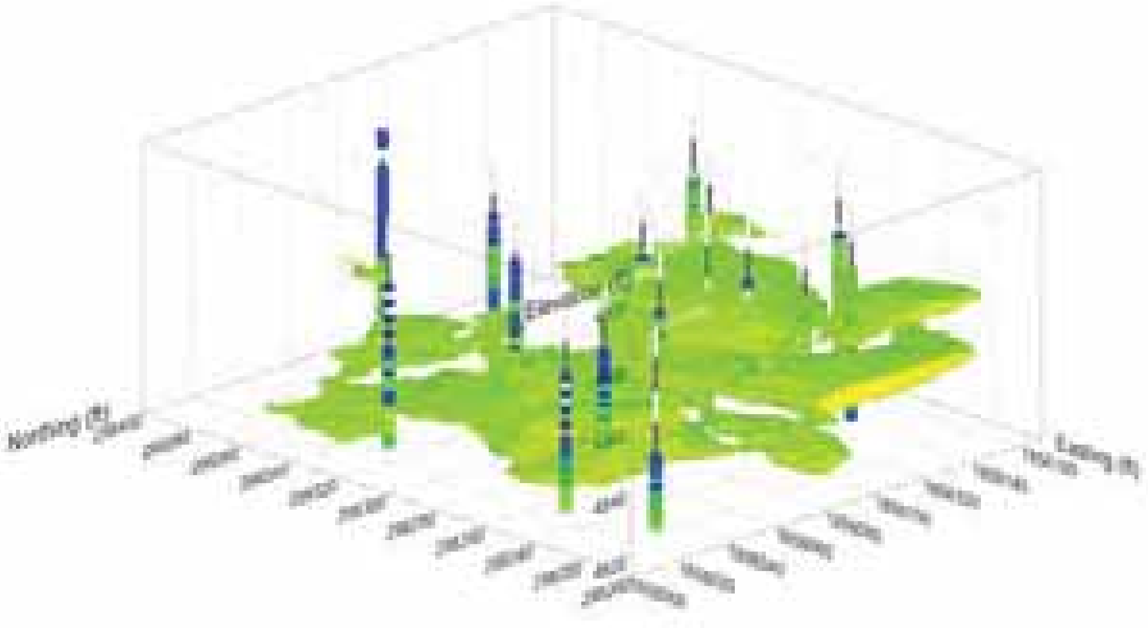
Final

Source Zone Delineation Demonstration Report

Operable Unit 12

Hill Air Force Base, Utah



March 2003

FINAL REPORT

Operable Unit 12

Source Zone Delineation Demonstration Report

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EXECUTIVE SUMMARY

This report documents the results of the Hill Air Force Base Operable Unit 12 (OU 12) Source Zone Delineation Demonstration. The demonstration was conducted to investigate volatile organic compound contamination in the vadose zone of the suspected OU 12 source area using rapid decision-making based on real-time data collected in the field via direct sampling ion trap mass spectrometry (DSITMS) for rapid identification of contaminant concentrations. The investigation consisted of two technology demonstrations – (1) wireline cone penetrometer system for multiple tool usage and (2) soil vapor extraction (SVE) for vadose zone characterization.

The Wireline CPT demonstration was conducted within the vadose zone and capillary fringe underlying the general area defined as the suspected source zone at OU 12. During the first four days of soil sampling using the Wireline CPT sampler, approximately 205 soil samples were collected from vertical traces at 5 discrete locations (approximately 50 samples per day). An increase in sample collection frequency occurred during the last five days of field operations, where approximately 395 soil samples were collected from vertical traces at 11 discrete locations (approximately 80 samples per day). In total, 599 soil samples were collected from vertical traces at 16 discrete locations during the nine working days of the Wireline CPT demonstration. Samples were generally collected along 1-foot sampling intervals from approximately 20 to 65 feet bgs.

Inference of the magnitude and spatial extent of TCE contamination in the vadose zone at OU 12 was accomplished using three-dimensional modeling of TCE concentration measured in the soil samples retrieved with the Wireline CPT sampler. An isometric view of the 100 μg/kg iso-concentration surface from the final three-dimensional model of TCE contamination in soil is shown in Figure ES-1. The view is from the southwest corner of the model domain, looking to the northeast. The spheres on each of the borings represent soil sample locations, color-coded according to the measured concentration of TCE. The highest concentrations of TCE were observed in samples collected from U2-1804 at a depth of 27 feet (154,000 μg/kg) and 29 feet (73,000 μg/kg) below ground surface (bgs); from U2-1807 at 33 feet bgs (144,000 μg/kg); and from U2-1817 at 29 feet bgs (131,900 μg/kg). In contrast, surrounding borings yielded no soil samples with a measured TCE concentration greater than 10,000 μg/kg. During the analysis of samples collected from U12-1807, four samples (30 to 33 feet bgs) were observed to contain a light nonaqueous phase liquid (LNAPL). In addition, two samples (27 to 29 feet bgs) from U12-1804 were observed to contain a LNAPL.

Based on the results of the TCE soil model, contamination in the vadose zone at OU 12 has a distinctly layered character. Individual layers are elliptical in plan-view, approximately 5 to 10 feet thick, several hundreds of square feet in areal extent, and are present over most of the entire thickness of the vadose zone within the modeled region. The layers of TCE contamination tend to reside in silty-sand soils, joined vertically by narrow and tortuous throat-like connections evocative of migration pathways. This spatial pattern of TCE contamination in soil suggests that water, percolating downward under the force of gravity and carrying with it dissolved TCE, spreads laterally when it encounters capillary barriers. Pathways through the barriers are ultimately found, providing the contaminated water with a new avenue for downward percolation.

