No	No	3	Negative	Negative	-	-	-
	22.5-25	No	No	5	Negative	-	0.37	0.28	5500
	25-27.5	No	No	2	Negative	Negative	-	-	-
	27.5-30	No	No	1	Negative	-	-	-	-
	30-32.5	No	No	0	Negative	Negative	-	-	-
	32.5-35	No	No	0	Negative	-	0.016	0.031	920
	35-37.5	No	No	0	Negative	Negative	-	-	-
	37.5-40	No	No	0	Negative	-	-	-	-
	40-42.5	No	No	0	Negative	Negative	-	-	-
	42.5-45	No	No	1	Negative	-	-	-	-
	45-47.5	No	No	1	Negative	Negative	-	-	-
	47.5-50	No	No	2	Negative	-	0.013	0.59	650
	50-52.5	No	No	1	Negative	Negative	-	-	<1000
	52.5-55	No	No	1	Negative	-	-	-	-
	55-57.5	No	No	0	Negative	Negative	-	-	-
	57.5-60	No	No	0	Negative	-	0.02	ND	520
	60-62.5	No	No	1	Negative	Negative	0.0085	0.11	920
	62.5-65	No	No	0	Negative	-	-	-	-
	65-67.5	No	No	0	Negative	Negative	-	-	-
	67.5-70	No	No	0	Negative	-	-	-	-
	70-72.5	No	No	0	Negative	Negative	-	-	-
	72.5-75	No	No	0	Negative	-	0.0089	0.14	1400
	75-77.5	No	No	0	Negative	Negative	-	-	3600
	77.5-80	No	No	0	Negative	-	-	-	-
	80-82.5	No	No	0	Negative	Negative	-	-	-
	82.5-85	No	No	0	Negative	-	0.0084	0.15	1300
	85-87.5	Split Spoon Core Collected							
	87.5-90								
	90-92.5	No	No	0	Negative	Negative	-	-	-
	92.5-95	No	No	0	Negative	-	0.037	ND	2900
	95-97.5	No	No	0	Negative	Negative	-	-	-
	97.5-100	No	No	0	Negative	-	-	-	-
	100-102.5	No	No	0	Negative	Negative	-	-	-
	102.5-105	No	No	0	Negative	-	0.011	ND	550
	105-107.5	No	No	0	-	-	-	-	-
	107.5-110	No	No	3.8	-	Negative	-	-	-
	110-112.5	No Recovery							
	112.5-115								

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-04	0-2.5	No	-	65	Negative	Negative	-	-	-
	2.5-5	No	-	129	Negative	-	-	-	-
	5-7.5	No	-	94	Negative	Negative	-	-	-
	7.5-10	No	-	122	Negative	-	7	35	59000
	10-12.5	No	-	115	Negative	Negative	-	-	-
	12.5-15	No	-	136	Negative	-	0.0076	2.1	16000
	15-17.5	Split Spoon Core Collected							
	17.5-20	No	-	91	Negative	Negative	-	-	-
	20-22.5	No	-	68	Negative	-	0.014	0.038	1500
	22.5-25	No	-	19	Negative	Negative	-	-	540
	25-27.5	Split Spoon Core Collected							
	27.5-30	No	Faint	19	Negative	Negative	-	-	-
	30-32.5	No	No	15	Negative	-	-	-	-
	32.5-35	No	No	11	Negative	Negative	-	-	-
	35-37.5	No	No	40	Negative	-	0.053	0.031	1600
	37.5-40	No	No	24	Negative	Negative	-	-	-
	40-42.5	No	No	15	Negative	-	ND	ND	1100
	42.5-45	No	No	12	Negative	Negative	-	-	-
	45-47.5	No	No	9	Negative	-	-	-	-
	47.5-50	No	No	8	Negative	Negative	-	-	-
	50-52.5	No	No	6	Negative	-	-	-	-
	52.5-55	No	No	5	Negative	Negative	-	-	510
	55-57.5	Split Spoon Core Collected							
	57.5-60	No	No	6	Negative	Negative	0.031	0.024	1200
	60-62.5	No	No	7	Negative	Negative	-	-	-
	62.5-65	No	No	7	Negative	-	-	-	-
	65-67.5	No	No	8	Negative	Negative	-	-	-
	67.5-70	No	No	11	Negative	-	0.01	0.024	1300
	70-72.5	No	No	14	Negative	Negative	ND	0.026	840
	72.5-75	No	No	8	Negative	-	-	-	-
	75-77.5	Split Spoon Core Collected							
	77.5-80	No	No	6	Negative	Negative	-	-	-
	80-82.5	No	No	15	Negative	-	ND	ND	410
	82.5-85	No	No	3	Negative	Negative	-	-	2500
	85-87.5	No	No	8	Negative	-	-	-	-
	87.5-90	No	No	13	Negative	Negative	-	-	-
	90-92.5	No	No	11	Negative	-	-	-	-
	92.5-95	No	No	15	Negative	Negative	ND	ND	520
	95-97.5	No	No	10	Negative	-	-	-	-
	97.5-100	No	No	6	Negative	Negative	-	-	-
	100-102.5	No	No	10	Negative	-	-	-	-
	102.5-105	No	No	12	Negative	Negative	-	-	-
	105-107.5	No	No	12	Negative	-	ND	ND	1200
	107.5-110	No	No	10	Negative	Negative	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-05	0-2.5	No	No	2	Negative	-	0.067	0.24	4700
	2.5-5	No	No	0	Negative	Negative	-	-	-
	5-7.5	No	No	0	Negative	-	-	-	-
	7.5-10	No	No	0	Negative	Negative	-	-	-
	10-12.5	No	No	0	Negative	-	-	-	2000
	12.5-15	No	No	4	Negative	Negative	0.01	0.1	1100
	15-17.5	No	No	1	Negative	-	-	-	-
	17.5-20	No	No	0	Negative	Negative	-	-	-
	20-22.5	No	No	1	Negative	-	-	-	-
	22.5-25	No	No	1	Negative	Negative	-	-	-
	25-27.5	No	No	11	Negative	-	0.038	0.036	2000
	27.5-30	No	No	0	Negative	Negative	-	-	-
	30-32.5	No	No	8	Negative	-	0.033	0.049	420
	32.5-35	No	No	4	Negative	Negative	-	-	-
	35-37.5	No	No	1	Negative	-	-	-	-
	37.5-40	No	No	0	Negative	Negative	-	-	1400
	40-42.5	No	No	3	Negative	-	0.012	0.022	1100
	42.5-45	No	No	1	Negative	Negative	-	-	-
	45-47.5	No	No	2	Negative	-	-	-	-
	47.5-50	No	No	1	Negative	Negative	-	-	-
	50-52.5	No	No	1	Negative	-	0.092	ND	30000
	52.5-55	No	No	0	Negative	Negative	-	-	-
	55-57.5	No	No	0	Negative	-	-	-	-
	57.5-60	No	No	0	Negative	Negative	-	-	-
	60-62.5	No	No	0	Negative	-	-	-	-
	62.5-65	No	No	0	Negative	Negative	-	-	-
	65-67.5	No	No	1	Negative	-	0.0032	ND	660
	67.5-70	No	No	0	Negative	Negative	-	-	-
	70-72.5	No	No	0	Negative	-	-	-	-
	72.5-75	No	No	0	Negative	Negative	-	-	1700
	75-77.5	No	No	1	Negative	-	-	-	-
	77.5-80	No	No	1	Negative	Negative	0.037	ND	2200
	80-82.5	No	No	0	Negative	-	-	-	-
	82.5-85	No Recovery							
	85-87.5	No	No	0	Negative	-	0.015	ND	1100
	87.5-90	No	No	0	Negative	Negative	-	-	-
	90-92.5	No Recovery							
	92.5-95								
	95-97.5	No	No	0	Negative	-	0.017	ND	780
	97.5-100	No	No	0	Negative	Negative	-	-	-
	100-102.5	No	No	0	Negative	-	-	-	-
	102.5-105	No	No	0	Negative	Negative	-	-	-
	105-107.5	No	No	0	Negative	-	0.02	ND	480
	107.5-110	No	No		Negative	Negative	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-06	0-2.5	No	No	16	Negative	-	-	-	-
	2.5-5	No	No	18	Negative	Negative	0.041	6.1	12000
	5-7.5	No Recovery							
	7.5-10								
	10-12.5								
	12.5-15								
	15-17.5	**Oily black coating**	-	218	Negative	-	59	480	62000
	17.5-20	No	-	607	Negative	**Red ball**	-	-	-
	20-22.5	**Oily black coating**	-	223	Negative	-	-	-	-
	22.5-25	**Oily black coating**	-	-	-	-	-	-	-
	25-27.5	No	-	226	Negative	**Black**	-	-	-
	27.5-30	**Sheen**	-	597	Negative	-	840	240	5000
	30-32.5	No	-	978	Negative	-	25	72	7500
	32.5-35	No	-	327	Negative	Negative	-	-	-
	35-37.5	No	Slight	154	Negative	-	-	-	480
	37.5-40	No	Slight	264	Negative	Negative	-	-	-
	40-42.5	No	Slight	117	Negative	-	5.6	1.6	750
	42.5-45	No	Slight	87	Negative	Negative	-	-	-
	45-47.5	No	Slight	70	Negative	-	-	-	-
	47.5-50	No	Slight	79	Negative	Negative	-	-	-
	50-52.5	No	Slight	69	Negative	-	1.5	-	-
	52.5-55	No	Slight	57	Negative	Negative	-	-	-
	55-57.5	No	Slight	28	Negative	-	-	-	-
	57.5-60	No	Slight	28	Negative	Negative	-	-	-
	60-62.5	No	Slight	70	Negative	-	-	-	-
	62.5-65	No	Slight	52	Negative	Negative	-	-	-
	65-67.5	No	Slight	51	Negative	-	-	-	-
	67.5-70	No	Slight	75	Negative	Negative	3.7	2.8	2900
	70-72.5	No	Yes	91	Negative	Negative	36	2	3700
	72.5-75	No	Slight	26	Negative	-	-	-	-
	75-77.5	No	Slight	3	Negative	-	-	-	3200
	77.5-80	No	Slight	3	Negative	Negative	-	-	-
	80-82.5	No Recovery							
	82.5-85								
	85-87.5	No	Slight	18	Negative	-	0.0031	0.52	610
	87.5-90	No	Slight	14	Negative	Negative	-	-	-
	90-92.5	No Recovery							
	92.5-95								
	95-97.5	No	No	11	Negative	-	-	-	-
	97.5-100	No	No	6	Negative	Negative	0.023	0.1	<1000
	100-102.5	No	Slight	13	Negative	-	-	-	410
	102.5-105	No	Slight	13	Negative	Negative	-	-	-
	105-107.5	No	Slight	13	Negative	-	ND	1.2	790
	107.5-110	No	Slight	11	Negative	Negative	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-07	0-2.5	No	-	9	Negative	Negative	-	14	20000
	2.5-5	No	-	0	Negative	-	0.026	-	-
	5-7.5	No	-	0	Negative	Negative	-	-	-
	7.5-10	No	-	0	Negative	-	-	-	-
	10-12.5	No	-	0	Negative	Negative	20	2.9	7900
	12.5-15	No	-	0	Negative	-	-	-	7600
	15-17.5	Split Spoon Core Collected							
	17.5-20	No	-	0	Negative	Negative	-	-	-
	20-22.5	No	-	34	Negative	-	8.3	3.2	9100
	22.5-25	No	-	14	Negative	Negative	-	-	-
	25-27.5	No	No	10	Negative	Negative	-	-	-
	27.5-30	No	No	9	Negative	-	-	-	-
	30-32.5	No	No	14	Negative	Negative	-	-	-
	32.5-35	No	No	9	Negative	-	-	-	-
	35-37.5	No	No	14	Negative	Negative	0.063	0.07	570
	37.5-40	No	No	11	Negative	-	-	-	-
	40-42.5	No	No	7	Negative	Negative	-	-	-
	42.5-45	No	No	4	Negative	-	-	-	-
	45-47.5	Split Spoon Core Collected							
	47.5-50	No	No	6	Negative	**Red spots**	ND	ND	2300
	50-52.5	No	No	3	Negative	-	-	-	760
	52.5-55	No	No	8	Negative	Negative	ND	ND	450
	55-57.5	No	No	4	Negative	-	-	-	-
	57.5-60	No	No	13	Negative	Negative	-	-	-
	60-62.5	No	No	13	Negative	-	-	-	-
	62.5-65	No	No	11	Negative	Negative	-	-	620
	65-67.5	No	No	11	Negative	-	-	-	-
	67.5-70	No	No	10	Negative	**Red spots**	0.02	0.23	1400
	70-72.5	No	No	14	Negative	-	-	-	-
	72.5-75	No Recovery							
	75-77.5	No	No	17	Negative	**Red spots**	ND	ND	<1000
	77.5-80	No	No	13	Negative	-	-	-	-
	80-82.5	No	No	20	Negative	Negative	-	-	-
	82.5-85	No	No	16	Negative	-	-	-	-
	85-87.5	Split Spoon Core Collected							
	87.5-90	No	No	4	Negative	**Red spots**	0.03	0.76	2400
	90-92.5	No	No	13	Negative	-	-	-	-
	92.5-95	No	No	8	Negative	Negative	-	-	-
	95-97.5	No	No	11	Negative	-	-	-	-
	97.5-100	No	No	14	Negative	Negative	ND	0.37	<1000
	100-102.5	No	No	15	Negative	-	0.003	0.17	1400
	102.5-105	No	No	10	Negative	Negative	-	-	-
	105-107.5	No	No	10	Negative	-	-	-	-
	107.5-110	No	No	8	Negative	Negative	-	-	-
	110-112.5	No	No	-	Negative	-	0.004	ND	1100

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-08	0-2.5	No	No	1.1	Negative	Negative	-	-	-
	2.5-5	No	No	242	Negative	Negative	-	-	32000
	5-7.5	No	No	957	Negative	Negative	1844	270	35000
	7.5-10	No	No	713	Negative	Negative	-	-	-
	10-12.5	**Oily**	Yes	308	Negative	**Pink bead**	976	510	13000
	12.5-15	**Oily**	Yes	280	Negative	**Pink bead**	-	-	-
	15-17.5	**Oily**	Yes	271	Negative	**Red film**	-	-	-
	17.5-20	-	Yes	189	Negative	**Red film**	-	-	-
	20-22.5	**Oily film**	Yes	185	Negative	Negative	-	-	-
	22.5-25	**Oily film**	Yes	224	Negative	Negative	262	28000	54000
	25-27.5	**Oily film**	Split Spoon Core Collected						
	27.5-30	**Oily film**							
	30-32.5	No	Yes	348	Negative	**Red film**	35	75	1400
	32.5-35	No	Yes	339	Negative	**Red film**	-	-	-
	35-37.5	Split Spoon Core Collected							
	37.5-40								
	40-42.5	**Oily film**	Yes	302	Negative	**Red film**	-	-	-
	42.5-45	**Oily film**	Yes	399	Negative	**Red film**	-	-	-
	45-47.5	**Oily film**	Yes	434	Negative	**Red spots**	-	-	-
	47.5-50	**Oily film**	Yes	296	Negative	**Red spots**	50	230	3000
	50-52.5	**Oily film**	Yes	379	Negative	**Red spots**	-	-	-
	52.5-55	**Oily film**	Yes	240	Negative	**Pink bead**	-	-	-
	55-57.5	**Oily film**	Split Spoon Core Collected						
	57.5-60	No	Yes	402	Negative	**Pink bead**	6.6	54	1700
	60-62.5	No	Yes	532	Negative	**Pink bead**	34	49	1900
	62.5-65	No	No	598	Negative	**Pink bead**	-	-	-
	65-67.5	No	No	285	Negative	**Red spots**	-	-	-
	67.5-70	No	No	326	Negative	**Red spots**	-	-	-
	70-72.5	No	Yes	539	Negative	**Pink bead**	11	1000	7600
	72.5-75	No	Yes	419	Negative	**Pink bead**	-	-	-
	75-77.5	No	Yes	286	Negative	**Pink bead**	-	-	-
	77.5-80	No	Yes	131	Negative	**Red spots**	-	-	-
	80-82.5	No	Yes	121	Negative	**Red spots**	-	-	920
	82.5-85	No	Yes	262	Negative	**Pink bead**	2.4	370	3300
	85-87.5	Split Spoon Core Collected							
	87.5-90	No	Yes	122	Negative	**Pink bead**	-	-	-
	90-92.5	No	Yes	232	Negative	**Pink bead**	1.5	21	480
	92.5-95	No	Yes	155	Negative	**Pink bead**	-	-	-
	95-97.5	No	No	198	Negative	**Pink bead**	-	-	-
	97.5-100	No	No	181	Negative	**Pink bead**	-	-	-
	100-102.5	No	No	173	Negative	**Pink bead**	-	-	-
	102.5-105	No	No	195	Negative	**Pink bead**	1.7	29	740
	105-107.5	No	No	61	Negative	**Red spots**	-	-	-
	107.5-110	No	No	67	Negative	Negative	-	-	-
	110-112.5	No	No	118	Negative	Negative	-	-	-