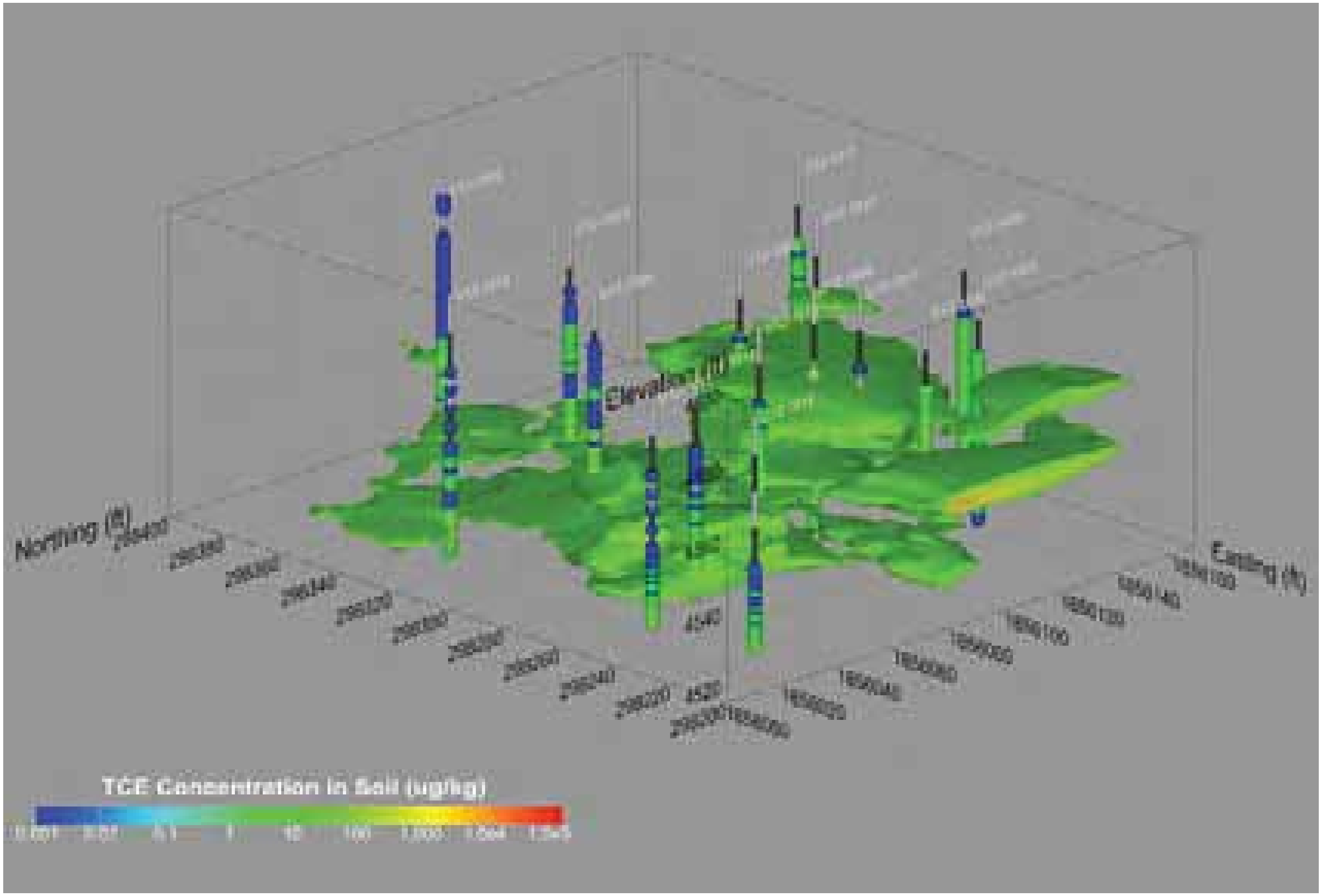


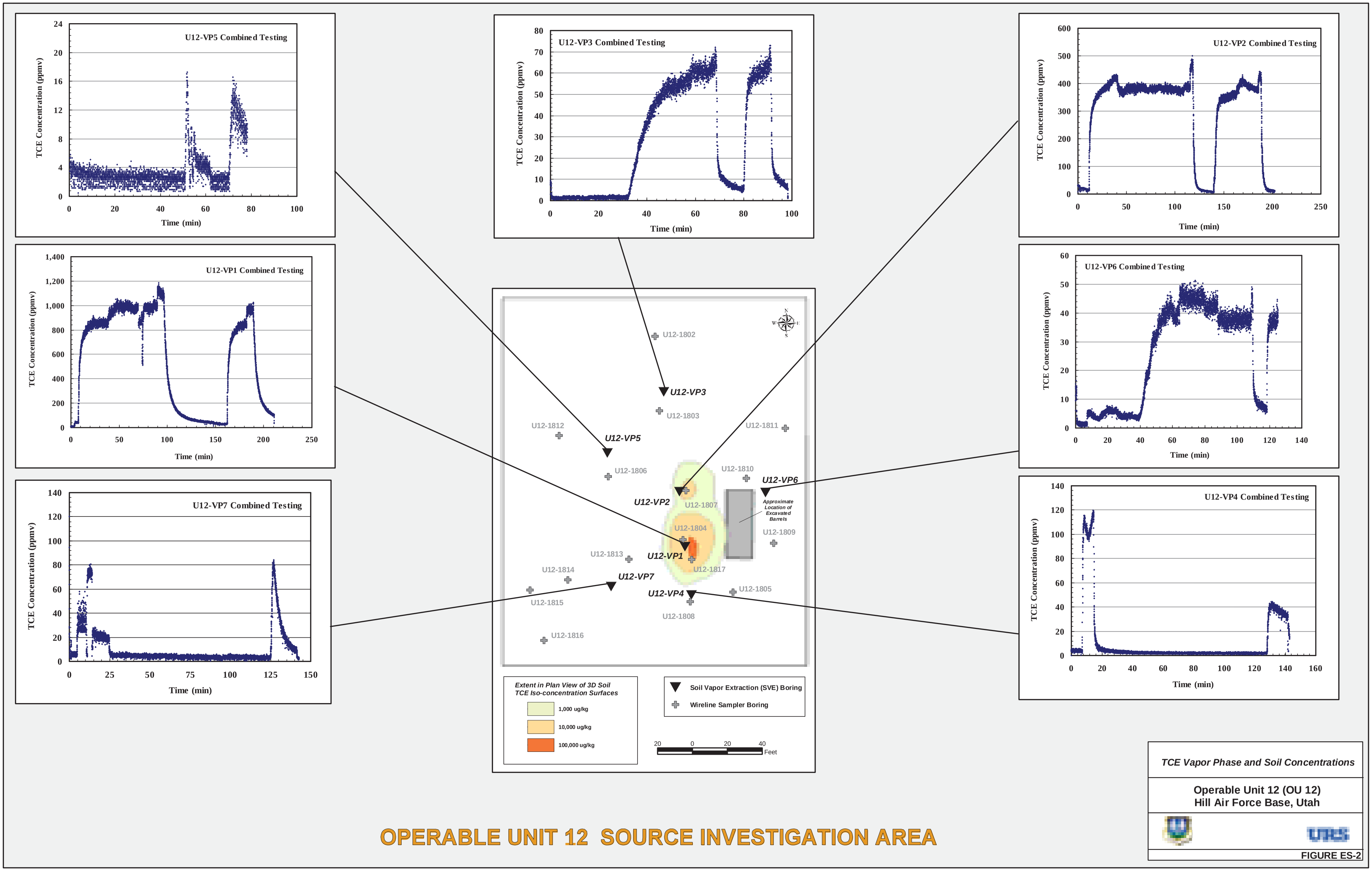
Figure ES-1. Iso-concentration surface of the 100 μg/kg TCE contamination in soil constructed using 599 wireline soil samples from 16 borings.

The SVE demonstration conducted in the suspected source zone at OU 12 focused on step tests for estimating TCE distribution within the vadose zone of the investigative area using a multiphase, multicomponent numerical model. The concentration of TCE in time was monitored on one-second intervals via the on-site laboratory using DSITMS, resulting in over 66,000 data. The TCE time-series data collected during the demonstration were compared with simulated time-series data using a theoretical distribution of TCE mass in the zone of influence and a sequential forward numerical modeling scheme in an attempt to help delineate source-zone contamination in the vadose zone of the investigative area. Although the step tests were optimized to assess contaminant distribution within the vadose zone of the investigative area, the data also provide an indication of the pneumatic response of the subsurface at OU 12 during vapor extraction operations. Based on a maximum radial extent of induced subsurface vacuum of 0.01 inch of water, the zone of pneumatic influence observed during the OU 12 SVE demonstration ranged from approximately 50 to 80 feet in the southern section of the investigative area to over 100 feet in the northern section. The average zone of pneumatic influence within the investigative area was approximately 85 feet. The average *in situ* air permeabilities observed during vapor extraction operations is typical of the fine-grained material in the vadose zone at OU 12 and ranged from 5 to 20 Darcy with a geometric mean of approximately 10 Darcy.

Over 160 theoretical source configurations were simulated numerically during the demonstration. The best correlation between the predicted and measured TCE vapor-phase concentration profile was obtained using a theoretical TCE source located approximately 8 feet northwest of U12-VP1 and 19 feet southeast of U12-VP2. This source was assumed to be 5 feet by 5 feet in areal extent, 10 feet thick, and containing 400 mg/kg TCE. For this source configuration, the predicted vapor-phase concentrations and the general concentration profiles were in relatively good agreement for five of the seven extraction wells but significant differences were observed for two wells distant from the assumed source location. In addition, the predicted TCE concentration profiles for U12-VP1 and U12-VP2 did not exhibit the characteristic exponential decline that was observed in the measured concentrations during periods of blower shutdown.

The vapor-phase concentration of TCE observed during SVE operations at OU 12 closely correlate with the spatial distribution of the TCE soil contamination as shown in Figure ES-2. The highest TCE vapor concentration was observed at U12-VP1 located approximately 20 feet west of the southern end of the drum excavation area. The maximum concentration of TCE in the extracted vapor from this location was approximately 1,150 ppmv. The next highest concentration of TCE was observed at U12-VP2, located approximately 35 feet north of U12-VP1 and 20 feet west of the north end of the drum excavation area. The maximum concentration of TCE in the extracted vapor at U12-VP2 during testing was approximately 500 ppmv. The concentration of TCE in the extracted vapor from the other five wells was less than approximately 100 ppmv during vapor extraction operations.

Although a final source configuration was not obtained with the sequential forward modeling scheme, the SVE modeling did suggest that the highest levels of soil contamination are located near the top of the screened intervals of U12-VP1 and U12-VP2. Based on the results of the model, it is inferred that the major source of TCE contamination is located in the upper portion of the vadose zone (20 to 35 feet bgs) offset slightly to the east of U12-VP1 and moderately more distant from U12-VP2. Based on the results of the SVE modeling, soil concentrations may be closely approaching the saturation limit where a dense



OPERABLE UNIT 12 SOURCE INVESTIGATION AREA

TCE Vapor Phase and Soil Concentrations

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE ES-2

nonaqueous phase liquid (DNAPL) is expected to exist; however, TCE concentrations observed during the Wireline CPT soil investigation do not support the presence of a separate DNAPL phase. The modeling of TCE contamination in the soil illustrated that the highest levels of soil contamination are in the range of 100 mg/kg to 200 mg/kg and are located near the top of the screened intervals of U12-VP1 and U12-VP2. Thus, it is likely that the major TCE contamination in the investigative area is associated with a sorbed fraction and probably a separate LNAPL phase that was identified in the vicinity of vapor extraction wells U12-VP1 and U12-VP2 during the Wireline CPT soil investigation (soil samples that exhibited LNAPL also were shown to contain elevated concentrations of TCE).

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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
ARA	Applied Research Associates, Inc.
amsl	Above Mean Sea Level
bgs	Below Ground Surface
cis-1,2-DCE	cis-1,2-Dichloroethene
cfm	Cubic Feet per Minute
CPT	Core Penetrometer Test
CSM	Conceptual Site Model
DCE	Dichloroethene
DNAPL	Dense Nonaqueous Phase Liquid
DSITMS	Direct Sampling Ion Trap Mass Spectrometry
EPA	Environmental Protection Agency
EPRIMS	Environmental Resources Program Management System
Hg	Mercury
HP	Horse Power
LNAPL	Light Nonaqueous Phase Liquid
MAMS-2	Missile Assembly Maintenance and Storage-2
mbar	Millibar
MeOH	Methanol
MWH	Montgomery Watson Harza
NA	Not Applicable
NAPL	Nonaqueous Phase Liquid
OU 12	Operable Unit 12
PCE	Tetrachloroethane
PEC	Performance Evaluation Check
ppb	Part-per-Billion
ppmv	Part-per-Million by Volume
PVC	Polyvinyl Choride
QA	Quality Assurance
QA/QC	Quality Assurance/Quality Control
ROI	Radius of Influence
scfm	Standard Cubic Feet per Minute
STP	Standard Temperature and Pressure
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TVD	Total Variation Diminishing
VOC	Volatile Organic Compound

1.0 INTRODUCTION

This report documents the results of the Source Zone Delineation Demonstration at Operable Unit 12 (OU 12), Hill Air Force Base (AFB) in Utah (see Figure 1-1). The demonstration was conducted to investigate volatile organic compound (VOC) contamination in the vadose zone of the suspected OU 12 source area using rapid decision-making based on real-time data collected in the field via a dynamic work plan approach. The investigation consisted of two technology demonstrations – (1) wireline cone penetrometer system for multiple tool usage and (2) soil vapor extraction (SVE) for vadose zone characterization. Sampling and analysis was conducted in the field via direct sampling ion trap mass spectrometry (DSITMS) for rapid identification of contaminant concentrations. Real-time data was required due to the rapid soil sampling capability of the wireline tool and to obtain adequate characterization of vapor-phase contaminant concentration profiles as a function of time across a varied flow regime. Additionally, optimization of vapor extraction rates and location of investigation was optimized as a result of immediate concentration profiles. This investigation represents the next progression in the characterization of OU 12 and builds upon the active soil-gas survey completed in the suspected source zone at OU 12 in October 2001 and March 2002 [*MWH*, 2002a].

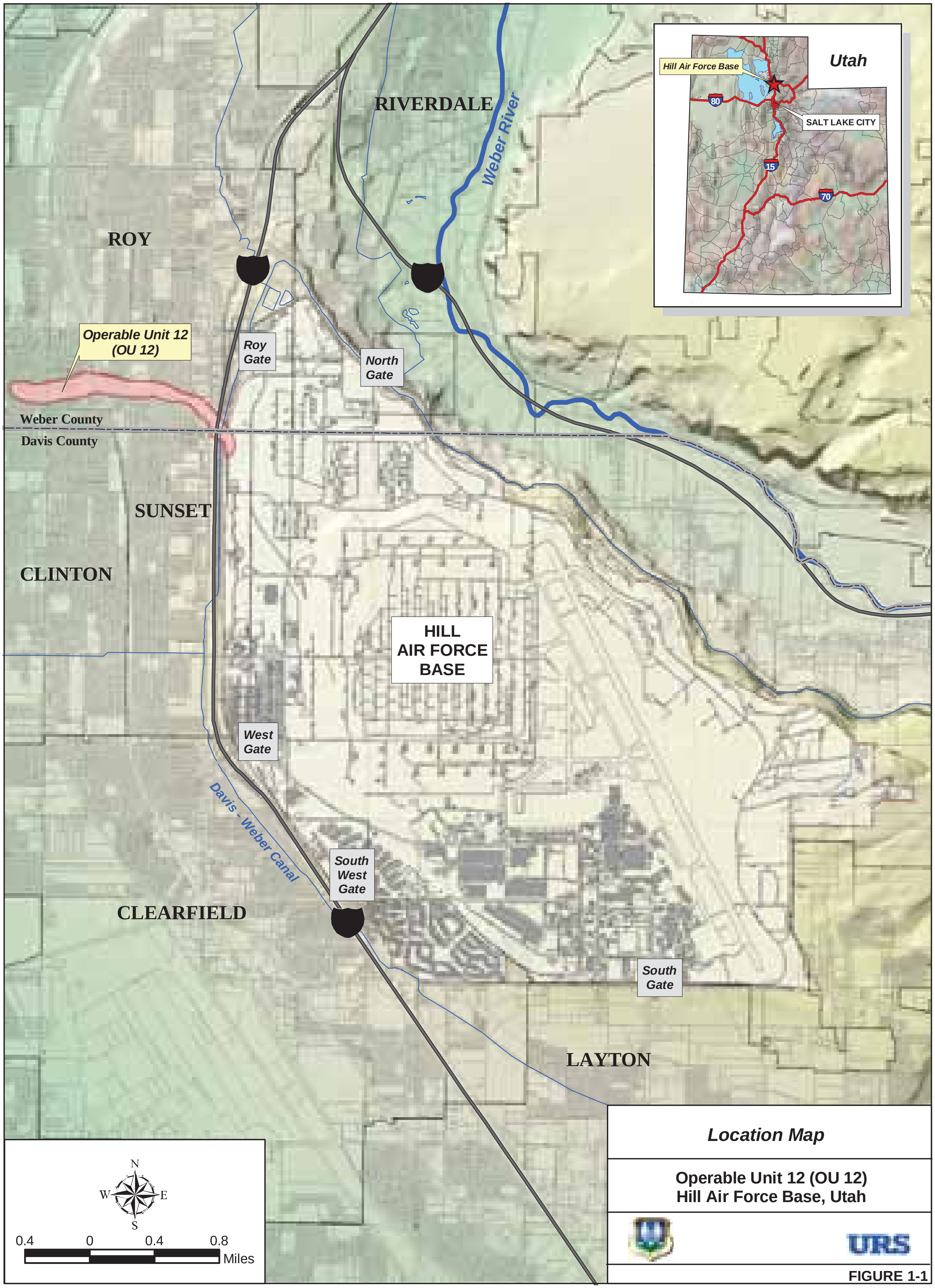
1.1 Project Objectives

The objectives for the Source Zone Delineation Demonstration at OU 12 included:

- Locating and spatially-defining any existing source of trichloroethene (TCE) in the vadose zone and capillary fringe of the suspected OU 12 source zone;
- Demonstrating the ability of ARA's Wireline CPT system and Tri-Corders Environmental, Inc. DSIMTS to rapidly characterize contaminant distribution within the vadose zone; and
- Demonstrating the ability of SVE to characterize the spatial and phase distribution of VOC mass within the vadose zone.

1.2 Dynamic Work Plan Approach

A dynamic work plan approach was utilized during the OU 12 Source Zone Delineation Demonstration. The dynamic work plan approach focuses on the decision-making process that integrates the data generated in the field to facilitate a rapid, cost effective characterization of the site. Formulated as a decision tree during the planning process, the dynamic work plan adapts site investigative activities in relation to the evolving, usually on a daily basis, conceptual site model (CSM). Dynamic work plans have been successfully demonstrated for over ten years by various parties [*Burton*, 1993 and *Robbat*, 1997]. Implementation of a dynamic work plan requires on-site generation and interpretation of data so that results are available fast enough to support the rapidly evolving on-site decision-making. Although not a new concept, recent advances in field analytical instrumentation and computerization have enabled dynamic work plans to be utilized in the characterization of complex sites.



Location Map

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE 1-1

Dynamic work plans rely on an adaptive sampling and analysis strategy. Rather than specify the sampling location and frequency, dynamic work plans specify the decision-making logic that will be used in the field to determine where to collect samples and when to terminate sampling. The conceptual model of the site is dynamic and changes to reflect the increased site knowledge gained from site investigative activities. Thus, an adaptive sampling program changes as the CSM is refined based on the analytical results produced in the field. In comparison, the traditional site investigation work plan is static in nature and depends on pre-specified sampling locations, sampling frequency, and the types of analysis to be performed.

A dynamic work plan approach requires detailed up-front planning, an advanced level of field-based technology and interpretative expertise, and the flexibility to make assessment decisions during field operations. Real-time, or near real-time visualization and interpretation of field-generated data enables a dynamic decision process to direct data collection during the site investigation activities. This approach employs multiple measurement and sampling technologies coupled with on-site technical decision-making by a skilled, multidisciplinary Core Technical Team. The purpose of the Core Technical Team is to provide a continuous, integrated, multidisciplinary presence throughout the project. Additionally, the Core Technical Team is responsible for decision-making in the field and directing the site investigation. The technical team generally is composed of professionals that possess expertise in geology, hydrogeology, analytical chemistry, and chemical/remediation process systems. The Core Technical Team for the OU 12 Source Zone Delineation Demonstration consisted of members from URS Corporation, Applied Research Associates, Inc. (ARA), Tri-Corders Environmental, Inc., Montgomery Watson Harza (MWH), and Hill AFB (see Figure 1-2).