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GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-09	0-2.5	No	No	55	Negative	Negative	-	-	-
	2.5-5	No	No	29	Negative	Negative	-	-	-
	5-7.5	No	Yes	54	Negative	Negative	0.24	0.11	13000
	7.5-10	No	No	12	Negative	Negative	-	-	-
	10-12.5	No	No	9	Negative	Negative	-	-	-
	12.5-15	No	No	7	Negative	-	-	-	5600
	15-17.5	Split Spoon Core Collected							
	17.5-20	No	No	12	Negative	Negative	0.15	ND	15000
	20-22.5	No	No	51	Negative	-	-	-	-
	22.5-25	No	No	47	Negative	**Red spots Pink bead**	-	-	-
	25-27.5	**Oil staining**	Yes	383	Negative	**Pink bead**	168	12	1000
	27.5-30	No	Yes	343	Negative	**Red spots**	-	-	-
	30-32.5	No	Yes	239	Negative	-	-	-	-
	32.5-35	No	Yes	225	Negative	**Pink bead**	198	0.28	670
	35-37.5	No		44	Negative	Negative	-	-	630
	37.5-40	No		133	Negative	Negative	-	-	-
	40-42.5	No		86	Negative	Negative	-	-	-
	42.5-45	No		165	Negative	Negative	22	0.14	1700
	45-47.5	Split Spoon Core Collected							
	47.5-50	No	Yes	61	Negative	Negative	-	-	-
	50-52.5	No	Yes	76	Negative	Negative	-	-	-
	52.5-55	No		177	Negative	Negative	-	-	-
	55-57.5	No	Yes	88	Negative	**Red spots Pink bead**	-	-	-
	57.5-60	No		163	Negative	**Red spots Pink bead**	4.4	0.088	660
	60-62.5	No	Yes	78	Negative	Negative	-	-	-
	62.5-65	No	Yes	26	Negative	Negative	-	-	-
	65-67.5	No		50	Negative	**Pink bead**	2.7		440
	67.5-70	No		37	Negative	Negative	-	-	-
	70-72.5	No		32	Negative	Negative	-	-	-
	72.5-75	No		15	Negative	Negative	-	-	2800
	75-77.5	Split Spoon Core Collected							
	77.5-80	No	Faint	28	Negative	**Red spots**	3.1	0.097	1100
	80-82.5	No	Faint	42	Negative	-	-	-	-
	82.5-85	No	Faint	41	Negative	Negative	1.6	0.14	420
	85-87.5	No	No	27	Negative	-	-	-	-
	87.5-90	No	No	15	Negative	Negative	-	-	-
	90-92.5	No	No	12	Negative	-	-	-	-
	92.5-95	No	No	25	Negative	Negative	0.52	1.1	<1000
	95-97.5	No	No	3	Negative	-	-	-	-
	97.5-100	No	No	1	Negative	Negative	-	-	-
	100-102.5	No	No	2	Negative	-	-	-	-
	102.5-105	No	No	4	Negative	Negative	-	-	-
	105-107.5	No	No	6	Negative	-	1.2	3.2	1100
	107.5-110	No	No	4	Negative	Negative	-	-	-
	110-112.5	No	No		Negative	-	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-10	0-2.5	No	-	9	Negative	Negative	-	-	-
	2.5-5	No	-	8	Negative	-	-	-	-
	5-7.5	No	-	8	Negative	Negative	0.11	39	13000
	7.5-10	No Recovery							
	10-12.5								
	12.5-15								
	15-17.5								
	17.5-20								
	20-22.5	No	-	2	Negative	Negative	0.96	0.14	16000
	22.5-25	No	-	3	Negative	-	-	-	-
	25-27.5	No	No	6	Negative	Negative	-	-	6500
	27.5-30	No	No	5	Negative	-	-	-	-
	30-32.5	No	No	5	Negative	Negative	-	-	-
	32.5-35	No	No	5	Negative	-	-	-	-
	35-37.5	No	No	9	Negative	Negative	ND	0.22	1100
	37.5-40	No	No	6	Negative	-	-	-	-
	40-42.5	No	No	8	Negative	Negative	0.0034	0.22	1500
	42.5-45	No	No	6	Negative	Negative	-	-	-
	45-47.5	Split Spoon Core Collected							
	47.5-50	No	No	3	Negative	Negative	-	-	810
	50-52.5	No	No	5	Negative	-	-	-	-
	52.5-55	No	No	3	Negative	Negative	-	-	-
	55-57.5	No	No	7	Negative	-	-	-	-
	57.5-60	No	No	9	Negative	Negative	ND	0.02	600
	60-62.5	No	No	8	Negative	-	-	-	-
	62.5-65	No	No	7	Negative	Negative	-	-	-
	65-67.5	No	No	8	Negative	-	0.002	ND	950
	67.5-70	No	No	8	Negative	Negative	-	-	-
	70-72.5	No Recovery							
	72.5-75								
	75-77.5	No	No	6	Negative	-	ND	0.11	710
	77.5-80	No	No	10	Negative	Negative	-	-	-
	80-82.5	No	No	7	Negative	-	0.0042	ND	1200
	82.5-85	No	No	8	Negative	Negative	-	-	1300
	85-87.5	No	No	8	Negative	-	-	-	-
	87.5-90	No	No	5	Negative	Negative	-	-	-
	90-92.5	No	No	9	Negative	-	ND	ND	1400
	92.5-95	No	No	2	Negative	Negative	-	-	-
	95-97.5	No	No	2	Negative	-	-	-	-
	97.5-100	No	No	3	Negative	Negative	-	-	-
	100-102.5	No	No	5	Negative	-	-	-	-
	102.5-105	No	No	6	Negative	Negative	-	-	-
	105-107.5	No	No	7	Negative	-	ND	ND	660
	107.5-110	No	No	7	Negative	Negative	-	-	-
	110-112.5	-	-	-	-	-	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-11	0-2.5	No	No	2	Negative	-	-	-	-
	2.5-5	No	No	1	Negative	Negative	-	-	-
	5-7.5	No	No	8	Negative	-	0.023	1.1	820
	7.5-10	No	No	5	Negative	Negative	-	-	-
	10-12.5	No	No	22	Negative	-	0.023	0.24	2200
	12.5-15	No	No	11	Negative	Negative	-	-	-
	15-17.5	No Recovery							
	17.5-20								
	20-22.5	No	No	19	Negative	-	0.027	0.049	-
	22.5-25	No	No	7	Negative	Negative	-	-	-
	25-27.5	No	No	4	Negative	-	-	-	880
	27.5-30	No	No	15	Negative	Negative	-	-	-
	30-32.5	No	No	14	Negative	-	0.016	0.058	620
	32.5-35	No	No	13	Negative	Negative	-	-	-
	35-37.5	No	No	15	Negative	-	-	-	-
	37.5-40	No	No	15	Negative	Negative	-	-	-
	40-42.5	No	No	5	Negative	-	0.013	0.028	880
	42.5-45	No	No	4	Negative	Negative	-	-	-
	45-47.5	No	No	-	Negative	-	-	-	-
	47.5-50	No	No	16	Negative	-	-	-	-
	50-52.5	No	No	15	Negative	Negative	-	-	-
	52.5-55	No	No	15	Negative	-	-	-	-
	55-57.5	No Recovery							
	57.5-60	No	No	16	Negative	-	0.021	ND	750
	60-62.5	No	No	16	Negative	Negative	-	-	600
	62.5-65	No	No	17	Negative	-	0.012	ND	820
	65-67.5	No Recovery							
	67.5-70	No	No	11	Negative	Negative	-	-	-
	70-72.5	No	No	16	Negative	-	-	-	-
	72.5-75	No	No	14	Negative	Negative	0.02	ND	620
	75-77.5	No	No	11	Negative	-	-	-	-
	77.5-80	No	No	6	Negative	Negative	-	-	-
	80-82.5	No	No	-	Negative	-	-	-	-
	82.5-85	No	No	8	-	-	0.03	ND	<1000
	85-87.5	No Recovery							
	87.5-90	No	No	7	Negative	Negative	-	-	-
	90-92.5	No	No	0	Negative	-	-	-	-
	92.5-95	No	No	5	Negative	Negative	0.02	ND	400
	95-97.5	No	No	3	Negative	-	-	-	-
	97.5-100	No	No	1	Negative	Negative	-	-	1300
	100-102.5	No Recovery							
	102.5-105	No	No	1	Negative	**Red specks**	0.015	ND	<1000
	105-107.5	No	No	0	Negative	-	-	-	-
	107.5-110	No	No	0	Negative	Negative	-	-	-
	110-112.5	No Recovery							
	112.5-115								

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-12	0-2.5	No	No	0	Negative	-	-	-	-
	2.5-5	No	No	0	Negative	Negative	-	-	-
	5-7.5	No	No	0	Negative	-	-	-	-
	7.5-10	No	No	2	Negative	Negative	1.1	0.46	3200
	10-12.5	No	No	0	Negative	-	-	-	-
	12.5-15	No	No	10	Negative	Negative	0.38	ND	4200
	15-17.5	No	No	0	Negative	-	-	-	-
	17.5-20	No	No	0	Negative	Negative	-	-	5200
	20-22.5	No	No	0	Negative	-	-	-	-
	22.5-25	No	No	2	Negative	Negative	0.063	ND	1100
	25-27.5	No	No	0	Negative	-	-	-	-
	27.5-30	No	No	6	Negative	Negative	-	-	-
	30-32.5	No	No	9	Negative	-	-	-	-
	32.5-35	No	No	6	Negative	Negative	-	-	-
	35-37.5	No	No	-	Negative	-	-	-	-
	37.5-40	No	No	32	Negative	Negative	2.6	ND	460
	40-42.5	No	No	116	Negative	-	-	-	-
	42.5-45	No	No	97	Negative	Negative	-	-	-
	45-47.5	No	Slight	33	Negative	-	-	-	-
	47.5-50	No	Slight	117	Negative	Negative	5.2	0.028	720
	50-52.5	No	Slight	74	Negative	-	-	-	-
	52.5-55	No	Slight	82	Negative	Negative	47	0.46	3200
	55-57.5	No	Slight	36	Negative	-	-	-	3800
	57.5-60	No	Slight	39	Negative	Negative	-	-	-
	60-62.5	No	No	65	Negative	-	-	-	-
	62.5-65	No	No	99	Negative	Negative	5.1	0.32	3200
	65-67.5	Split Spoon Core Collected							
	67.5-70	No	No	36	Negative	Negative	-	-	-
	70-72.5	No	No	23	Negative	-	-	-	-
	72.5-75	No	No	32	Negative	Negative	1.8	0.069	400
	75-77.5	No	No	3	Negative	-	-	-	-
	77.5-80	No	No	7	Negative	Negative	-	-	-
	80-82.5	No	No	36	Negative	-	3.1	0.05	520
	82.5-85	No	No	4	Negative	Negative	-	-	-
	85-87.5	No	Slight	0	Negative	-	-	-	-
	87.5-90	No	Slight	0	Negative	Negative	-	-	480
	90-92.5	No	Slight	0	Negative	-	-	-	-
	92.5-95	No	Slight	0	Negative	Negative	-	-	-
	95-97.5	No	Slight	0	Negative	-	-	-	-
	97.5-100	No	Slight	0	Negative	Negative	0.085	0.081	480
	100-102.5	No	Slight	0	Negative	-	-	-	-
	102.5-105	No	Slight	24	Negative	Negative	-	-	-
	105-107.5	No	Slight	27	Negative	-	-	-	-
	107.5-110	No	Slight	15	Negative	Negative	-	-	-
	110-112.5	No	Slight	60	Negative	-	0.59	58	780

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-13	0-2	No	-	0	Negative	-	-	-	-
	2-4	No	-	0	Negative	Negative	8.6	1.6	50000
	4-6.5	No Recovery							
	6.5-9								
	9-11.5	No	-	0	Negative	-	-	-	-
	11.5-14	**Oily black material**	-	34	Negative	**Black**	134	710	170000
	14-16.5	No Recovery							
	16.5-19	**Oily black material**	Yes	42	Negative	**Black**	-	-	-
	19-21.5	**Oily brown liquid**	Yes	133	Negative	**Red layer**	193	170	26000
	21.5-24	No	Yes	313	Negative	**Red layer**	-	-	-
	24-26.5	**Sheen**	Yes	167	Negative	Negative	-	-	-
	26.5-29	No	Yes	44	Negative	Negative	-	-	820
	29-31.5	No	Yes	17	Negative	-	-	-	-
	31.5-34	No	Yes	15	Negative	Negative	-	-	-
	34-36.5	No	Yes	3	Negative	-	-	-	-
	36.5-39	No	Yes	0	Negative	Negative	0.075	0.059	480
	39-41.5	No	Yes	0	Negative	-	-	-	-
	41.5-44	No	Yes	0	Negative	Negative	-	-	-
	44-46.5	No	Slight	0	Negative	-	-	-	-
	46.5-49	No	Slight	0	Negative	Negative	-	-	-
	49-51.5	No	Slight	0	Negative	-	-	-	-
	51.5-54	No	No	0	Negative	Negative	-	-	-
	54-56.5	No	Slight	0	Negative	-	-	-	-
	56.5-59	No	Slight	0	Negative	Negative	-	-	-
	59-61.5	No	Slight	0	Negative	-	-	-	1600
	61.5-64	No	Slight	0	Negative	Negative	-	-	-
	64-66.5	No	Slight	0	Negative	-	0.51	ND	1500
	66.5-69	No	Slight	0	Negative	Negative	-	-	-
	69-71.5	No	No	0	Negative	-	-	-	-
	71.5-74	No Recovery							
	74-76.5	No	Slight	0	Negative	-	-	-	<1000
	76.5-79	No	Slight	0	Negative	Negative	0.061	ND	<1000
	79-81.5	No Recovery							
	81.5-84								
	84-86.5								
	86.5-89								
	89-91.5								
	91.5-94								
	94-96.5								
	96.5-99								
	99-101.5	No	No	0	Negative	-	-	-	-
	101.5-104	No	No	0	Negative	Negative	-	-	-
	104-106.5	No	No	0	Negative	-	-	-	-
	106.5-109	No	No	0	Negative	Negative	0.0057	ND	<1000
	109-111.5	No	No	0	Negative	-	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-14	0-2.5	No	-	3	Negative	-	-	-	-
	2.5-5	No	-	153	Negative	-	18	52	42000
	5-7.5	No	-	37	Saturated	-	-	-	-
	7.5-10	No	-	92	Saturated	**Slight pink**	-	-	-
	10-12.5	No	-	234	Saturated	**Foamy**	-	-	-
	12.5-15	No	-	235	Saturated	**Foamy**	138	550	28000
	15-17.5	No	Strong	218	Saturated	**Foam with layer**	-	-	-
	17.5-20	No	Strong	100	Saturated	**Foam with layer**	-	-	-
	20-22.5	**Brown liquid**	Strong	26	Negative	-	-	-	1200
	22.5-25	No	Strong	78	Negative	**Foam**	-	-	-
	25-27.5	**Black liquid**	Strong	171	Saturated	-	84	3100	12000
	27.5-30	**Brown liquid**	Strong	178	Saturated	**Black layer**	-	-	-
	30-32.5	No	Strong	176	Saturated	**Product layer**	-	-	-
	32.5-35	No	Strong	152	Saturated	**Pink foam**	-	-	-
	35-37.5	**Free product layer**	Strong	124	-	**Pink**	-	-	-
	37.5-40	**Free product layer**	Strong	128	-	**Red sheen**	25	520	3400
	40-42.5	**Free product layer**	Strong	226	Saturated	**Pink coating**	-	-	-
	42.5-45	No	Strong	177	Saturated	**Pink coating**	-	-	-
	45-47.5	**Black staining**	-	105	Saturated	**Pink coating**	1.2	54	1600
	47.5-50	**Black staining**	-	40	Saturated	**Black layer**	-	-	930
	50-52.5	**Black staining**	-	64	Saturated	**Pink coating**	-	-	-
	52.5-55	No	-	77	Saturated	**Pink coating**	-	-	-
	55-57.5	No	-	18	Saturated	**Pink coating**	-	-	-
	57.5-60	No	-	85	Saturated	**Slight pink**	0.63	31	780
	60-62.5	No	-	51	Saturated	Negative	0.68	3.1	1100
	62.5-65	No	-	5	Negative	Negative	-	-	480
	65-67.5	**Sheen**	-	14	Negative	**Pink coating**	-	-	-
	67.5-70	**Brown liquid**	-	-	Negative	**Pink coating**	-	-	-
	70-72.5	No	-	42	Negative	**Pink coating**	-	-	-
	72.5-75	No	-	44	Negative	**Pink coating**	ND	3.4	<1000
	75-77.5	No Recovery							
	77.5-80								
	80-82.5								
	82.5-85								
	85-87.5	**Brown liquid**	-	32	Negative	-	0.63	88	500
	87.5-90	**Brown liquid**	-	0	Negative	**Red layer**	-	-	-
	90-92.5	**Brown liquid**	-	0	Negative	**Black layer**	-	-	-
	92.5-95	**Free product layer**	-	36	Negative	**Black layer**	ND	220	2300
	95-97.5	No Recovery							
	97.5-100	**Free product layer**	-	27	Negative	**Red**	-	-	-
	100-102.5	**Free product layer**	Strong	47	Negative	**Red**	-	-	-
	102.5-105	**Free product layer**	Strong	11	Negative	**Red**	ND	360	1000
	105-107.5	**Free product layer**	-	37	Negative	**Red**	-	-	-
	107.5-110	No	-	34	Negative	**Red**	-	-	-
	110-112.5	**Staining**	-	26	Negative	**Red**	-	-	-
	112.5-115	-	-	29	-	**Red**	0.99	1800	1500
	115-117.5	-	-	66	-	Negative	-	-	-