As the prime contractor, URS was responsible for the design, implementation, and reporting requirements associated with the Source Zone Delineation Demonstration. Additionally, URS conducted the SVE investigation at OU 12 to serve as a technology demonstration for the utility of SVE as a characterization tool for VOC contamination in the vadose zone. To aid in the characterization of the OU 12 source zone and provide preliminary site data for the placement of the soil vapor monitoring probes, ARA conducted a Wireline CPT investigation. The Wireline CPT investigation also served as a technology demonstration for the rapid characterization of a VOC source zone. The Wireline CPT system consists of an innovative retrieval system and an assortment of characterization tools that can be retrieved and interchanged from any depth in the vadose zone without retracing the rod-string from the ground. Tri-Corders Environmental, Inc. provided field analytical services for the rapid analysis of low concentration VOCs in the environmental media analyzed at OU 12. Field analysis included the use of DSITMS for near continuous analysis of soil and vapor samples collected via the Wireline CPT and soil vapor extraction systems. MWH assisted with the installation of the vapor extraction/monitoring probes and with data logging during the Wireline CPT demonstration.

Members of the team were responsible to make recommendations on field investigative activities (e.g., sampling locations and frequency) based on the preliminary CSM of the site and the most current data gathered during field operations. Although the URS Project Manager and ARA Project Manager served as team co-leaders, final decision-making authority resided with the URS Project Manager during the demonstration.

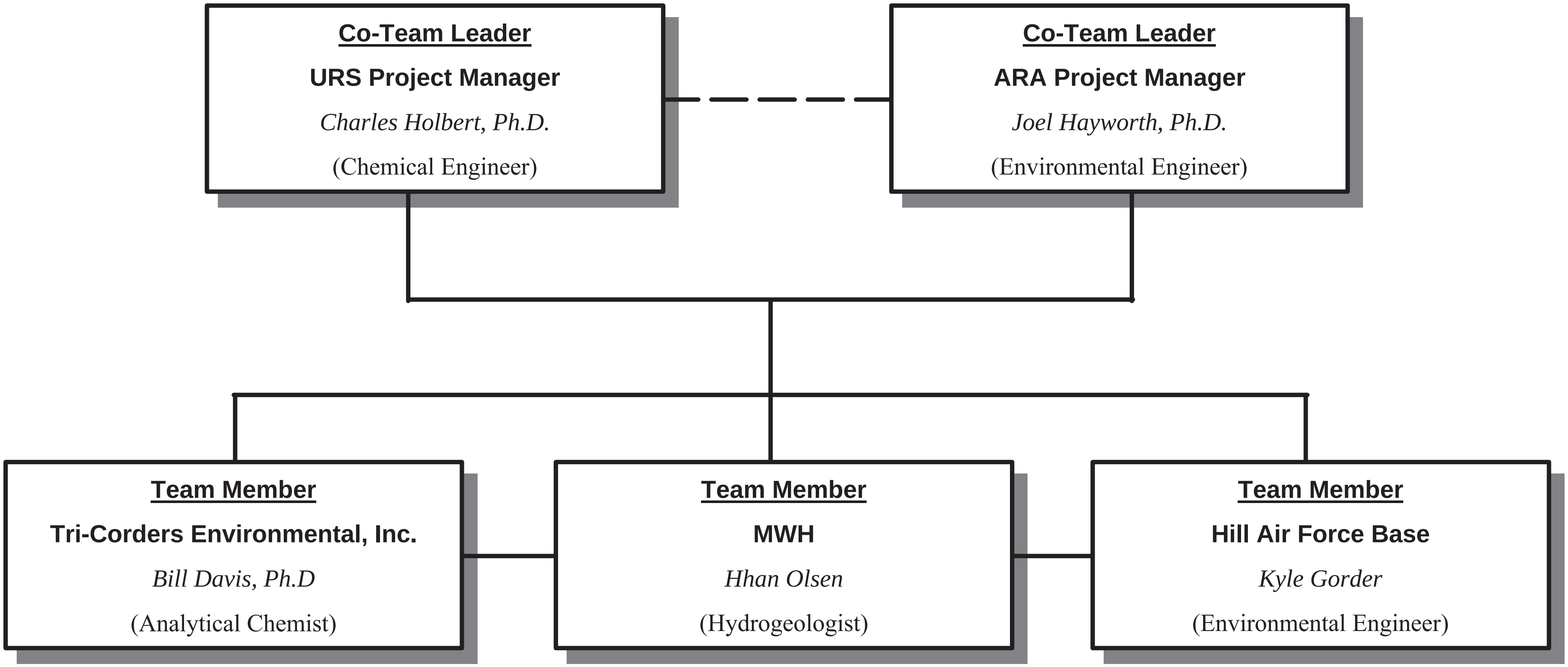


Figure 1-2. OU 12 source zone demonstration Core Technical Team.

1.3 Overview of Source Zone Delineation Tasks

The delineation of the suspected source zone at OU 12 was conducted using a dynamic work plan approach. To ensure the project objectives were met, field operations were performed according to the following strategy:

- Up-front systematic planning;
- Use of an adaptive (dynamic) sampling plan;
- On-site analysis and "immediate" availability of results using the DSITMS; and
- Rapid on-site decision-making by the Core Technical Team and guided by real-time data.

The primary tasks associated with the Source Zone Delineation Demonstration included the following:

Task 1. Mobilization and Setup. The CPT truck was mobilized to the OU 12 site and the wireline sampling tool system was prepared for field operations. The on-site laboratory consisting of the DSITMS also was mobilized to the OU 12 site and initialized for field operations.

Task 2. Wireline CPT Demonstration. The Wireline CPT investigation was conducted within the vadose zone and capillary fringe underlying the suspected source zone at OU 12. The investigation focused on TCE analysis of vadose zone soils, since the TCE groundwater plume emanating from OU 12 had been previously defined. Soil sampling began along a pre-determined sampling transect and one-foot vertical intervals from the ground surface. Characterization of the spatial extent and magnitude of TCE contamination in the vadose zone was concurrent with field sampling efforts. Iterative, short-delay modeling of the extent of contamination provided field personnel with guidance for selecting new Wireline CPT sampling locations.

Task 3. Vapor Extraction/Monitoring Probe Installation. Soil vapor monitoring/extraction probes were installed at seven locations in the suspected OU 12 source zone using direct push technology. At each location, probes were installed from approximately 30 to 60 feet below ground surface (bgs) with screened intervals ranging from 15 to 20 feet in length. Exact depths and locations were based upon review of the Wireline CPT data collected during the project.

Task 4. SVE Demonstration. The SVE system was constructed and operated for approximately 5 days in the suspected source zone at the OU 12 site. The SVE system was operated at varied rates of flow to determine vapor phase contaminant concentration profiles under both advective and diffusive dominated flow regimes.

1.4 Report Organization

The remaining sections of this report are organized as follows:

- Section 2.0 provides a summary of the OU 12 site, including a description of the suspected contaminant source and the vadose zone stratigraphy.
- Section 3.0 summarizes the Wireline CPT technical approach, field implementation, and DSITMS soil analytics.
- Section 4.0 summarizes the SVE technical approach, field implementation, and DSITMS vapor analytics.
- Section 5.0 presents the results of the Wireline CPT soil sampling and SVE demonstration.
- Section 6.0 provides a cost comparison between conventional vadose zone investigation methodologies and the technologies demonstrated as part of this project.
- Section 7.0 presents conclusions and recommendations based on the results of the demonstration.

2.0 SITE DESCRIPTION

This section provides a summary of the OU 12 site. Several environmental investigations have been conducted at the OU 12 site (formerly part of OU 5), including CPT investigations, aquifer testing, groundwater and soil sampling, hydraulic flow and contaminant transport modeling, and two active soil-gas surveys.

2.1 Site Description

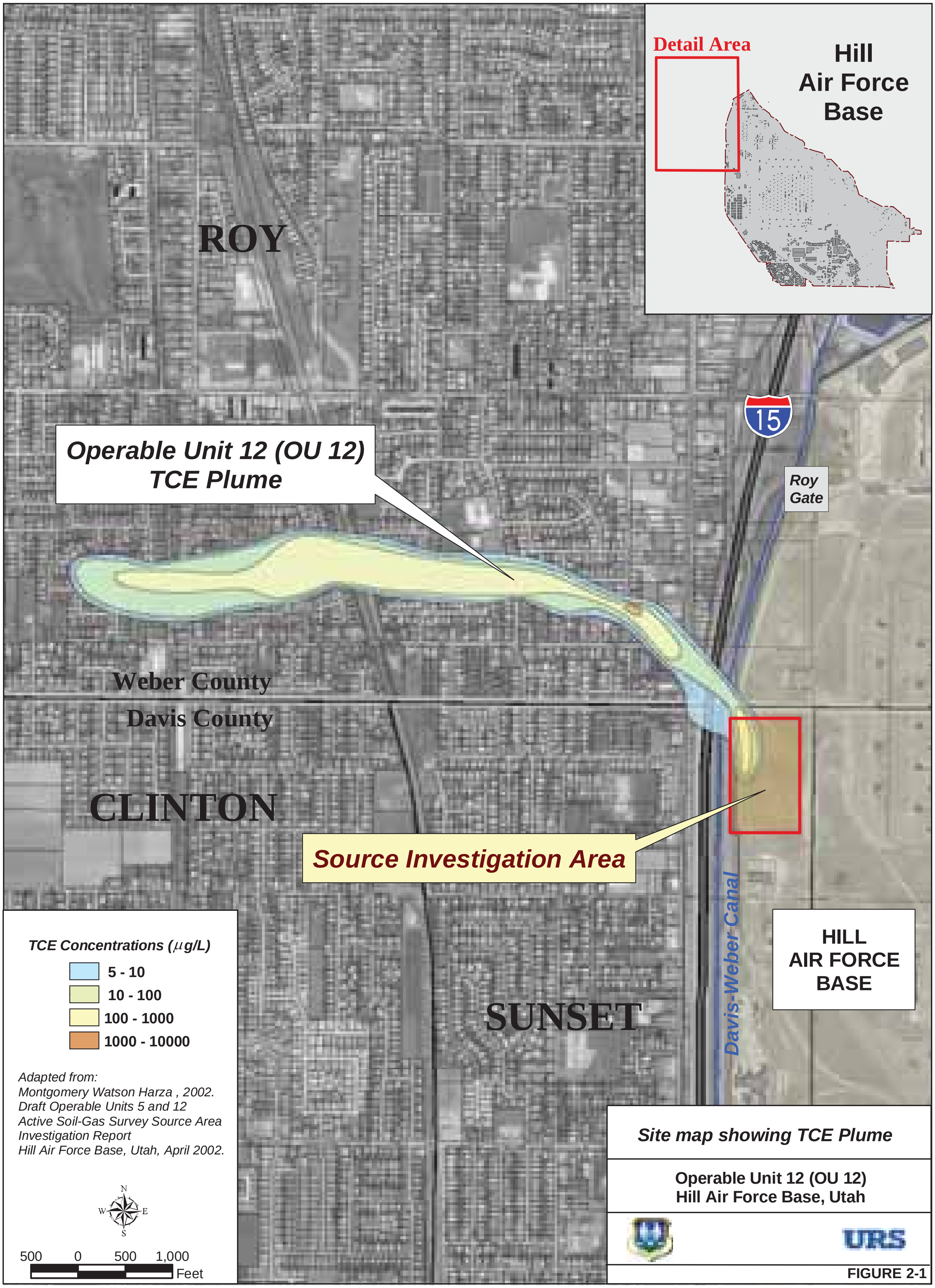
The OU 12 site is located in the northwestern region of Hill AFB, near the western boundary of the Base (see Figure 1-1). Environmental investigations at OU 5 in 2000 identified contamination beneath the City of Roy. This plume (above the maximum contaminant level [MCL] of 5 μg/L) and the on-Base contamination were designated as OU 12 in October 2001 [*MWH*, 2002b]. The primary contaminant of concern in the groundwater at OU 12 is TCE. Other contaminants of concern at OU 12 include cis-1,2-dichloroethene (cis-1,2-DCE), carbon tetrachloride, and tetrachloroethene (PCE).

The on-Base portion of OU 12 is located just inside of the Base perimeter fence and west of the Missile Assembly Maintenance and Storage-2 (MAMS-2) area. The area of activity consists of relatively flat, unpaved open space dominated by sagebrush and rabbit brush. Remnants of a former Wastewater Treatment Plant are located in the southeastern part of the site. Debris is scattered across the site, including several rusted-through half-buried drums, abandoned foundations, and various small metallic objects. Several trench-like features also are present in the area.

2.2 Suspected Contaminant Source

Although the source of the TCE groundwater plume at OU 12 had not been identified, a soil-gas survey indicated the suspected source area is northwest of the former Wastewater Treatment Plant. Additionally, increasing and/or highly variable TCE concentrations in monitoring well U9-16-011 indicated a continuing source in the area north of the former Wastewater Treatment Plant [*MWH*, 2002a]. A well-delineated TCE groundwater plume emanates from the suspected source zone at OU 12 as shown in Figure 2-1. The local groundwater flow direction is to the west, towards the town of Roy, Utah and the Great Salt Lake. The TCE groundwater plume extends down gradient approximately 8,000 feet; variations in plume width from origin to terminal end-point are small (average width of approximately 500 feet). From plume origin terminus, depth to the plume varies from approximately 85 feet bgs (at the origin) to approximately 4 feet bgs in the area of monitoring well U5-1143 off Base. Concentrations of TCE as high as 1,300 μg/L have been detected off Base at monitoring well U5-1112 [*MWH*, 2002a]. Within the suspected source zone, depth to groundwater is approximately 70 feet bgs.

Prior to this project, attempts to locate and delineate the spatial distribution of the suspected TCE source zone have been minimal (with the exception of the recent soil-gas survey). However, indirect evidence strongly supported the possible presence of a TCE source zone within the vadose zone (primarily) and the capillary fringe (secondarily) underlying the OU 12 site. This indirect evidence suggests that TCE is



TCE Concentrations (μg/L)

- 🟦 5 - 10
- 🟩 10 - 100
- 🟨 100 - 1000
- 🟧 1000 - 10000

Adapted from:
Montgomery Watson Harza , 2002.
Draft Operable Units 5 and 12
Active Soil-Gas Survey Source Area
Investigation Report
Hill Air Force Base, Utah, April 2002.

Site map showing TCE Plume

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE 2-1

held as a residual phase within the unsaturated soils and possibly within a capillary smear zone underlying OU 12. Indirect evidence supporting the presence of a vadose zone TCE source area included:

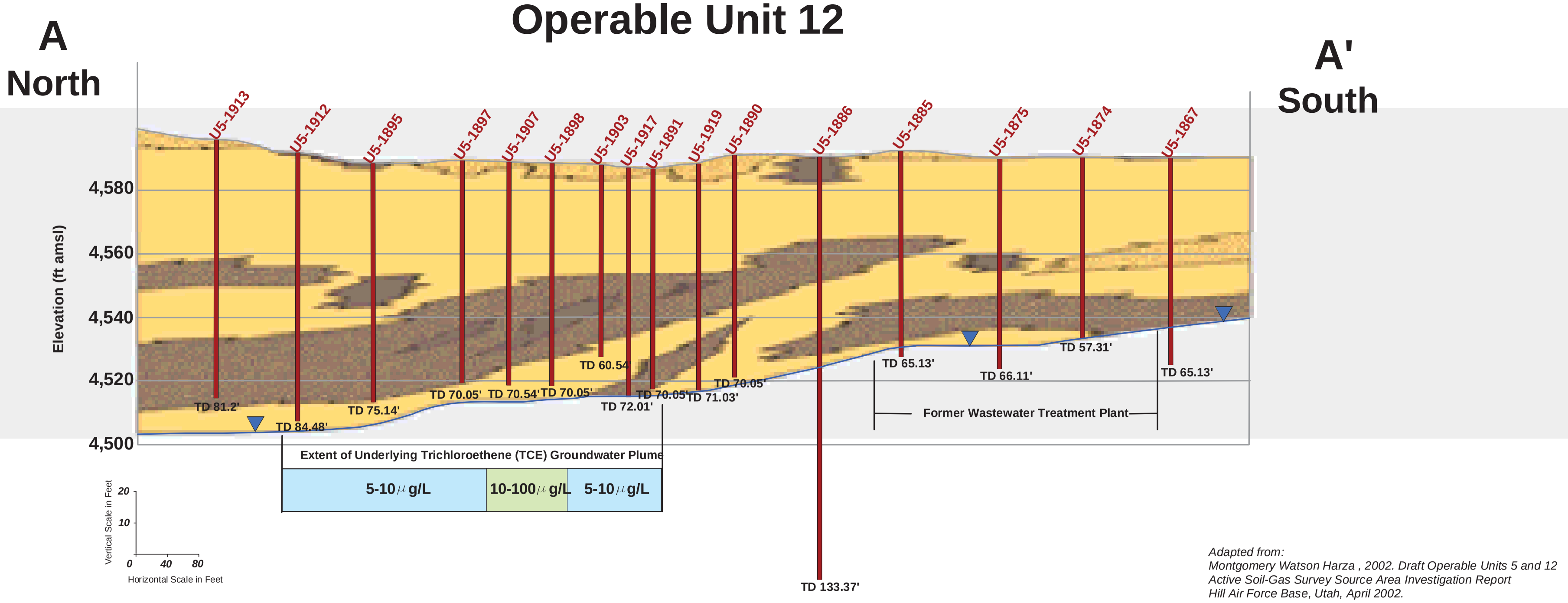
- A well-defined groundwater plume with high TCE groundwater concentrations in the central, near-source region (see Figure 2-1).
- Results of recent soil gas surveys defining the presence of TCE in soil gas within the vadose zone underlying OU 12.
- The recent discovery of buried drums near the ground surface generally correlated with soil-gas survey results (see Figure 2-2).
- The presence of a solid ash-like material within a drum having TCE concentrations exceeding 16,000 mg/kg.
- The apparent absence of pure-phase TCE within the saturated zone underlying OU 12 (as indicated by past investigations).
- Fluctuations in groundwater TCE concentrations in down-gradient monitoring wells suggesting periodic dissolution of residual-phase TCE within the vadose zone during infiltration events, and/or periodic dissolution of TCE within the capillary smear zone during changes in the local water table elevation.