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TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-15	0-2.5	No	No	2	Negative	-	-	-	-
	2.5-5	No	No	2	Negative	Negative	-	-	-
	5-7.5	No	No	2	Negative	-	-	-	-
	7.5-10	No	No	2	Negative	Negative	0.027	ND	8100
	10-12.5	No	No	3	Negative	-	-	-	-
	12.5-15	No	No	3	Negative	Negative	-	-	6400
	15-17.5	No	No	3	Negative	-	0.46	ND	1300
	17.5-20	No	No	3	Negative	Negative	-	-	-
	20-22.5	No	No	3	Negative	-	-	-	-
	22.5-25	No	No	3	Negative	Negative	-	-	-
	25-27.5	No	No	3	Negative	-	0.01	ND	440
	27.5-30	No	No	2	Negative	Negative	-	-	-
	30-32.5	No	No	5	Negative	-	-	-	-
	32.5-35	No	No	0	Negative	Negative	0.016	ND	700
	35-37.5	No	No	5	Negative	-	-	-	-
	37.5-40	No	No	4	Negative	Negative	-	-	-
	40-42.5	No	No	4	Negative	-	-	-	-
	42.5-45	No	No	1	Negative	Negative	-	-	670
	45-47.5	No	No	5	Negative	-	0.14	0.034	760
	47.5-50	No	No	4	Negative	Negative	-	-	-
	50-52.5	No	No	6	Negative	-	0.11	ND	<1000
	52.5-55	No	No	-	Negative	Negative	-	-	-
	55-57.5	No	No	1	Negative	-	-	-	-
	57.5-60	No	No	1	Negative	Negative	-	-	-
	60-62.5	No	No	1	Negative	-	0.33	0.049	900
	62.5-65	No Recovery							
	65-67.5	Split Spoon Core Collected							
	67.5-70	No	Slight	0	Negative	Negative	-	-	-
	70-72.5	No	Slight	0	Negative	-	-	-	-
	72.5-75	No Recovery							
	75-77.5	No	No	0	Negative	-	-	-	480
	77.5-80	No	No	6	Negative	Negative	0.026	0.12	450
	80-82.5	No Recovery							
	82.5-85								
	85-87.5	No	No	1	Negative	-	0.047	0.046	<1000
	87.5-90	No	No	1	Negative	Negative	-	-	-
	90-92.5	No	No	0	Negative	-	0.02	0.12	<1000
	92.5-95	No Recovery							
	95-97.5								
	97.5-100								
	100-102.5	No	No	1	Negative	-	-	-	-
	102.5-105	No	No	3	Negative	Negative	-	-	-
	105-107.5	No	Slight	3	Negative	-	0.06	0.34	990
	107.5-110	No	Slight	1	Negative	Negative	-	-	-
	110-112.5	No	Yes	1	Negative	-	-	-	-

See notes on page 19

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-16	0-2.5	No	No	1	Negative	-	-	-	-
	2.5-5	No	Yes	12	Negative	**Pink ball**	-	-	-
	5-7.5	No	Yes	16	Negative	**Dark**	2	9.8	26000
	7.5-10	No	Slight	9	Negative	**Pink coating**	-	-	11000
	10-12.5	No	Slight	26	Negative	**Red droplets**	-	-	-
	12.5-15	**Free product**	Slight	15	Negative	**Pink ball**	-	-	-
	15-17.5	No	Slight	18	Negative	-	-	-	-
	17.5-20	No	Slight	31	Negative	Negative	3.3	0.99	6100
	20-22.5	No	No	48	Negative	-	-	-	-
	22.5-25	No	No	35	Negative	Negative	-	-	-
	25-27.5	No	Slight	49	Negative	-	-	-	-
	27.5-30	No	Slight	91	Negative	Negative	7.1	5.3	760
	30-32.5	No	Slight	25	Negative	-	-	-	-
	32.5-35	No	Slight	34	Negative	Negative	-	-	-
	35-37.5	No	Slight	50	Negative	-	3	0.88	1400
	37.5-40	No	Slight	49	Negative	Negative	-	-	-
	40-42.5	No	Slight	25	Negative	-	-	-	-
	42.5-45	No	Slight	98	Negative	Negative	3.2	0.93	1300
	45-47.5	No	Slight	4	Negative	-	-	-	-
	47.5-50	No	Slight	4	Negative	Negative	-	-	-
	50-52.5	No	Slight	17	Negative	Negative	4.3	1.4	4100
	52.5-55	No	Slight	7	-	-	-	-	-
	55-57.5	No	Slight	11	-	-	-	-	-
	57.5-60	No	Slight	11	Negative	Negative	-	-	-
	60-62.5	No	Slight	8	Negative	-	1.3	0.066	500
	62.5-65	No	Slight	80	Negative	Negative	-	-	-
	65-67.5	No	Slight	4	Negative	-	-	-	-
	67.5-70	No	Slight	3	Negative	-	-	-	-
	70-72.5	No	Slight	3	Negative	-	-	-	650
	72.5-75	No	Slight	4	Negative	-	-	-	-
	75-77.5	No	No	14	Negative	-	0.025	0.031	<1000
	77.5-80	No	No	14	Negative	Negative	-	-	-
	80-82.5	No	No	10	Negative	-	-	-	-
	82.5-85	No	No	13	Negative	Negative	-	-	-
	85-87.5	No	No	17	Negative	-	-	-	-
	87.5-90	No	No	17	Negative	Negative	0.023	0.2	560
	90-92.5	No	No	17	Negative	-	-	-	-
	92.5-95	No	No	15	Negative	Negative	0.032	0.088	<1000
	95-97.5	No	No	18	Negative	-	-	-	-
	97.5-100	No	No	8	Negative	Negative	-	-	-
	100-102.5	No	No	17	Negative	-	-	-	-
	102.5-105	No	No	16	Negative	Negative	-	-	420
	105-107.5	No	No	23	Negative	Negative	0.0018	0.37	<1000
	107.5-110	No	No	19	Negative	-	-	-	-
	110-112.5	No	Slight	19	Negative	Negative	-	-	-

See notes on page 19

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-17	0-2.5	No Recovery							
	2.5-5	No	No	6	Negative	Negative	-	-	-
	5-7.5	No	No	6	Negative	-	0.048	0.48	13000
	7.5-10	No	No	4	Negative	Negative	-	-	-
	10-12.5	No	No	3	Negative	-	-	-	-
	12.5-15	No	No	0	Negative	Negative	-	-	5400
	15-17.5	No Recovery							
	17.5-20	No	No	0	Negative	Negative	0.14	0.2	5100
	20-22.5	No	No	2	Negative	-	-	-	-
	22.5-25	No	Faint	0	Negative	Negative	0.02	0.15	600

See notes on page 19

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

		Results of Field Screening Tests					**Results of Lab Testing for Chemical Composition**		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-18	0-2.5	No	No	8	Negative	Negative	-	-	-
	2.5-5	No	No	47	Negative	Negative	-	-	-
	5-7.5	No	Yes	129	Negative	**Pink bead**	-	-	-
	7.5-10	No	Yes	295	Negative	**Pink bead**	42	27	4100
	10-12.5	No	No	49	Negative	Negative	-	-	690
	12.5-15	No	No	140	Negative	Negative	2.6	4.1	1700
	15-17.5	Split Spoon Core Collected							
	17.5-20	No	No	98	Negative	Negative	-	-	-
	20-22.5	No	No	56	Negative	Negative	-	-	-
	22.5-25	No	No	83	Negative	-	-	-	-
	25-27.5	No	Faint	74	Negative	Negative	-	-	-
	27.5-30	No	Faint	79	Negative	Negative	2.2	4.6	970
	30-32.5	No	Faint	44	Negative	Negative	-	-	-
	32.5-35	No	Faint	91	Negative	Negative	4.4	1.1	1300
	35-37.5	Split Spoon Core Collected							
	37.5-40	No	Faint	18	Negative	Negative	-	-	-
	40-42.5	No	Faint	76	Negative	-	2.3	0.14	740
	42.5-45	No	Faint	55	Negative	Negative	-	-	-
	45-47.5	No	Faint	22	Negative	-	-	-	-
	47.5-50	No	Faint	17	Negative	Negative	-	-	-
	50-52.5	No	Faint	13	Negative	-	-	-	830
	52.5-55	No	Faint	34	Negative	Negative	0.48	0.083	640
	55-57.5	No	Faint	26	Negative	-	-	-	-
	57.5-60	No	Faint	28	Negative	Negative	-	-	-
	60-62.5	No	Faint	13	Negative	-	-	-	-
	62.5-65	No	Faint	18	Negative	Negative	-	-	-
	65-67.5	No	No	16	Negative	-	-	-	-
	67.5-70	No	No	12	Negative	**Pink bead**	0.51	0.19	720
	70-72.5	No	No	13	Negative	-	-	-	-
	72.5-75	No	No	20	Negative	**Pink bead**	0.7	0.095	530
	75-77.5	Split Spoon Core Collected							
	77.5-80	No	No	10	Negative	-	-	-	-
	80-82.5	No	No	13	Negative	Negative	-	-	-
	82.5-85	No	No	15	Negative	-	-	-	-
	85-87.5	No	No	32	Negative	Negative	0.026	ND	420
	87.5-90	No	No	13	Negative	-	-	-	-
	90-92.5	No	No	10	Negative	Negative	-	-	-
	92.5-95	No	No	13	Negative	-	-	-	-
	95-97.5	No	No	7	Negative	**Pink bead**	0.11	ND	540
	97.5-100	No	No	8	Negative	-	-	-	-
	100-102.5	No	No	12	Negative	Negative	-	-	-
	102.5-105	No	No	8	Negative	-	-	-	<1000
	105-107.5	No	No	6	Negative	**Pink bead**	0.039	ND	580
	107.5-110	No	No	13	Negative	-	-	-	-
	110-112.5	No	No	13	Negative	Negative	0.002	ND	<1000
	112.5-115	No Recovery							

See notes on page 19

GROUNDWATER SERVICES, INC.