2.3 Preliminary Vadose Zone Stratigraphy

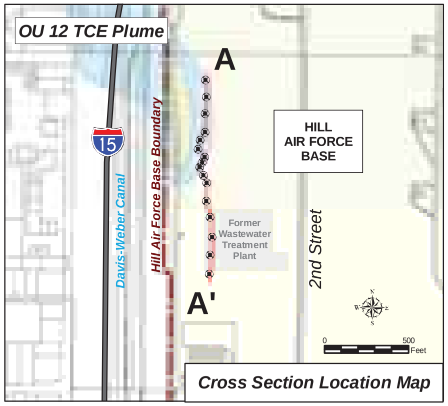
The vadose zone stratigraphy of the OU 12 site is complex. The upper portion consists mainly of sand with gravel and silty-sand interbeds, grading to increasing amounts of sandy-silt and silt with depth. The highest measured concentrations of TCE in the soil gas appear to be associated with the deeper, finer-grained intervals. Depth to groundwater increases from approximately 50 feet bgs in the south to 80 feet bgs in the north. The cross-section shown in Figure 2-3 illustrates the initial conceptualization of the vadose zone stratigraphy, based on a generalized interpretation of logs from CPT borings advanced during a soil gas survey conducted at the site in late 2001 and early 2002 [*MWH*, 2002a].

Figure 2-2. Recently discovered drums located near ground surface at OU 12.

CROSS SECTION A - A' LOOKING EAST
Operable Unit 12



Adapted from:
Montgomery Watson Harza , 2002. Draft Operable Units 5 and 12 Active Soil-Gas Survey Source Area Investigation Report Hill Air Force Base, Utah, April 2002.



Lithology

- 🟨 Sand
- ▨ Sand With Interbedded Silt
- ▨ Silt With Interbedded Sand
- ■ Silt

U5-1890 | Soil-Gas Sampling Location

▼ Approximate Location of Groundwater Table

Simplified Representation of Vadose Zone Stratigraphy

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 2-3

3.0 WIRELINE CPT SOIL SAMPLING DEMONSTRATION

The design of the Wireline CPT demonstration was based on data obtained from previous site investigation and characterization activities conducted at OU 12. To formulate the design basis, numerous data sources were reviewed, including site stratigraphy obtained from cone penetrometer soundings, groundwater analytical data, and soil-gas concentration data obtained during the two phases of soil-gas sampling conducted within the suspected OU 12 source zone. These data were used to formulate the preliminary CSM and identify the initial sampling plan associated with the Wireline CPT investigation. An adaptive sampling and analysis strategy was used during the demonstration and was based on field-generated data subjected to professional interpretation by the Core Technical Team. Characterization of the spatial extent and magnitude of TCE contamination in the vadose zone was concurrent with field sampling efforts. Iterative, short-delay modeling of the extent of contamination provided field personnel with guidance for selecting new Wireline CPT sampling locations during site investigation activities.

3.1 Wireline CPT Technical Approach

The Wireline CPT demonstration was conducted within the vadose zone and capillary fringe underlying the general area defined as the suspected zone at OU 12. The investigation focused on TCE analysis of vadose zone soils, since the TCE groundwater plume emanating from OU 12 had been previously defined.

Based on the indirect evidence cited in Section 2.0 of this report in relation to the suspected source zone location, high-density soil sampling and analysis coupled with a judgment-based decision process for sample selection was utilized during the Wireline CPT demonstration. Judgment-based sampling decisions were intended to maximize the likelihood of locating and delineating the suspected TCE source zone at OU 12 within the limited deployment time allocated. The total decision error (sampling error and measurement error) associated with this demonstration was minimized by the following:

- Collecting a high number of soil samples within a vertical trace using CPT coupled with the Wireline soil sampler.
- Processing a high number of soil samples using Tri-Corders Environmental, Inc.'s DSITMS (EPA SW 846 modified method 5035).
- Providing a high number of quality assurance (QA) samples relative to the number of site samples using the DSITMS.
- Using a judgment-based sampling and analysis strategy based on in-field expertise to guide soil sampling and analysis.

The initial proposed sampling transect for the Wireline CPT demonstration is shown in Figure 3-1. This initial sampling transect was based on the fact that the recently discovered buried drums did not correlate exactly with the apparent origin of the groundwater plume or the highest concentration of TCE observed during the soil-gas survey at OU 12. It was surmised that any TCE trapped within the vadose zone was

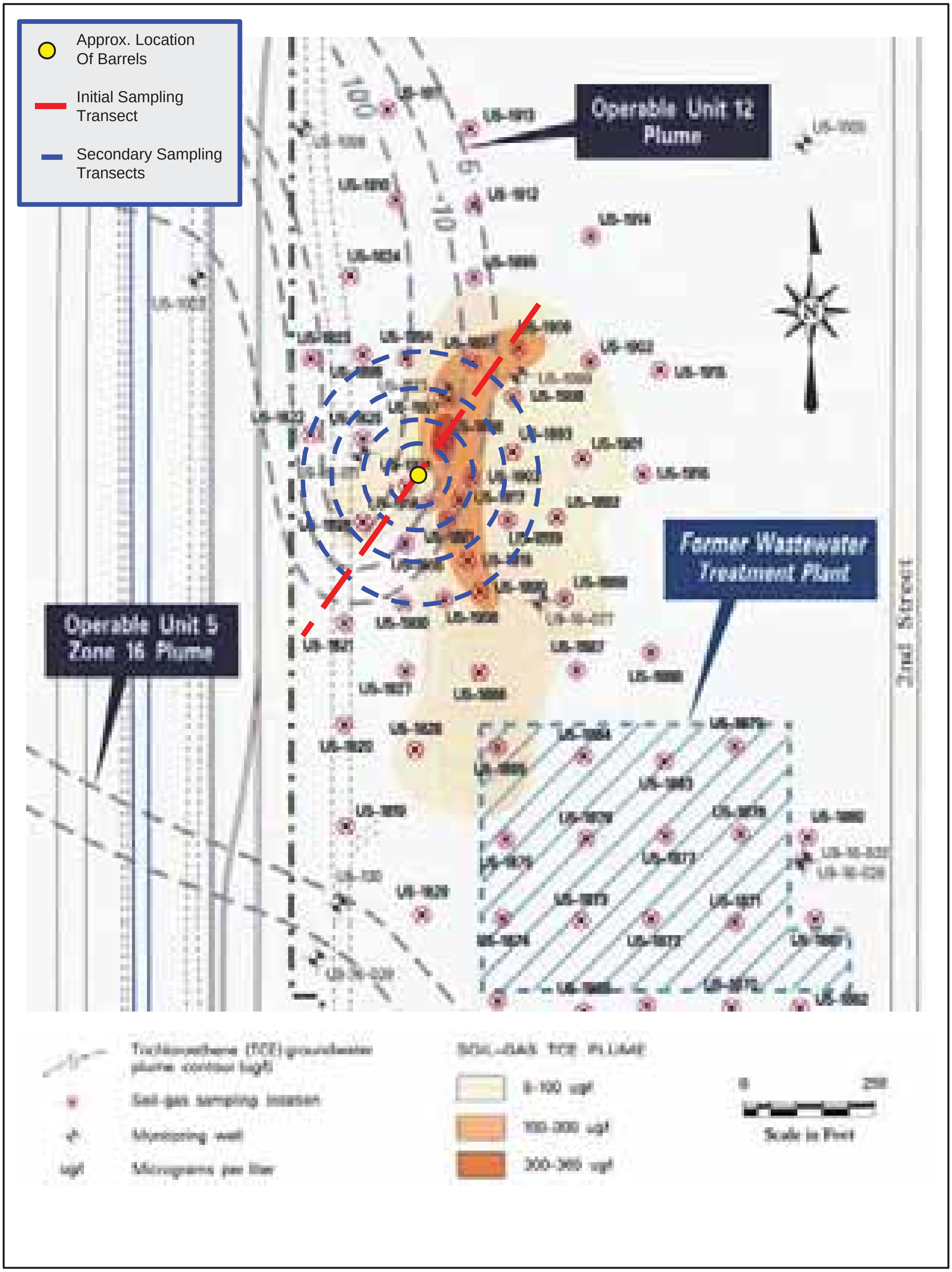


Figure 3-1. Initial proposed Wireline CPT sampling transects.

likely present between the drum discovery area and the origin of the groundwater plume. As illustrated in Figure 3-1, initial sampling was proposed along a straight line roughly connecting the barrel location with the plume origin. However, an adaptive sampling and analysis strategy was used during the demonstration and was based on field-generated data subjected to professional interpretation by the Core Technical Team. Characterization of the spatial extent and magnitude of TCE contamination in the vadose zone was concurrent with field sampling efforts. Iterative, short-delay modeling of the extent of contamination provided field personnel with guidance for selecting new Wireline CPT sampling locations during site investigation activities. Other potential sampling transects which were considered during the Wireline CPT demonstration also are shown in Figure 3-1. These potential transects form concentric circles expanding outward from the barrel location to the western property boundary.

3.2 Wireline CPT Implementation and Operations

The Wireline CPT system is an advancement of conventional CPT that allows nearly all characterization work to be accomplished in a single penetration. The Wireline CPT system, unlike conventional CPT, is capable of retrieving and interchanging CPT “tools” without retracting the rod-string from the ground. Retracting and repenetrating the rod-string is a time consuming process because the rod string is made up of one-meter sections connected by threaded couplings. Retraction and repenetration involves dissasembly and reassembly of the entire rod-string.

The Wireline system utilizes slightly larger rods than conventional CPT (two inches in diameter compared to the 1.75-inch diameter of a standard CPT rod), allowing passage of tools through the rod’s hollow center. The Wireline system also has a unique locking/release mechanism that allows interchange of tools by a retrieval wire. The locking mechanism is identical for each individual Wireline tool, to allow interchangeability. The lock mechanism utilizes two horizontally opposed, horizontally rotating locking "dogs" which, when engaged, occupy a slot formed in the interior of a rod segment. When upward force is applied to the locking wedge via tension on a retrieval wire, the wedge slides upward allowing the dogs to move freely inward. The dogs retract into the lock housing which allows the tool to be retrieved to ground surface. The locking wedge is spring loaded, so outward pressure is applied to the dogs. An illustration of the locking and retrieval mechanism with the soil sampler in place is provided in Figure 3-1.

With conventional CPT, multiple tools can be deployed in a single penetration by stacking multiple tools in series on the same rod-string. This method is effective, but the number and type of tools that can be deployed together is limited. This method is not effective for collecting multiple soil samples. The Wireline soil sampler is especially effective when collecting multiple-depth soil samples. Using the Wireline system, core samples can be collected from multiple depths without retracting the rod-string. Using conventional CPT, the entire rod-string would have to be retracted to retrieve each soil sample and re-penetrated to collect another sample.

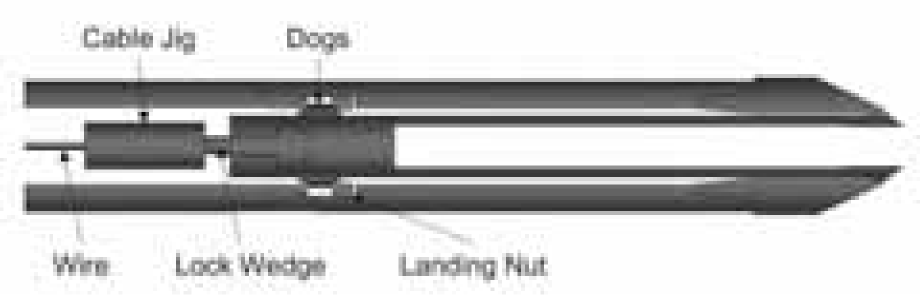


Figure 3-2. Wireline locking and retrieval mechanism.

Soil samples were collected using the CPT coupled with the Wireline soil sampler. Samples for field-based analysis using DSITMS were removed from the bottom of the Wireline soil sampler core barrels using a syringe sampler (approximately 10 grams of sample), placed directly into tared 40 ml VOA vials, weighed, and delivered to the DSITMS for analysis (see Figure 3-2). The 40 ml VOA vials contained approximately 20 ml of distilled water or 10 ml of methanol as an extractant. Following submittal to the on-site laboratory, the vials were filled with additional extractant, re-weighed, and analyzed using EPA Method 5035. The final weights of extractant and soil were used to calculate contaminant concentrations in each sample collected.

Mobilization and process system setup for the Wireline CPT soil sample collection system and DSITMS on-site laboratory began on 19 August 2002. Full soil sampling operations began on 21 August 2002 following two days of system setup and troubleshooting. Several operational problems occurred during the first 4 days (21 – 24 August 2002) of soil sampling using the Wireline CPT sampler. Poor sample recovery resulted in the accumulation of dirt/grit in the locking and retrieval mechanism of the wireline tool. Subsequently, a significant amount of time was spent trying to lock and unlock the wireline tool, and on several occasions the Wireline CPT rod had to be retracted in order to clean the interior of the locking dogs. During this period, approximately 205 soil samples were collected from vertical traces at 5 discrete locations (approximately 50 samples per day).

An increase in sample collection frequency occurred during the last 5 days (26 - 30 August 2002) of the Wireline CPT field operations. During this period, approximately 395 soil samples were collected from vertical traces at 11 discrete locations (approximately 80 samples per day). This increase of roughly 38% in sample collection was associated with several aspects of the demonstration, including the arrival of additional soil samplers for the Wireline CPT tool and an experienced Wireline CPT operator. Additionally, the decision not to collect samples from the upper gravelly sand zone that extended from approximately 18 to 22 feet bgs decreased the amount of soil that was lost from the Wireline soil sampler within the CPT rod. This resulted in a dramatic reduction in the accumulation of soil/grit in the interior of the locking dogs of the Wireline tool assembly.

During the nine working days of the Wireline CPT demonstration, 599 soil samples were collected from vertical traces at 16 discrete locations (approximately 1,000 linear feet of drilling). Samples were generally collected along 1-foot sampling intervals from approximately 20 to 65 feet bgs. The results of the Wireline CPT soil sampling investigation are discussed in Section 5.0 of this report.

Wireline CPT Rig and DSITMS On-Site Labortaory

Wireline CPT Soil Sampler Installation

Sample Collection From Wireline Soil Sampler

Wireline Soil Sample Collection and Weighing

Geologic Logging of Wireline Soil Samples

Soil Samples Collected From a Single Wireline CPT Push

Figure 3-3. Illustration of OU 12 wireline CPT soil sampling demonstration.

3.3 DSITMS Soil Analytics

Direct sampling ion trap mass spectrometry (DSITMS) introduces sample materials directly into an ion trap mass spectrometer by means of a very simple interface, such as a capillary restrictor or a polymer membrane. There is typically very little, if any, sample preparation and no chromatographic separation of the sample constituents. This means that the response of the instrument to the analytes or contaminants in a sample is nearly instantaneous and analyses are typically completed in less than five minutes.

Soil samples collected using the Wireline CPT soil sampler and sub-sampled using EPA Method 5035 were analyzed for TCE, PCE, DCE, and vinyl chloride using DSITMS according to US EPA Method 8265. Samples were collected using either distilled water or methanol (MeOH) as an extractant. Approximately 10 grams of soil was extracted with approximately 30 milliliters of distilled water or 10 milliliters of MeOH. The DSITMS was initially calibrated over the range of 0 μg/L to 250 μg/L in water using the 40-ml vial purge interface using a standard stock solution of TCE. This aqueous calibration range corresponded to approximately 8 μg/kg to 1,000 μg/kg when soil slurry analyses were performed on 10-gram soil samples. Subsequent calibrations were based on the soil concentrations observed in previous samples and the required extractant utilized.

Soil slurry samples were analyzed using the calibrated DSITMS system. Soil concentrations were calculated based on the aqueous concentration measured and the soil mass used during the extraction. Each sample analysis required approximately 3 minutes to perform. Normal quality control procedures were followed to insure the DSITMS system was operating within acceptable control limits during all data collection activities. Following the initial DSITMS system calibration, an external performance evaluation check (PEC) standard was analyzed to insure the calibration was accurate and contained no bias. Normal operating procedures required a minimum of one PEC analysis per day, but multiple PEC analyses generally were performed daily.

System blanks and continuing calibration check standards were analyzed at a rate of at least one each for every 20 field sample analyses performed. In addition, at least one field duplicate and matrix spike analysis were performed for every 20 field-sample analyses performed. Additional blank and calibration check standard analyses, beyond the minimum required were performed at the operator’s discretion, based on instrument performance and the requirements of the field decisions based on the data. For example, blanks were always analyzed immediately after analysis of very high-level field samples to insure that no sample carry over occurred during subsequent analyses. One significant advantage of the DSITMS and the 3-minute VOC analysis is that the analyst is able to adapt in real time to the QA demands of the project as the data are collected. This allows the analyst to run blank analyses after any high concentration samples to insure there is no carry over between soil sample analyses. It also allows the adjustment of matrix spike and continuing calibration check sample concentrations to reflect those currently being measured in the site soil samples.

During the Wireline CPT demonstration, 599 discrete soil samples were analyzed in nine working days for TCE, PCE, DCE, and vinyl chloride. Project reporting limits for TCE, PCE, DCE, and vinyl chloride in soil extracted with distilled water were 17 µg/kg, 26 µg/kg, 17 µg/kg, and 16 µg/kg, respectively. Project reporting limits for soil extracted with methanol were significantly higher (ranged from 800 µg/kg to 6,400 µg/kg) due to the large dilution factor required for the methanol-extracted analysis. During the Wireline CPT soil investigation, 230 quality assurance (QA) samples were analyzed. The QA samples included continuing calibration check samples, blanks, matrix spike samples, and PEC samples. A summary of the total analysis according to the QA sample type and the frequency of the QA analysis during the demonstration is provided in Table 3-1. No QA problems were encountered during the Wireline CPT demonstration and all QA sample analyses met the data QA limits specified for the project.