TABLE 6
RESULTS OF SOIL CORE INSPECTION AND TESTING AT BORINGS A1-1 THROUGH A1-19

DNAPL Characterization Study
Sauget Area 1, Sauget and Cahokia, Illinois

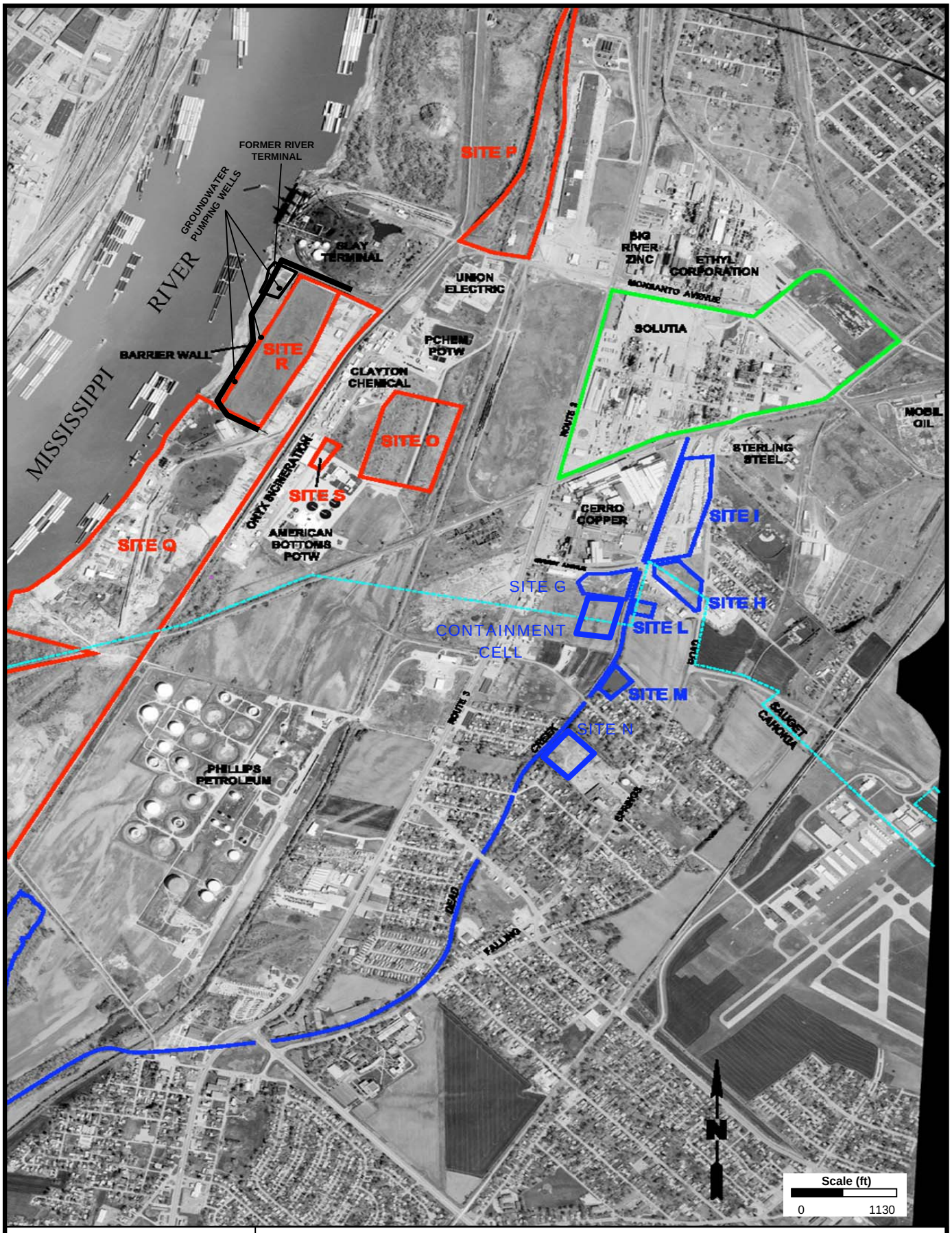
		Results of Field Screening Tests					Results of Lab Testing for Chemical Composition		
Boring ID	Depth Interval (ft bgs)	Visible Evidence of NAPL on Soil Core	Chemical or Hydrocarbon Odor	Maximum PID Headspace (ppm)	NAPL FLUTe Ribbon Test	Oil-in-Soil Test Kit with Sudan IV Dye	Total VOCs (mg/kg)	Total SVOCs (mg/kg)	Total Organic Carbon (mg/kg)
A1-19	0-2.5	No	-	9	Negative	Negative	-	-	-
	2.5-5	No	-	55	Negative	Negative	-	-	69000
	5-7.5	No	-	493	Negative	Negative	900	410	120000
	7.5-10	No	-	293	Negative	Negative	-	-	-
	10-12.5	No	-	200	Negative	Negative	1000	230	88000
	12.5-15	No	-	123	Negative	Negative	-	-	-
	15-17.5	No	-	94	Negative	Negative	-	-	-
	17.5-20	Split Spoon Core Collected							
	20-22.5	No	-	81	Negative	Negative	-	-	-
	22.5-25	No	-	281	Negative	Negative	-	-	-
	25-27.5	No	-	312	Negative	**Pink bead**	-	-	-
	27.5-30	No	-	507	Negative	**Pink bead**	39	430	6000
	30-32.5	**Black staining**	-	192	Negative	**Pink bead**	-	-	-
	32.5-35	**Black staining**	-	726	Negative	**Pink bead**	14	39	3600
	35-37.5	**Black staining**	-	67	Negative	**Pink bead**	-	-	1300
	37.5-40	**Black staining**	-	252	Negative	**Pink bead**	-	-	-
	40-42.5	**Black staining**	-	216	Negative	**Pink bead**	-	-	-
	42.5-45	**Black staining**	-	341	Negative	**Red spots**	5.9	59	3200
	45-47.5	Split Spoon Core Collected							
	47.5-50	No	-	94	Negative	Negative	-	-	-
	50-52.5	No	-	127	Negative	Negative	-	-	-
	52.5-55	No	-	206	Negative	**Pink bead**	-	-	-
	55-57.5	No	-	107	Negative	**Pink bead**	-	-	-
	57.5-60	No	-	218	Negative	**Pink bead**	4.4	96	2500
	60-62.5	No	-	224	Negative	**Red spots**	-	-	-
	62.5-65	No	-	271	Negative	**Red spots**	-	-	-
	65-67.5	**Sheen**	Yes	227	Negative	**Red spots pink bead**	7.3	59	1400
	67.5-70	**Sheen**	Yes	204	Negative	**Red spots pink bead**	-	-	-
	70-72.5	**Sheen**	Yes	287	Negative	**Red spots pink bead**	-	-	-
	72.5-75	**Sheen**	Yes	203	Negative	**Red spots pink bead**	-	-	-
	75-77.5	**Black staining**	Yes	303	Negative	**Red spots pink bead**	4.2	21	1100
	77.5-80	**Black staining**	Yes	155	Negative	**Red spots pink bead**	-	-	2200
	80-82.5	**Black staining**	Yes	373	Negative	**Red spots pink bead**	-	-	-
	82.5-85	**Black staining**	Yes	174	Negative	**Red spots pink bead**	-	-	-
	85-87.5	Split Spoon Core Collected							
	87.5-90	**Black staining**	Yes	506	Negative	**Red spots pink bead**	3.3	64	1500
	90-92.5	**Black staining**	Yes	402	Negative	**Red spots pink bead**	-	-	-
	92.5-95	**Black staining**	Yes	412	Negative	**Red spots pink bead**	ND	416	5100
	95-97.5	**Black staining**	Yes	294	Negative	**Red spots pink bead**	-	-	-
	97.5-100	**Black staining**	Yes	205	Negative	**Red spots pink bead**	-	-	-
	100-102.5	No	Yes	273	Negative	**Red spots pink bead**	1.9	1300	5300
	102.5-105	No	Yes	246	Negative	**Red spots pink bead**	-	-	-

Notes:
1) Field screening test results shown in bold are considered indications of confirmed or possible NAPL presence within the soil cores.
2) Boring locations are shown on Figures 17, 18, and 19.
3) General descriptions of soil core examination & testing methods:
   PID Headspace: Representative portion of each core placed in sealed plastic bag at ambient temperature and head-space tested with organic vapor analyzer equipped with photo-ionization detector (11.7 eV lamp).
   NAPL FLUTe Ribbon Test: A strip of fabric impregnated with hydrophobic dyes is applied directly to the soil core and fabric inspected for visible evidence of a reaction.
   Oil-in-Soil Test: Measured volumes of soil and clean water are added to a vial that contains a polystyrene bead and a sugar cube with Sudan IV dye. The vial is agitated to completely dissolve the sugar cube and release the Sudan IV dye. The vial is then inspected for the presence of a NAPL layer, for red spots that indicate NAPL, or for a pink halo or hue on the polystyrene bead.
4) See Tables D-1 and D-2 for results of soil sample analyses for VOCs, SVOC, and total organic carbon.
5) "ND" = Not detected. " - " = No data for this test for this depth interval
6) For intervals where Level "C" PPE was used, there is no data for the column titled "Chemical or Hydrocarbon Odor."

GROUNDWATER SERVICES, INC.

FIGURES

Figure 1 Site Location Map
Figure 2 Map Showing NAPL Survey Results: May 2004
Figure 3 Map Showing NAPL Survey Results: October 2004
Figure 4 Map Showing NAPL Survey Results: September 2005
Figure 5 Detailed Cross Section at Well BR-I
Figure 6 Interpreted Bedrock Surface Elevations from 3-D Seismic Survey
Figure 7 North-South Stratigraphic Cross Section of Sites I and G
Figure 8 East-West Stratigraphic Cross Section of Sites G and H
Figure 9 East-West Stratigraphic Cross Section of Site I
Figure 10 Maximum Total VOCs in Fill and Aquifer Matrix
Figure 11 Vertical Distribution of Total VOCs in Fill and Aquifer Matrix
Figure 12 Vertical Distribution of Chlorobenzene in Fill and Aquifer Matrix
Figure 13 Maximum Total SVOCs in Fill and Aquifer Matrix
Figure 14 Vertical Distribution of Total SVOCs in Fill and Aquifer Matrix
Figure 15 Vertical Distribution of 1,4-Dichlorobenzene in Fill and Aquifer Matrix
Figure 16 Vertical Distribution of 1,2,4-Trichlorobenzene in Fill and Aquifer Matrix
Figure 17 Remedial Volume – Fill and Shallow Hydrogeologic Unit
Figure 18 Remedial Volume – Middle Hydrogeologic Unit
Figure 19 Remedial Volume – Deep Hydrogeologic Unit
Figure 20 Alternate Approach for Estimating DNAPL Volume – Fill and Shallow Hydrogeologic Unit
Figure 21 Alternate Approach for Estimating DNAPL Volume – Middle Hydrogeologic Unit
Figure 22 Alternate Approach for Estimating DNAPL Volume – Deep Hydrogeologic Unit



GROUNDWATER SERVICES, INC.

LEGEND

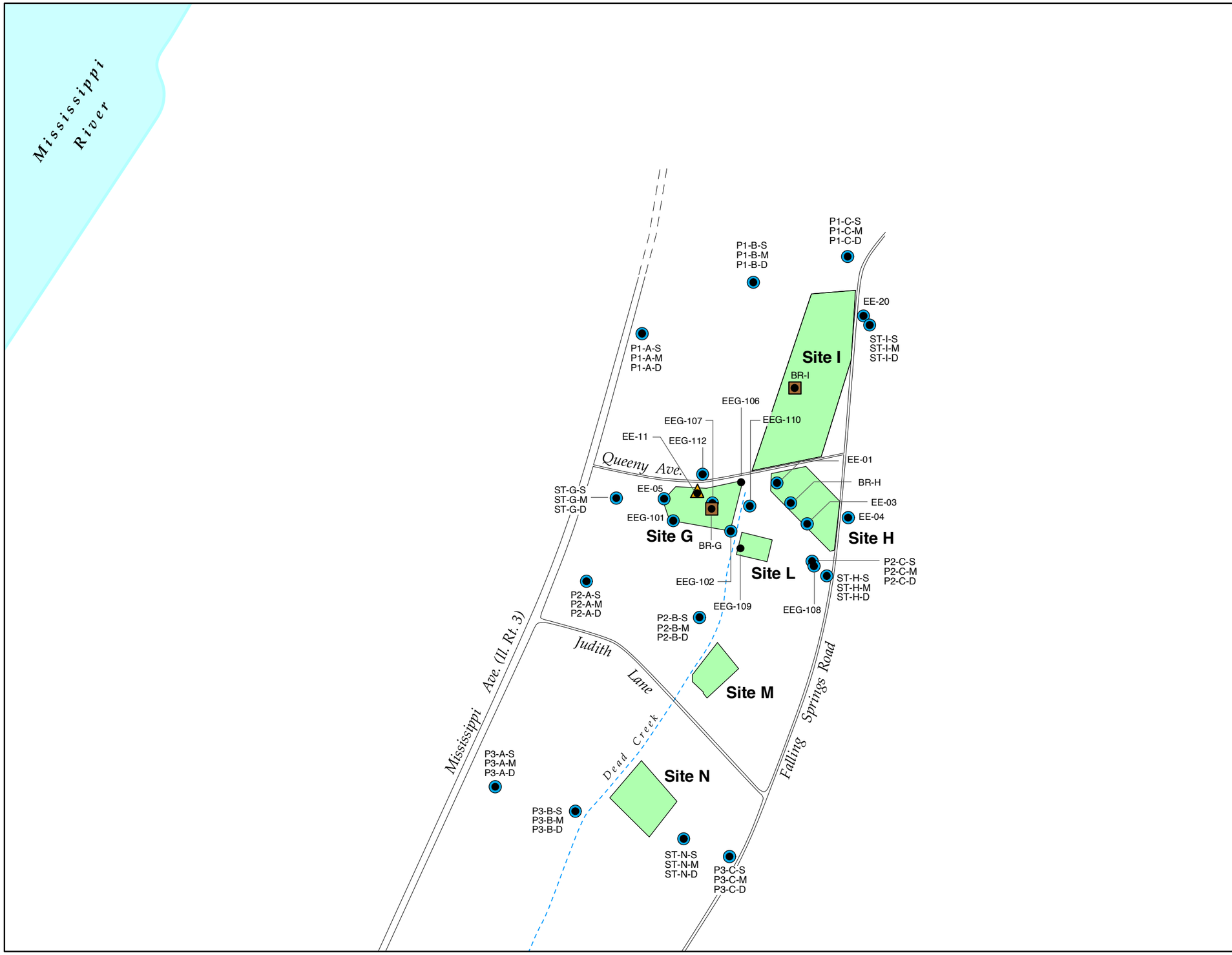
- W. G. Krummrich Facility
- Sauget Area #1
- Sauget Area #2

SITE LOCATION MAP

DNAPL Characterzation and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.:	G2876	Drawn by:	TUH
Issued:	08/28/06	Approved by:	JAK
Scale:	As Shown	Revised:	

FIGURE 1



N

LEGEND

- Monitoring well or piezometer
- LNAPL or evidence of LNAPL was found during May 2004 survey.
- DNAPL or evidence of DNAPL was found during May 2004 survey.
- No evidence of LNAPL or DNAPL was found during May 2004 survey.

Note: Wells EEG -106 and EEG -109 could not be measured due to bent well casing.

SCALE (ft.)

0 400 800

GROUNDWATER SERVICES, INC.

MAP SHOWING NAPL SURVEY RESULTS: MAY 2004

Sauget Area 1, Sauget and Cahokia, Illinois

GSI Job No:	G-2876	Drawn By:	TUH
Issued:	1/06/06	Chk'd By:	JAK
Revised:	_____	Appv'd By:	
Scale:	As Shown		**FIGURE 2**

LEGEND

- Monitoring well or piezometer
- LNAPL or evidence of LNAPL was found during October 2004 survey.
- DNAPL or evidence of DNAPL was found during October 2004 survey.
- No evidence of LNAPL or DNAPL was found during October 2004 survey.

Note

The locations checked during this survey included EE-11, BR-G, BR-H, BR-I, and A1-1 through A1-18.

Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

MAP SHOWING NAPL SURVEY RESULTS: OCTOBER 2004

Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 3**

LEGEND

- Monitoring well or piezometer
- LNAPL or evidence of LNAPL was found during 2005 survey.
- DNAPL or evidence of DNAPL was found during 2005 survey.
- No evidence of LNAPL or DNAPL was found during 2005 survey.

Note

The locations checked on Sept. 20, 27 or 28, 2005, included EE-11, BR-G, BR-H, BR-I, and A1-1 through A1-18. A1-19 was checked on Oct. 20, 2005.

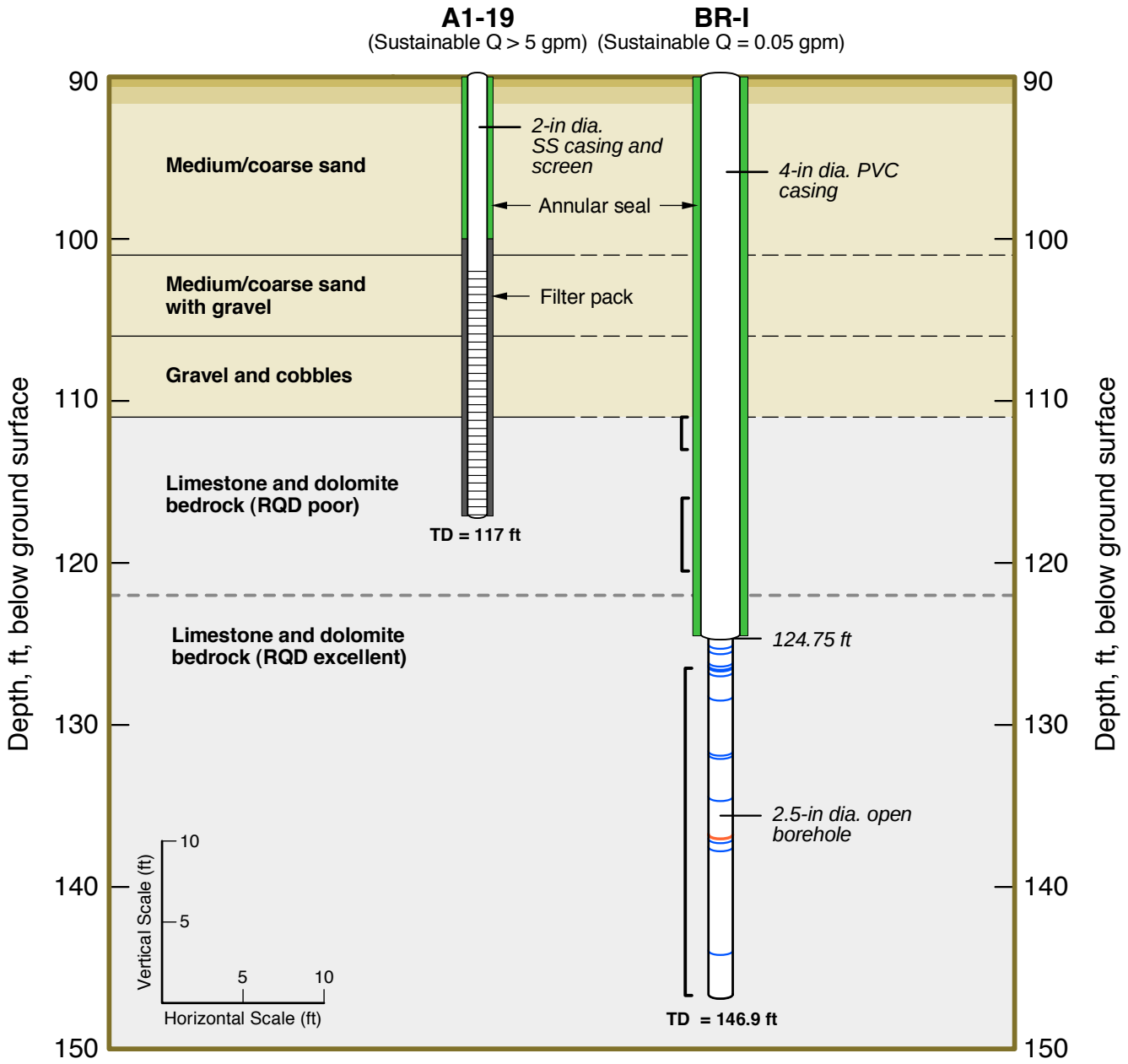
Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

MAP SHOWING NAPL SURVEY RESULTS: SEPT. - OCT. 2005

Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 4**



LEGEND

- Acoustic feature with rank of 3 (distinct feature with apparent aperture)
- Acoustic feature with rank of 4 (very distinct wide possible interconnected fracture)
- Alluvial Aquifer
- Bedrock
- Wireline cores

Notes: 1) During drilling of BR-I, a 4-inch diameter PVC casing was installed and grouted in place, and wireline cores were collected from 111-113 ft and 116-120.5 ft bgs. Sand was observed in the wireline core collected from 118-120.5 ft bgs. The 4-inch diameter PVC casing was then removed and re-set to a depth of approximately 124.75 ft bgs.

2) Acoustic features were identified in an acoustic televiewer survey conducted by Colog in October 2005.

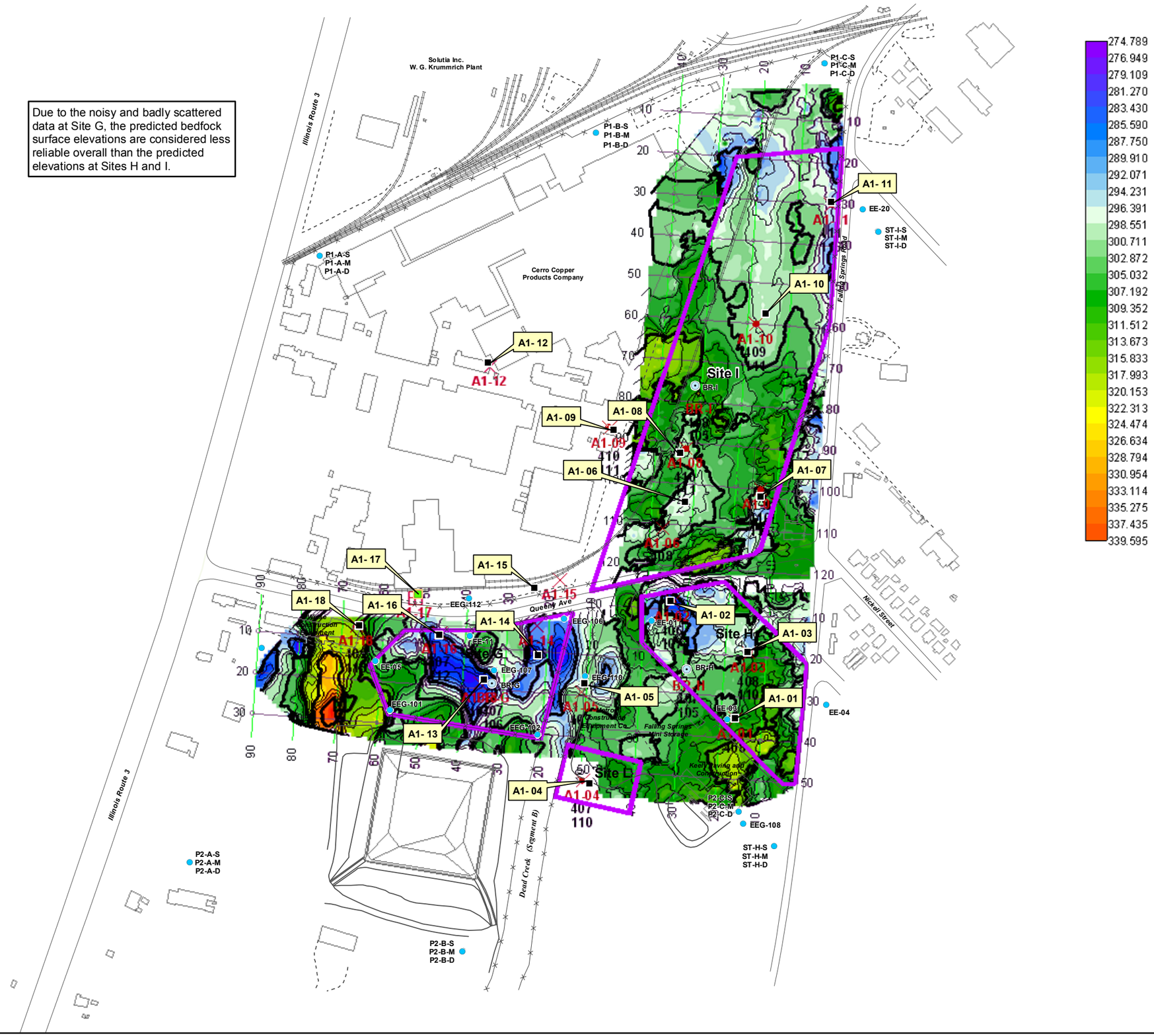
3) RQD = Rock Quality Designation

GROUNDWATER SERVICES, INC.

GSI Job No.	G-2876	Drawn By:	DLB
Issued:	08/28/06	Chk'd By:	JAK
Revised:	_____	Aprv'd By:	
Scale:	As Shown		**FIGURE 5**

DETAILED CROSS-SECTION AT BR-I
From 90 to 150 ft Below Grade
Sauget Area 1
Sauget and Cahokia, Illinois

Due to the noisy and badly scattered data at Site G, the predicted bedfock surface elevations are considered less reliable overall than the predicted elevations at Sites H and I.



LEGEND

- Monitoring wells and piezometers screened in alluvial aquifer.
- Newly installed shallow piezometer (A1-17)
- Existing bedrock wells
- Newly installed bedrock piezometers
- Site Areas
- Fenceline

Notes:

1) This map was constructed by a geophysics contractor based on interpretation of 3-D seismic reflection survey data. Seismic survey data were acquired June 7-30, 2004. This revised interpretive map, which was generated on October 6, 2004, incorporates bedrock surface data from piezometers A1-2, 3, 4, 7, 8, 9, 10, 11, 16, and 18.

2) Bedrock surface elevations are in feet above mean sea level.

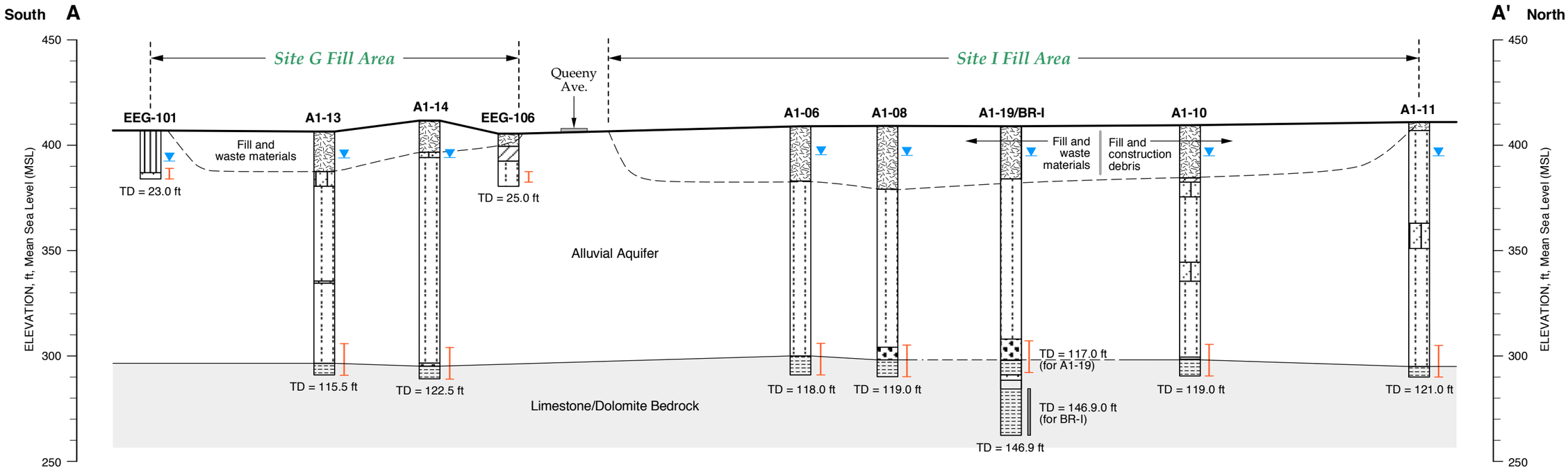
Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

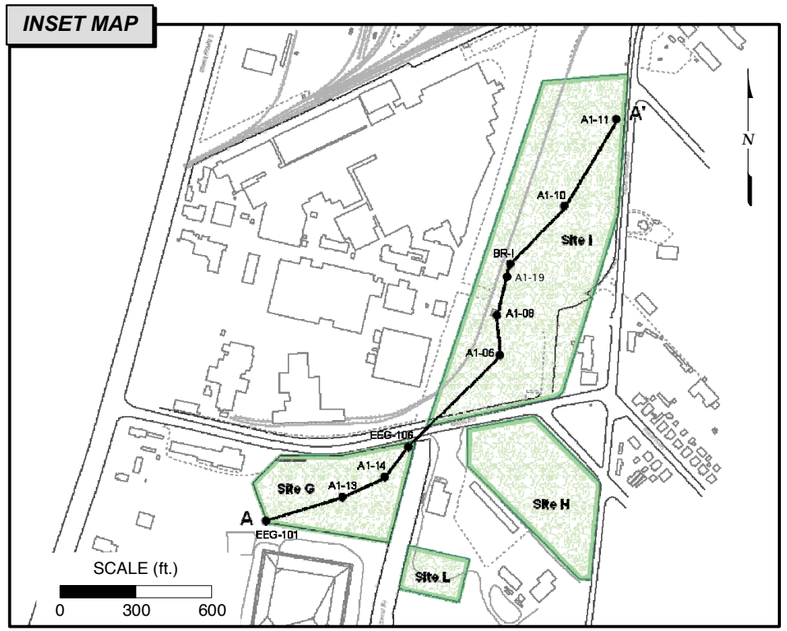
INTERPRETED BEDROCK SURFACE ELEVATIONS FROM 3-D SEISMIC SURVEY

Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 6**



INSET MAP



Notes:

1) Well BR-I has a 4-inch diameter PVC casing installed and cemented in bedrock to a depth of 124.75 ft bgs and a 2.5-inch diameter open borehole drilled into the bedrock from 125.5 to 146.9 ft bgs. Cores were collected from the following depth intervals: 111-113 ft, 116-120.5 ft, and 126.5-146.9 ft bgs. No sampling was conducted while drilling through fill materials, the alluvial aquifer, and the upper few feet of bedrock.

2) Well BR-G is located approximately 30 feet east of piezometer A1-13. BR-G has a 4-inch diameter PVC casing installed and cemented in bedrock to a depth of 112 ft bgs, and a 2.5-inch diameter open borehole drilled into the bedrock to 131.5 ft bgs. Cores were collected from 112-131.5 ft bgs. No sampling was conducted while drilling through fill materials, the alluvial aquifer, and the upper few feet of bedrock.

3) Piezometer A1-19 is located approximately 15 ft south of well BR-I. Cores were collected continuously to 117 ft bgs.

LEGEND

- FILL
- Silty SAND (SM)
- SILT (ML)
- CLAY (CL)
- SAND (SP)
- GRAVEL (GP)
- Bedrock
- TD — Total depth of boring ft below ground surface (BGS)
- Static water level (SWL), as measured on 10/26-27/04
- Screened interval
- Open borehole

Horizontal Scale, ft.

0 100 200 300 400

Vertical Scale: 1 Inch = 50 ft
Vertical Exaggeration: 4x

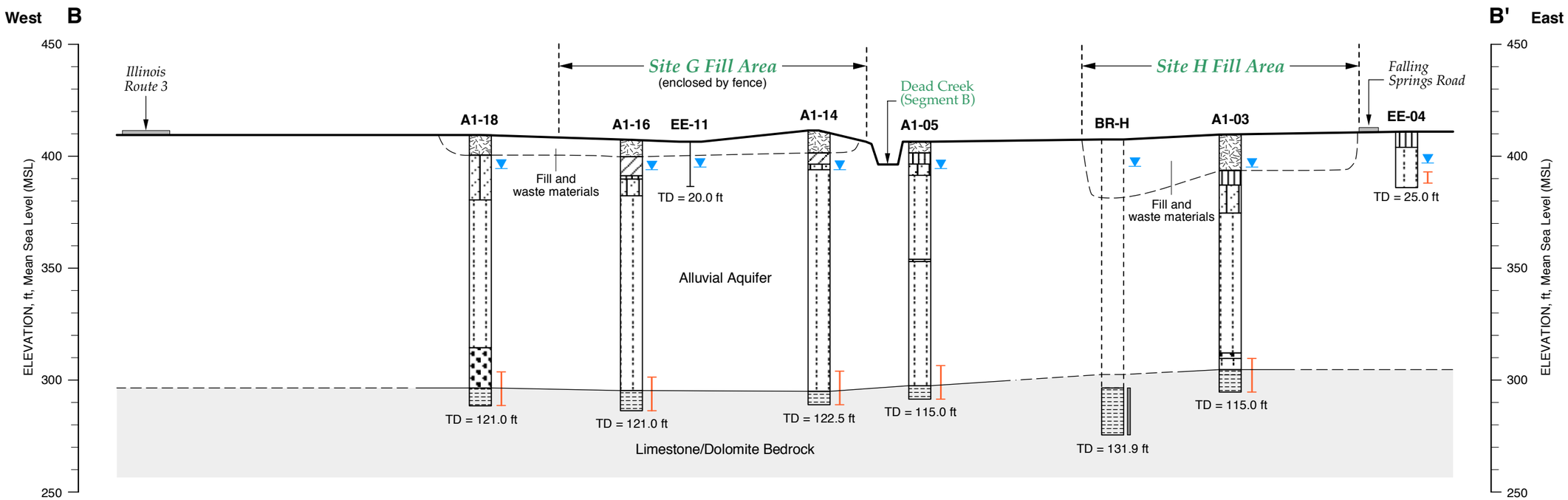
FIGURE 7

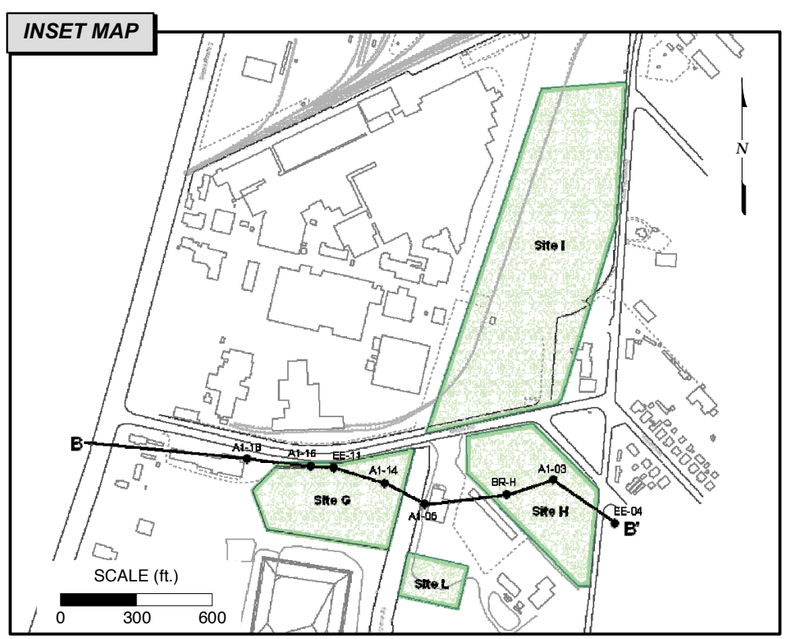
GROUNDWATER SERVICES, INC.

GSI Job No.	G-2876	Drawn By:	DLB/TUH
Issued:	08/28/06	Chk'd By:	JAK
Revised:	_____	Aprv'd By:	JAK
Scale:	As Shown		**FIGURE 7**

NORTH-SOUTH STRATIGRAPHIC CROSS-SECTION OF SITES I AND G

Sauget Area 1
Sauget and Cahokia, Illinois





Note:

Well BR-H has a 4-inch diameter PVC casing installed and cemented in bedrock to a depth of 109.5 ft bgs and a 2-inch diameter open corehole drilled into the bedrock from 109.5 to 131.9 ft bgs. Cores were collected from 111-131.9 ft bgs. No soil sampling was conducted while drilling through fill materials, the alluvial aquifer, and the upper few feet of bedrock.

LEGEND

- FILL
- Silty SAND (SM)
- SILT (ML)
- CLAY (CL)
- SAND (SP)
- GRAVEL (GP)
- Bedrock
- TD — Total depth of boring ft below ground surface (BGS)
- Static water level (SWL), as measured on 10/26-27/04
- Screened interval
- Open Borehole

Horizontal Scale, ft.

0 100 200 300 400

Vertical Scale: 1 Inch = 50 ft
Vertical Exaggeration: 4x

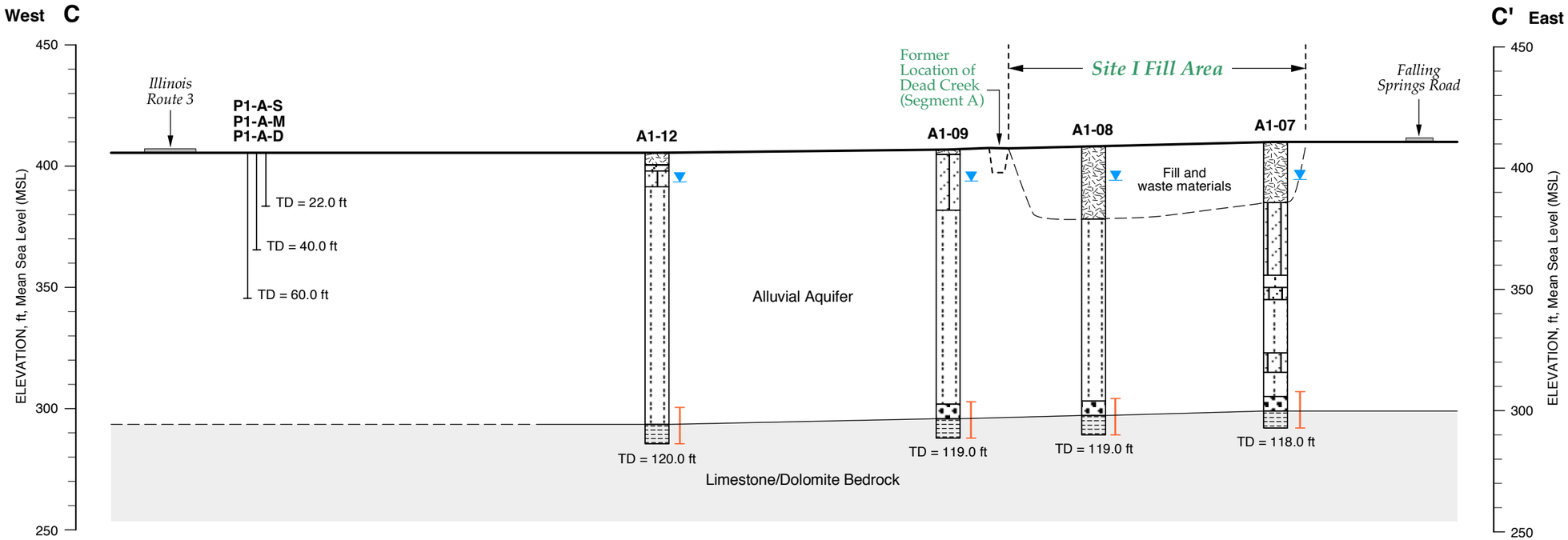
FIGURE 8

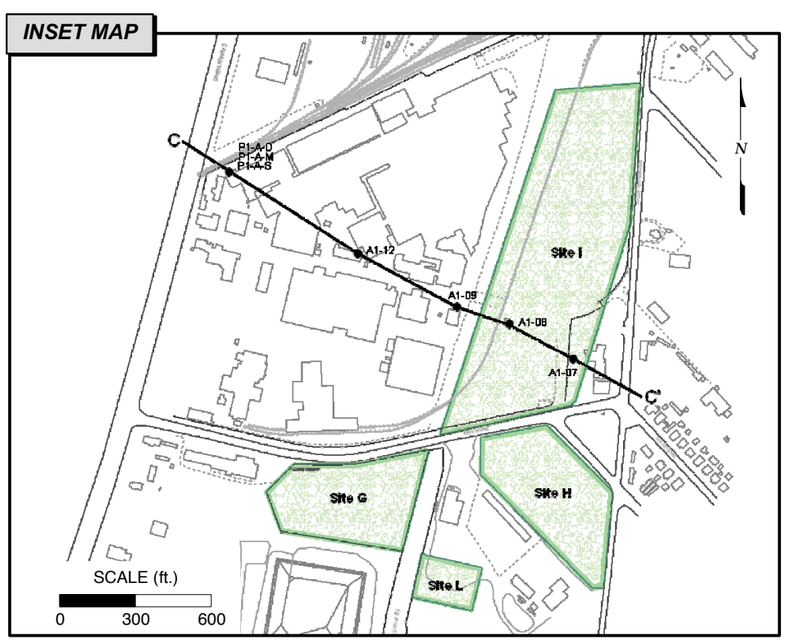
GROUNDWATER SERVICES, INC.

GSI Job No.	G-2876	Drawn By:	DLB/TUH
Issued:	08/28/06	Chk'd By:	JAK
Revised:	_____	Aprv'd By:	JAK
Scale:	As Shown		**FIGURE 8**

EAST-WEST STRATIGRAPHIC CROSS-SECTION OF SITES G AND H

Sauget Area 1
Sauget and Cahokia, Illinois





LEGEND

- FILL
- Silty SAND (SM)
- SILT (ML)
- CLAY (CL)
- SAND (SP)
- GRAVEL (GP)
- Bedrock

TD Total depth of boring ft below ground surface (BGS)

Static water level (SWL), as measured on 10/26-27/04

Screened interval

Horizontal Scale, ft.

0 100 200 300 400

Vertical Scale: 1 Inch = 50 ft
Vertical Exaggeration: 4x

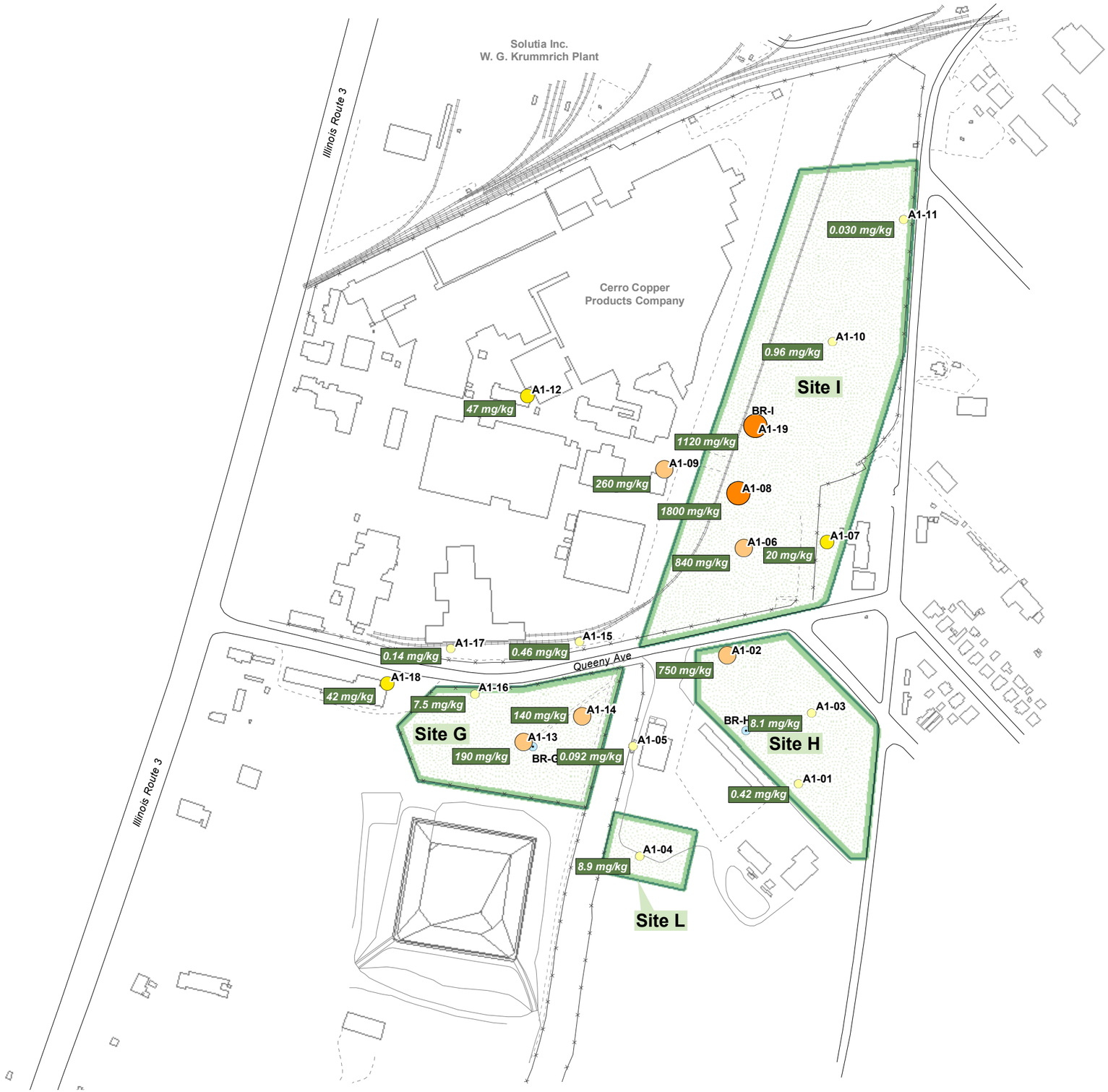
FIGURE 9

GROUNDWATER SERVICES, INC.

GSI Job No.	G-2876	Drawn By:	DLB/TUH
Issued:	08/28/06	Chk'd By:	JAK
Revised:	———	Aprv'd By:	JAK
Scale:	As Shown		FIGURE 9

EAST-WEST STRATIGRAPHIC CROSS-SECTION OF SITE I

Sauget Area 1
Sauget and Cahokia, Illinois



LEGEND

Existing bedrock wells

Total VOCs (mg/kg)

- <10
- 10-100
- 101-1000
- >1000

Note

Values shown on this map are maximum total VOCs detected on soil samples from each boring. At most borings a total of eleven or twelve soil samples were analyzed for VOCs.

Scale (ft)

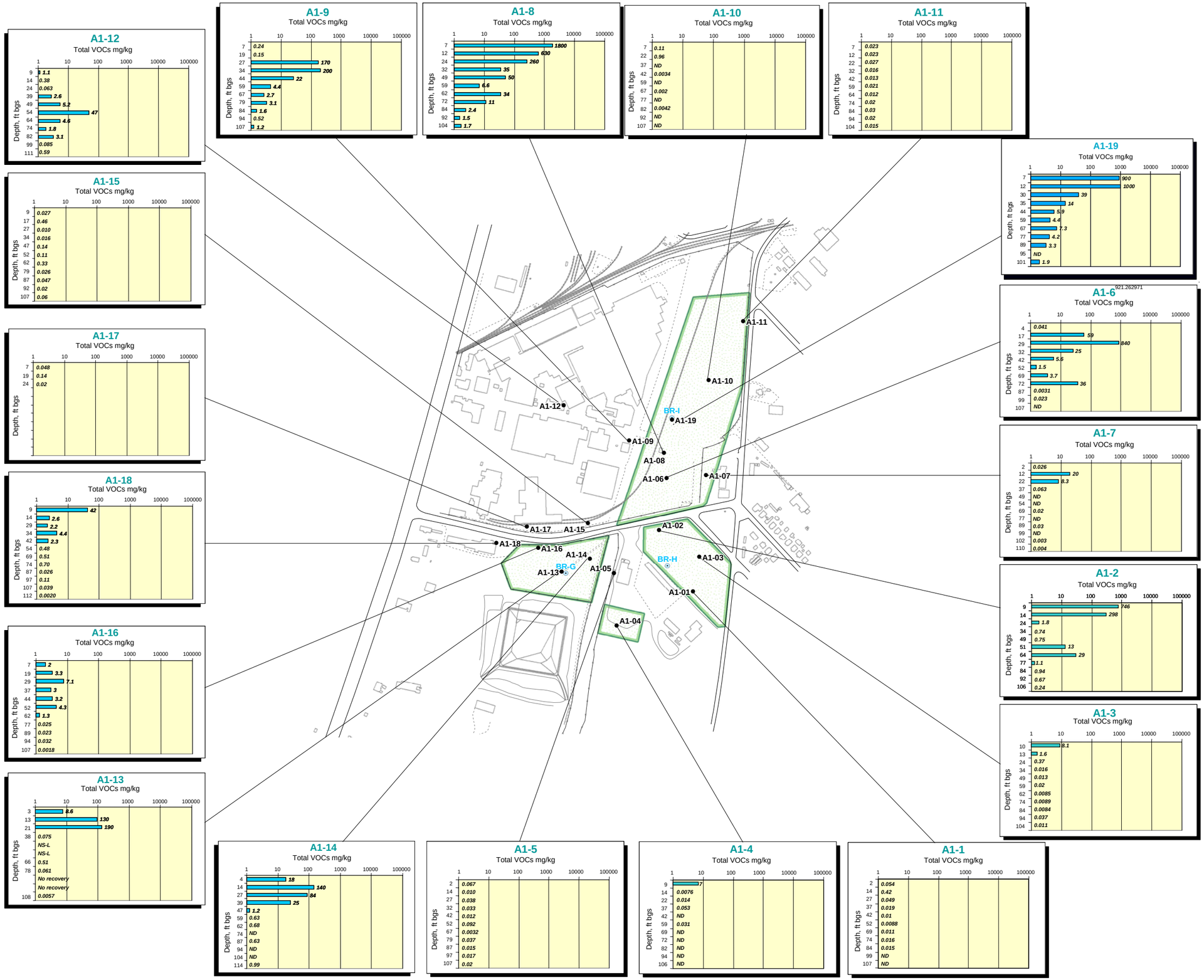
0 145 290

GROUNDWATER SERVICES, INC.

MAXIMUM TOTAL VOCs IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 10**



LEGEND

- Existing bedrock wells
- Piezometers installed during DNAPL characterization study.

Note

1) Constituent values are depicted using a log scale.
2) ND = No VOCs detected in this sample.
3) No recovery = Core barrel recovered no soil from this depth interval.
4) NS-L = Not sampled or sample jar was lost.

Scale (ft)

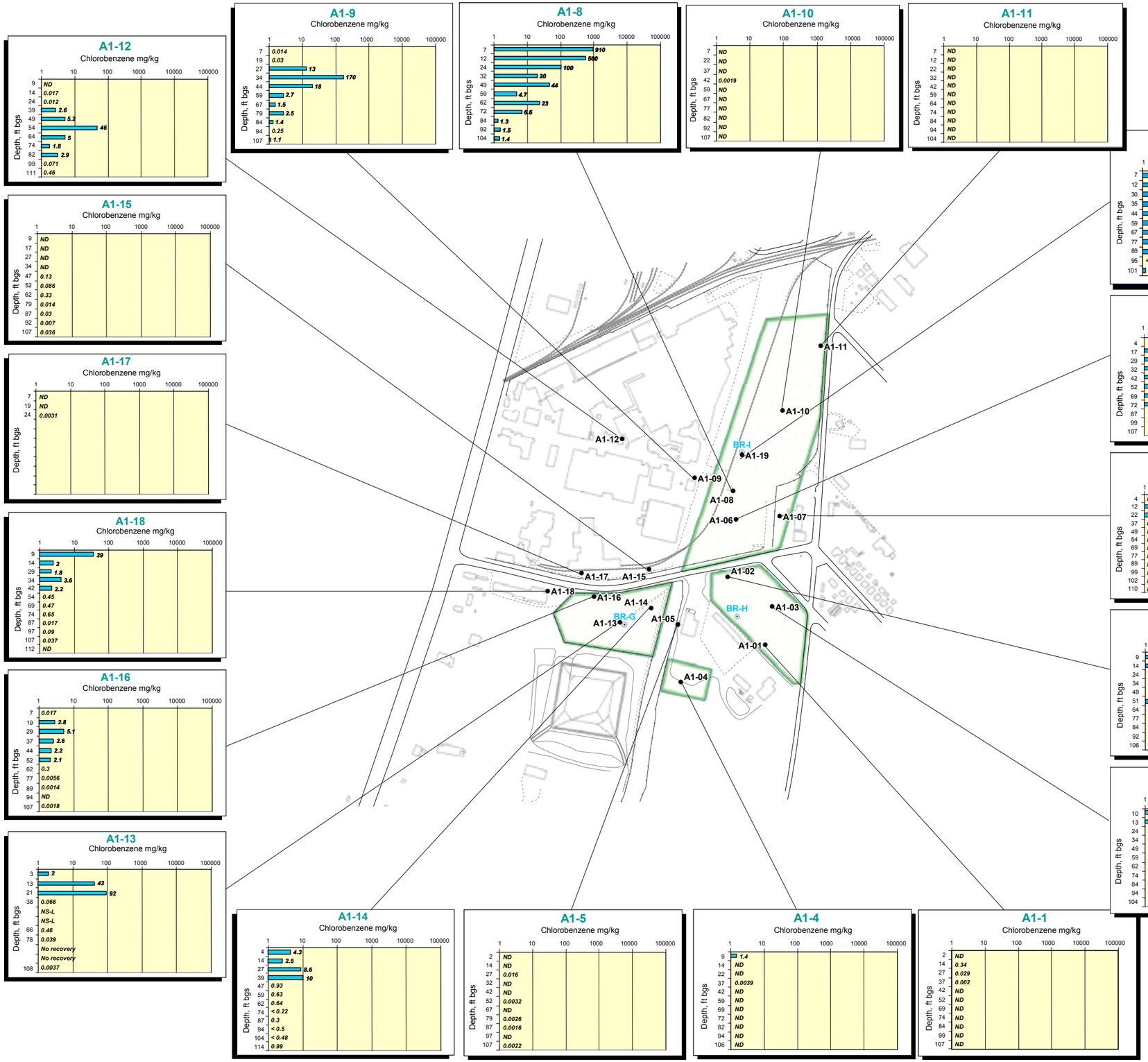
0 300 600

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF TOTAL VOCs IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 11**



LEGEND

- Existing bedrock wells
- Piezometers installed during DNAPL characterization study.

Note

1) Constituent values are depicted using a log scale.
2) ND = No chlorobenzene was detected. Detection limit was 0.1 mg/kg or lower.
3) <7 = No chlorobenzene was detected at a detection limit of 7 mg/kg.
4) No recovery = Core barrel recovered no soil from this depth interval.
5) NS-L = Not sampled or sample jar was lost.

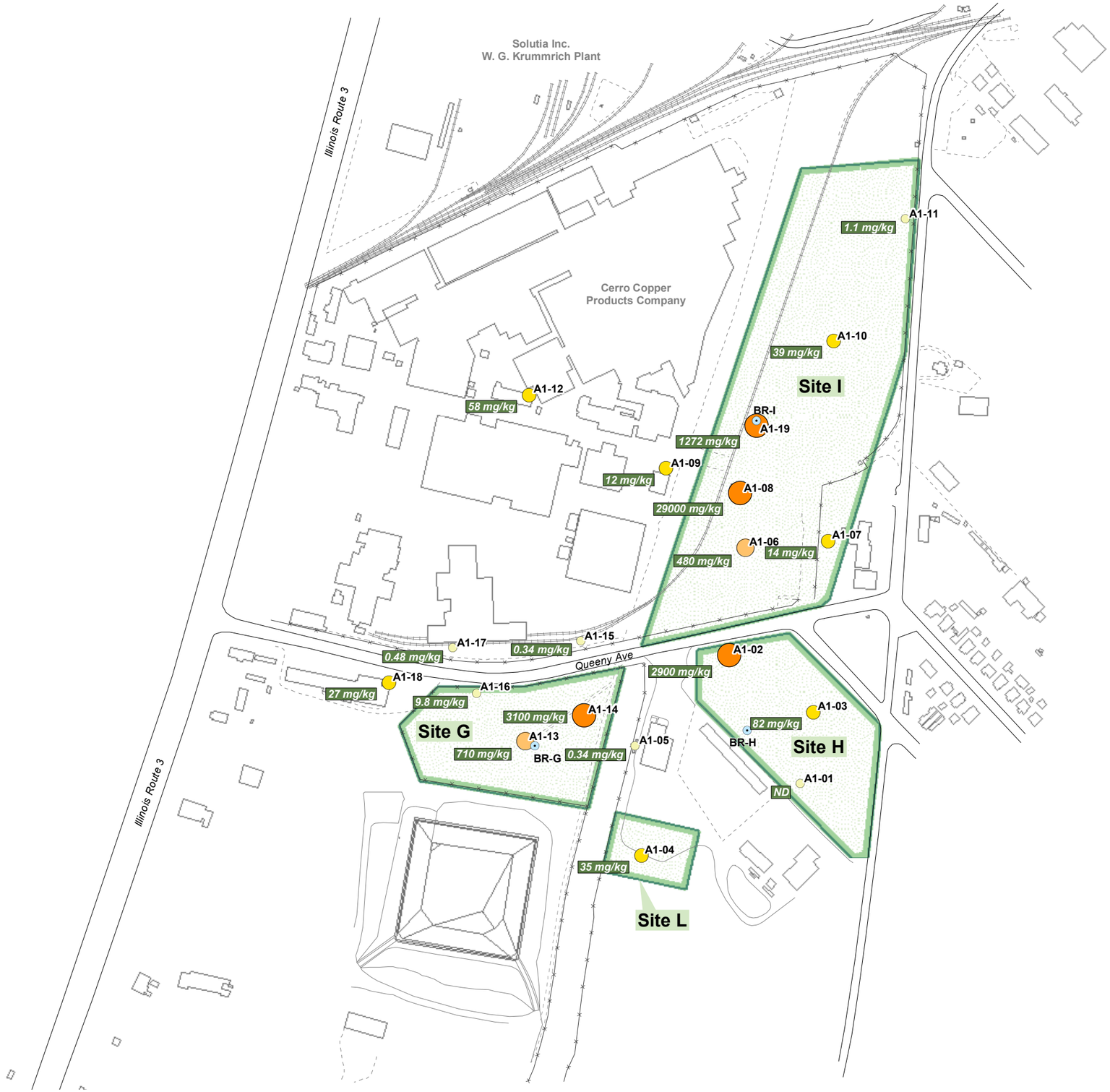
Scale (ft)
0 300 600

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF CHLOROBENZENE IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	1/6/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 12**



LEGEND

Existing bedrock wells

Total VOCs (mg/kg)

- <10
- 10-100
- 101-1000
- >1000

Note

Values shown on this map are maximum total SVOCs detected on soil samples from each boring. At most borings a total of eleven or twelve soil samples were analyzed for SVOCs.

Scale (ft)

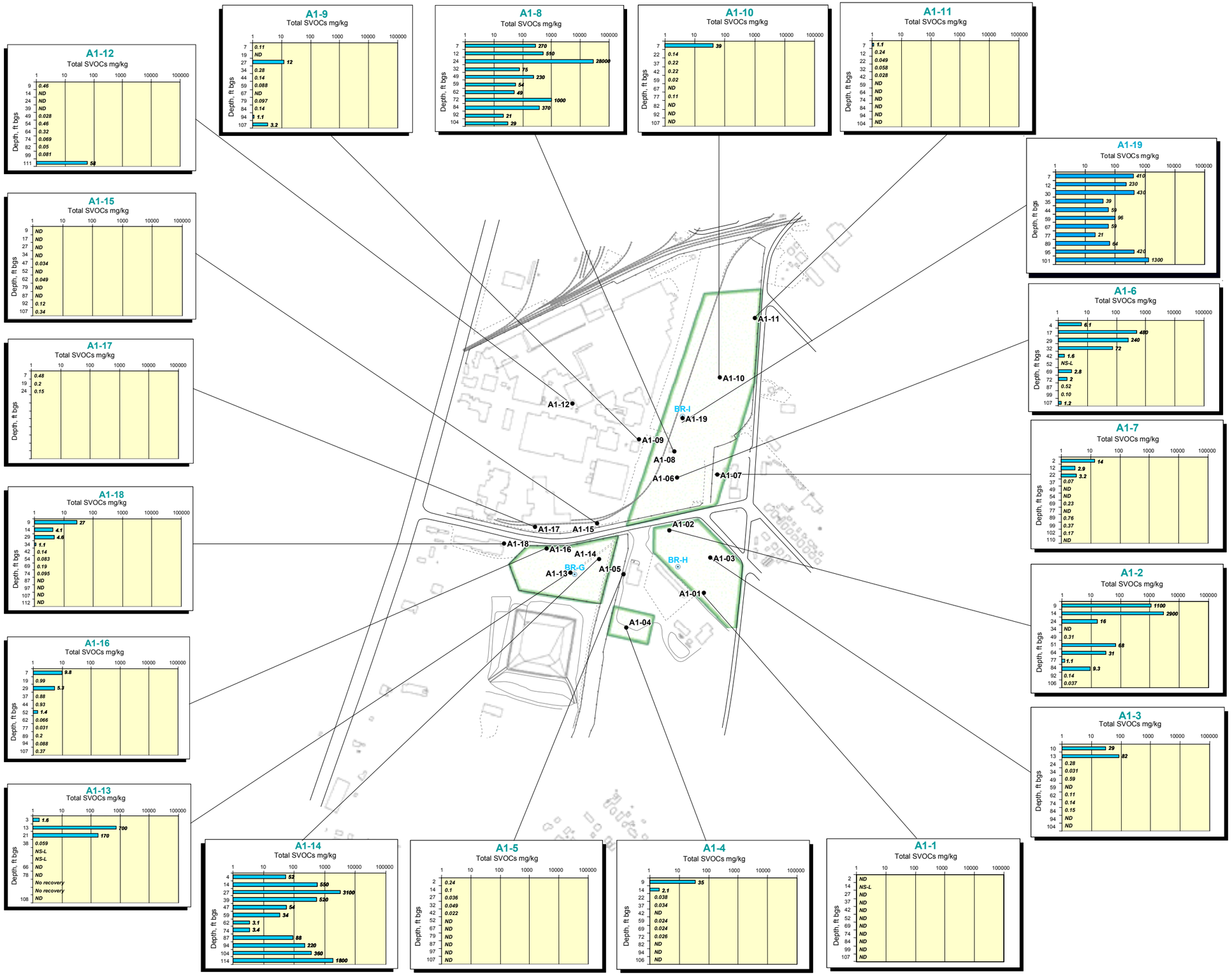
0 145 290

GROUNDWATER SERVICES, INC.

MAXIMUM TOTAL SVOCs IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 13**



LEGEND

- Existing bedrock wells
- Piezometers installed during DNAPL characterization study.

Note

1) Constituent values are depicted using a log scale.
2) ND = No SVOCs detected in this sample.
3) No recovery = Core barrel recovered no soil from this depth interval.
4) NS-L = Not sampled or sample jar was lost.

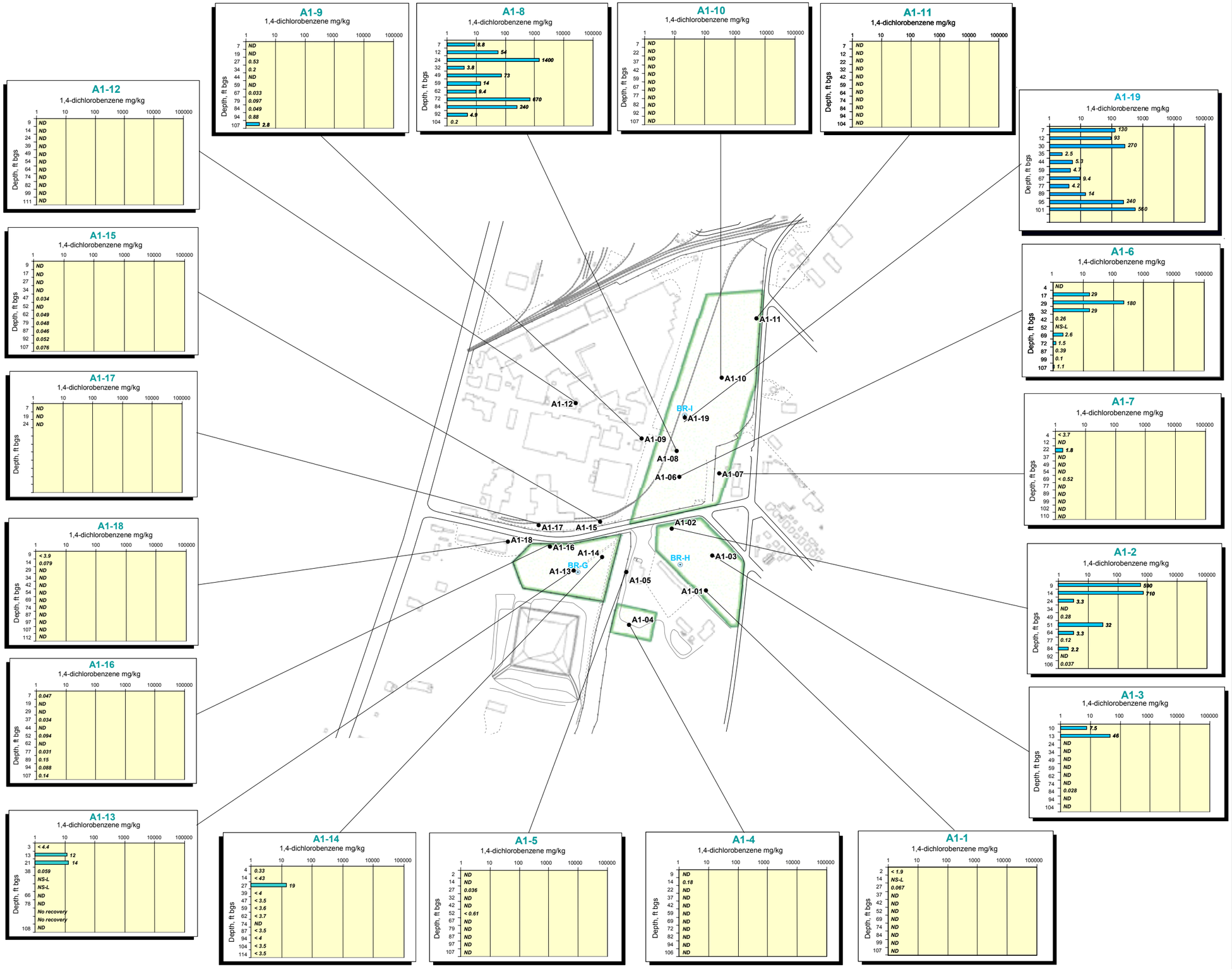
Scale (ft)
0 300 600

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF TOTAL SVOCs IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	1/6/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 14**



LEGEND

- Existing bedrock wells
- Piezometers installed during DNAPL characterization study.

Note

1) Constituent values are depicted using a log scale.
2) ND = No 1,4-dichlorobenzene was detected. Detection limit was 0.5 mg/kg or lower.
3) <7 = No 1,4-dichlorobenzene was detected at a detection limit of 7 mg/kg.
4) No recovery = Core barrel recovered no soil from this depth interval.
5) NS-L = Not sampled or sample jar was lost.

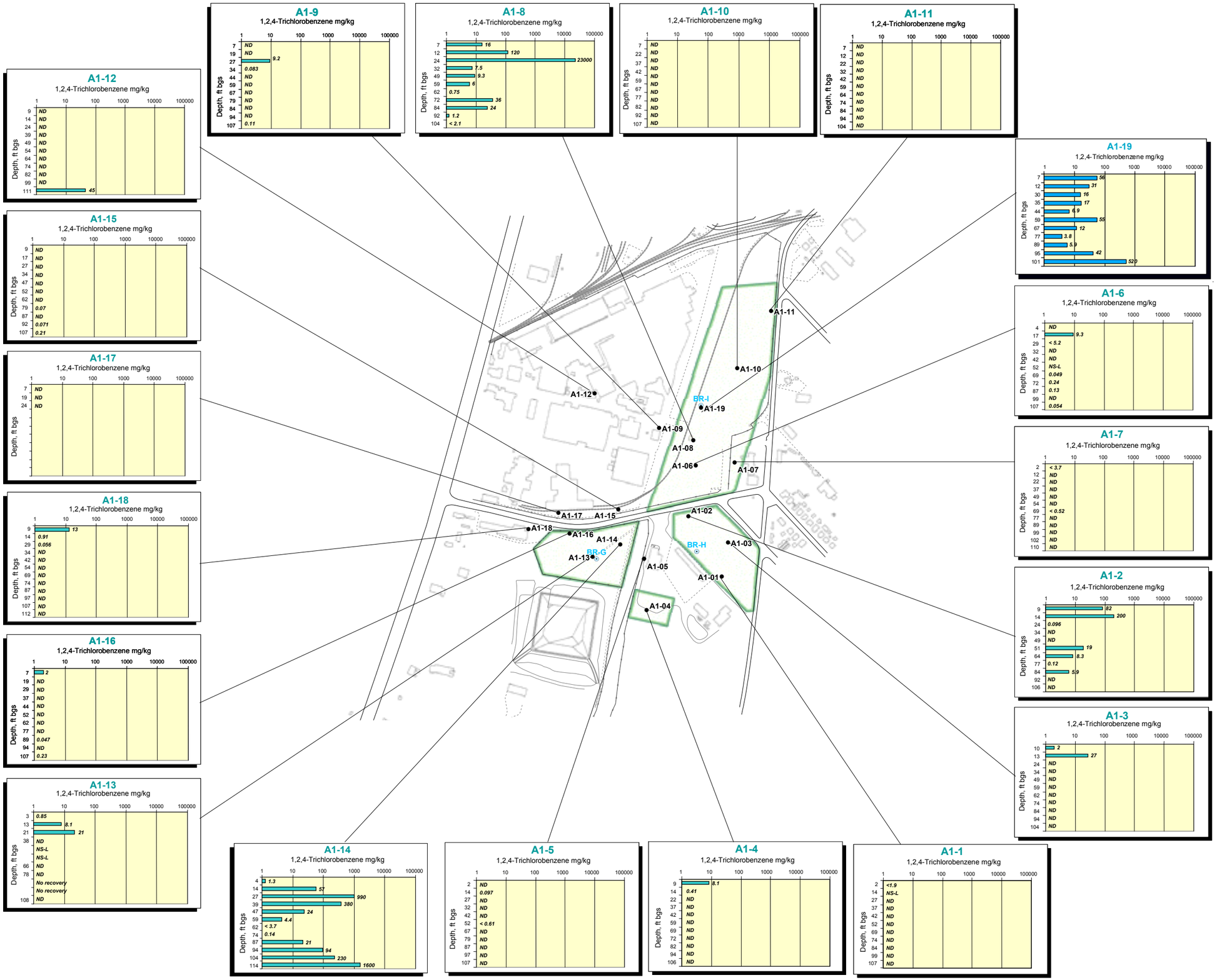
Scale (ft)
0 300 600

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF 1, 4-DICHLOROBENZENE IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	1/6/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 15**



LEGEND

- Existing bedrock wells
- Piezometers installed during DNAPL characterization study.

Note

1) Constituent values are depicted using a log scale.
2) ND = No 1,2,4-trichlorobenzene was detected. Detection limit was 0.5 mg/kg or lower.
3) <7 = No 1,2,4-trichlorobenzene was detected at a detection limit of 7 mg/kg.
4) No recovery = Core barrel recovered no soil from this depth interval.
5) NS-L = Not sampled or sample jar was lost.

Scale (ft)
0 300 600

GROUNDWATER SERVICES, INC.

VERTICAL DISTRIBUTION OF 1, 2, 4-TRICHLOROBENZENE IN FILL AND AQUIFER MATRIX

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	1/6/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 16**

N

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6.

Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

DNAPL AREAS - FILL AND SHALLOW HYDROGEOLOGIC UNIT

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 17**

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6.

Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

DNAPL AREAS - MIDDLE HYDROGEOLOGIC UNIT

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 18**

N

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6.

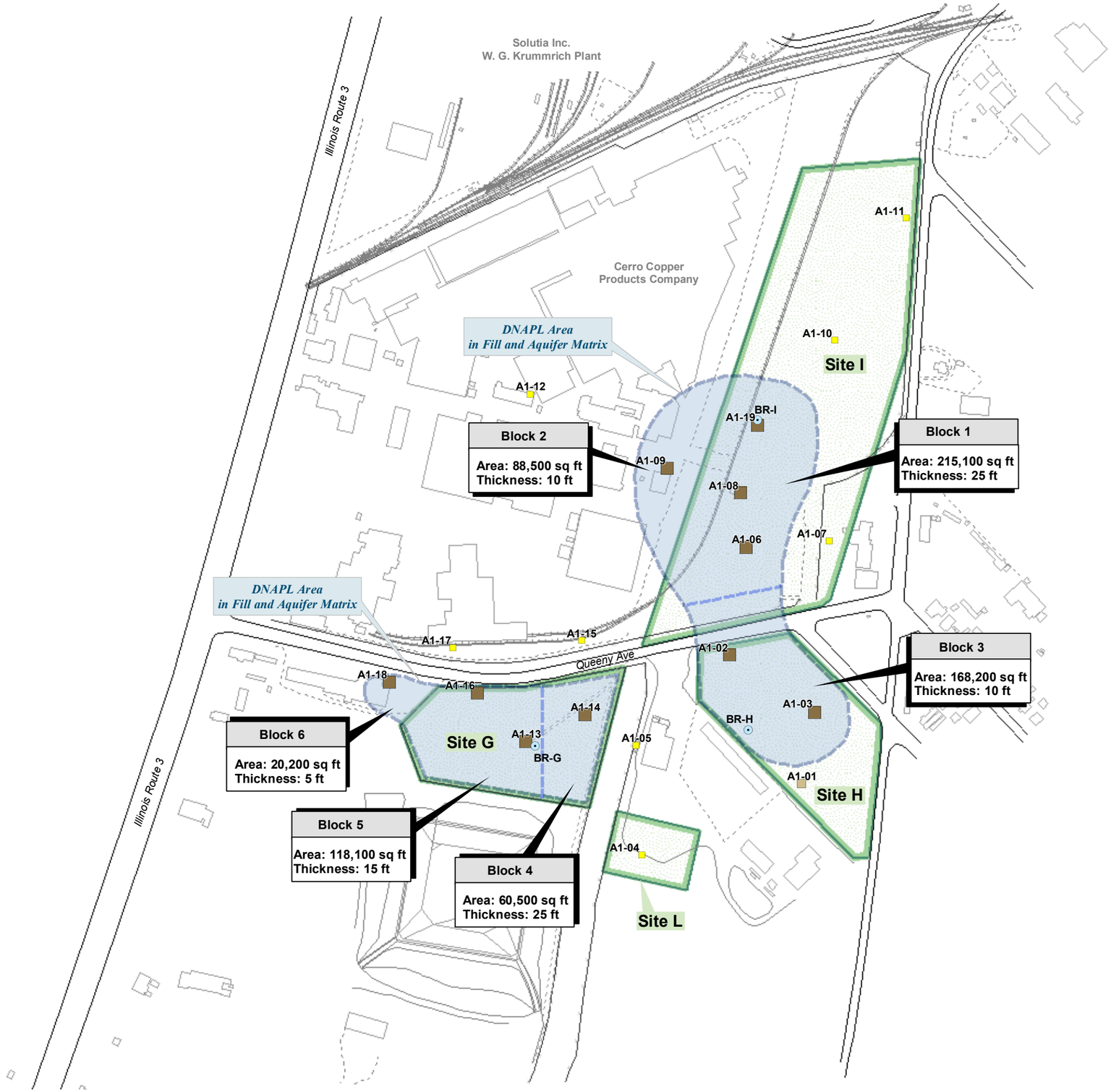
Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

DNAPL AREAS - DEEP HYDROGEOLOGIC UNIT

DNAPL Characterization and Remediation Study
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 19**



N

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6 of the DNAPL Report.

4) "Thickness" = Estimated thickness of fill materials and/or aquifer matrix within this hydrogeologic unit that contain DNAPL based on the criteria outlined on this figure and the inspection and testing results on Table 6 of the DNAPL Report.

Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

ALTERNATE APPROACH FOR ESTIMATING DNAPL VOLUME - FILL AND SHALLOW HYDROGEOLOGIC UNIT

Response to Comments on the DNAPL Report
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 20**

N

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6 of the DNAPL Report.

4) "Thickness" = Estimated thickness of fill materials and/or aquifer matrix within this hydrogeologic unit that contain DNAPL based on the criteria outlined on this figure and the inspection and testing results on Table 6 of the DNAPL Report.

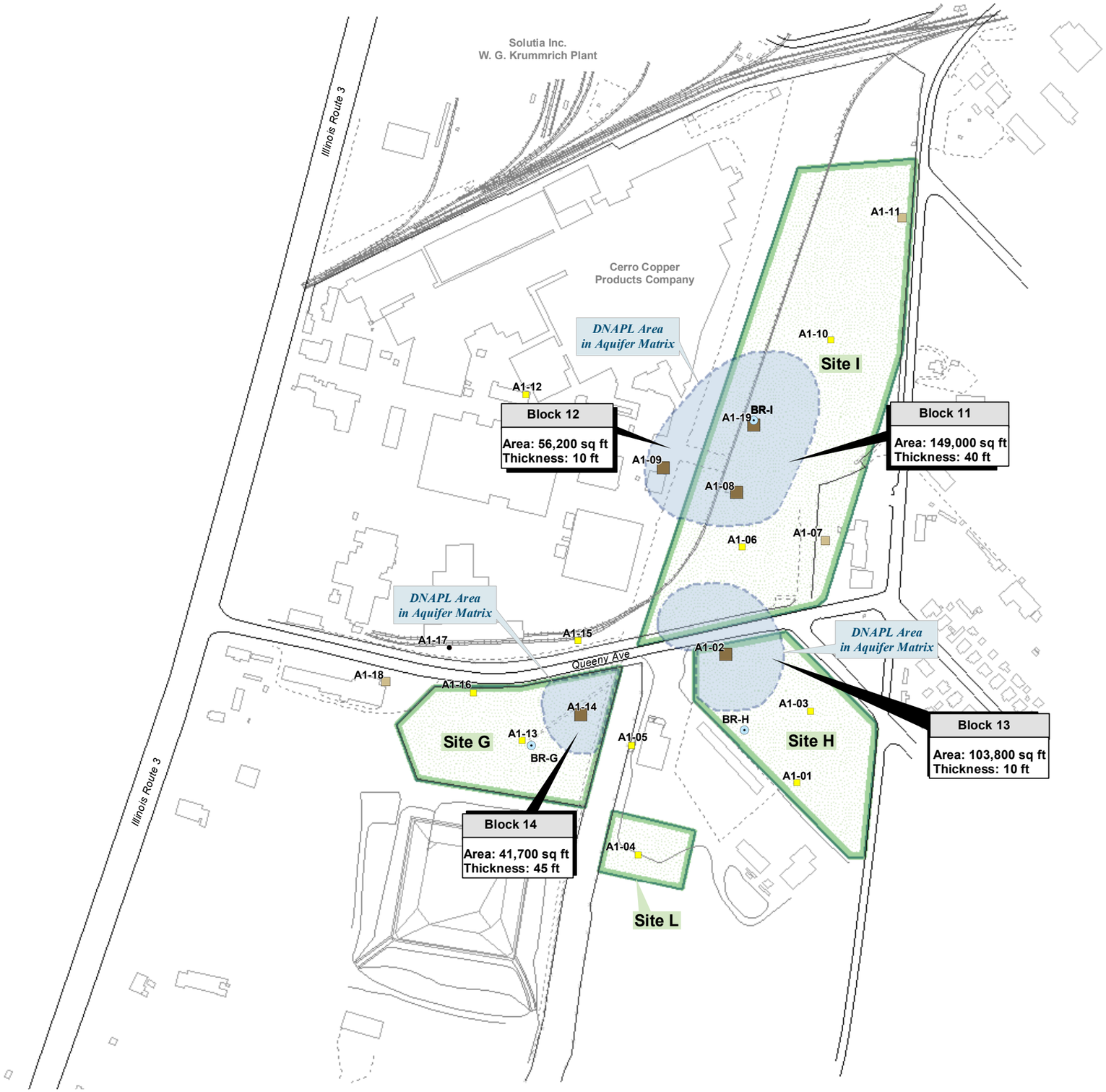
Scale (ft)
0 145 290

GROUNDWATER SERVICES, INC.

ALTERNATE APPROACH FOR ESTIMATING DNAPL VOLUME - MIDDLE HYDROGEOLOGIC UNIT

Response to Comments on the DNAPL Report
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 21**



N

LEGEND

Existing bedrock wells

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs ≥ 1 mg/kg and/or total SVOCs ≥ 1 mg/kg.

Field evidence of NAPL based on visual inspection of cores and/or vial test kit results. Total VOCs < 1 mg/kg and total SVOCs < 1 mg/kg.

No field evidence of NAPL based on visual inspection of cores or vial test kit results.

Note

1) The vial test kits contained Sudan IV dye, which is soluble in DNAPL and petroleum and stains DNAPL and petroleum products red. Each test kits also contained a small bead of polystyrene, which will develop a pink halo or hue in the presence of TPH at concentrations exceeding approximately 500 mg/kg.

2) Vial test results for a soil sample were considered as evidence for the presence of NAPL if: i) a layer of LNAPL or DNAPL was observed in the vial; ii) red spots or staining were noted in the vial; or iii) the polystyrene ball in the vial was observed to have a pink halo or hue.

3) Results of soil core inspection and testing for borings A1-1 through A1-19 are documented on Table 6 of the DNAPL Report.

4) "Thickness" = Estimated thickness of fill materials and/or aquifer matrix within this hydrogeologic unit that contain DNAPL based on the criteria outlined on this figure and the inspection and testing results on Table 6 of the DNAPL Report.

Scale (ft)
0 150 300

GROUNDWATER SERVICES, INC.

ALTERNATE APPROACH FOR ESTIMATING DNAPL VOLUME - DEEP HYDROGEOLOGIC UNIT

Response to Comments on the DNAPL Report
Sauget Area 1
Sauget and Cahokia, Illinois

GSI Job No.	G -2876	Drawn By:	TUH/cdm
Issued:	08/28/06	Chk'd By:	JAK
Revised:		Aprv'd:	
Scale:	As Shown		**Figure 22**

APPENDICES

Appendix A Evaluation of Historical NAPL Survey Data on Table 4-0c

Appendix B Selected Historical Groundwater Analytical Data for Sauget Area 1

Appendix C Laboratory Test Results for Oil Samples from Wells EE-11 and BR-I and Groundwater Sample from Well BR-G

Appendix D Tabulated Soil Analytical Results from Severn Trent Laboratories

Appendix E Core Testing Results from PTS Laboratories

Appendix F Boring Logs and As-Built Diagrams for A1-1 through A1-19

Appendix G Treatability Test Data Report

Appendix H Data Validation Report

Appendix I Colog Report for Well Surveys at BR-I

Appendix J Bedrock Transport Analysis