Between the daily calibrations conducted between 28 August 2002 and 29 August 2002, the working standard solutions were remade from the 4,000 ng/µL stock solution. Vinyl chloride was not added to the working stock solutions (40 ng/µL and 400 ng/µL) prepared on 29 August 2002. Since no vinyl chloride had been detected at the site during the previous seven days of the demonstration, it was decided by the project Core Technical Team that it was not necessary to include this analyte in the stock solution.

Table 3-1. Summary of Wireline CPT QA Sample Analyses

QA Sample Type	Total QA Sample Analysis	Average Number of Soil Samples per QA Sample Analysis
Continuing Calibration	74	8
Blank	78	8
Matrix spike	35	17
Performance evaluation check samples	43	14

4.0 SOIL VAPOR EXTRACTION DEMONSTRATION

Measurement of vapor-phase TCE concentrations during SVE was conducted at OU 12 to help delineate source-zone contamination in the vadose zone of the investigative area. The distribution of VOCs can be inferred by giving careful consideration to the vapor extraction operations, and by inverse numerical modeling, either through a formal inversion scheme or through an iterative process of sequential forward modeling. The advantages of SVE as a characterization tool are the relative ease and low-cost of implementation, the large volume of the unsaturated zone affected and the extensive amount of data collected as compared to soil borings, and the added benefit of active remediation occurring simultaneously with characterization. Used in conjunction with conventional subsurface data, SVE can increase the understanding of existing site conditions while decreasing the number of soil borings required to obtain a valid representation of contaminant mass and potential migration pathways.

The design of the SVE demonstration was based on data obtained from previous site investigation and characterization activities conducted at OU 12. These data were used to formulate the preliminary CSM and identify the initial monitoring/extraction well locations associated with the SVE demonstration. The locations of the soil vapor monitoring/extraction probes were refined based on the data obtained during the Wireline CPT demonstration.

4.1 SVE Technical Approach

The SVE demonstration was conducted in the suspected TCE source zone at OU 12 to obtain the following information:

- Additional vadose zone characterization data in the suspected source zone at OU 12;
- *In-situ* air permeability as a function of space and time;
- Vent performance characteristics, such as capacities and subsurface vacuum distributions for various extraction well locations; and
- Concentrations of TCE in the recovered vapor.

The SVE demonstration focused on step tests for estimating TCE distribution within the suspected source zone at OU 12 using a multiphase, multicomponent numerical model. During the step tests, the concentration of TCE in time was monitored via the on-site laboratory using DSITMS. The time-series data collected during field operations will be compared with simulated time-series data using a theoretical distribution of TCE mass in the zone of influence and a sequential forward numerical modeling scheme. In addition, the data obtained during the step tests were used to assess the pneumatic response from the vadose zone at each vapor monitoring/extraction point.

SVE data lends itself to a wide range of evaluation, including a simplified mass balance approach to more sophisticated multiphase, multicomponent numerical modeling in the unsaturated zone. A discussion of vapor transport in unsaturated porous media as it relates to numerical modeling and characterization of contaminant mass in the vadose zone is provided in the *Work Plan for the Source Zone Delineation Demonstration, Operable Unit 12, Hill Air Force Base, Utah* (URS, 2002).

Preliminary design simulations were conducted to assess vapor transport characteristics at OU 12 in relationship to the SVE operational parameters. A three-dimensional, finite-difference code for simulating isothermal vapor flow and transport of multicomponent mixtures called VENT3D [*Benson*, 1998] was used for the preliminary design modeling. VENT3D solves the three-dimensional vapor phase advective and/or dispersive flux of multicomponent mixtures using an orthogonal grid (see Figure 4-1). In addition, any number of vapor extraction and injection wells can be simulated, and grid-variable initial permeability and contaminant distributions can be specified. Each layer in the model is given distinct values of porosity, initial moisture content, and a vertical permeability anisotropy ratio. The uppermost layer, as well as the vertical boundaries, can be specified as pneumatically and chemically permeable or impermeable. Thus, ground covers such as plastic or asphalt can be simulated.

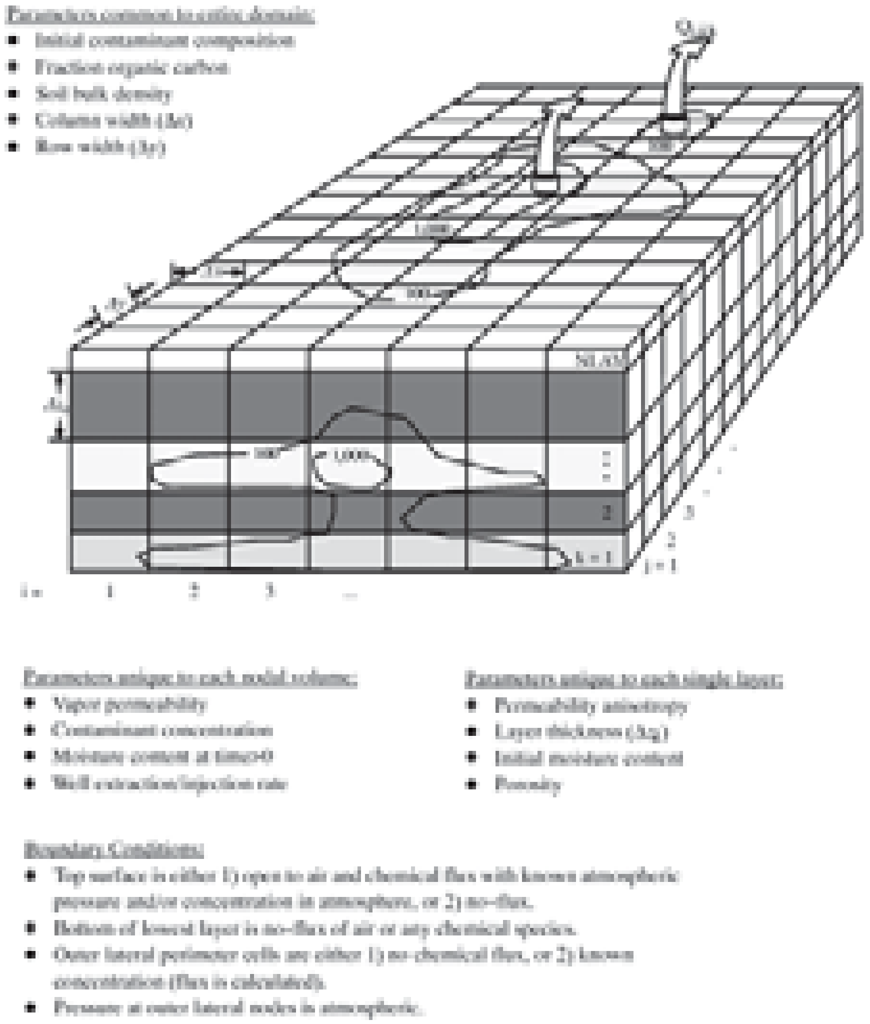


Figure 4-1. Schematic of VENT3D structure (*Benson*, 1998).

The equilibrium four-phase distribution of each compound in the mixture is solved in VENT3D between time steps, facilitating the explicit solution of the time-variable retardation of the various compounds. The compounds are moved by one of three explicit transport algorithms. In high velocity environments, a third-order, Courant-number-weighted algorithm can be used for higher accuracy. In dispersive-dominated environments, a combination of upwind and central-weighted algorithms can be used. The movement of soil moisture is also simulated, and permeability is time and grid variable as a function of fluid (contaminant and water) saturation. Effective molecular diffusion is calculated by the Millington and Quirk correlation. The model also can be used to simulate the movement of compound mixtures by diffusion only, for use in fate-and-transport studies.

The simulation grid used for the preliminary SVE modeling was 740 feet long (x-direction), 500 feet wide (y-direction), and 80 feet deep (z-direction). The grid block spacing was constant in all directions with spacings of 20 feet in both the x-direction and y-direction and 10 feet in the z-direction. The x-direction contained 25 grid-blocks, the y-direction contained 37 grid-blocks, and the z-direction contained 8 grid-blocks. An average permeability of 1 Darcy (estimated from slug test conducted at OU 5) was assumed in the horizontal direction based on an average OU 12 hydraulic conductivity of 5 feet/day. The average vertical permeability was assumed to be 10% the value of the horizontal permeability. The average fractional organic carbon content of the soil was assumed to be 0.001 with an average water saturation of 10%. The top and side layers of the simulation grid were assumed open to both air and chemical movement; the bottom layer was assumed closed (i.e., zero-flux boundary). One extraction well was located in the middle of the areal extent of the simulation grid and screened from 40 to 50 feet bgs. A homogeneous source containing 10,000 mg/kg TCE (corresponding to a residual NAPL saturation of 1.3%) was placed at the same depth and at varying distances from the extraction well. Two different source configurations were investigated: (1) a 20-foot by 40-foot source contained in the homogeneous permeability field, and (2) a 20-foot by 40-foot source trapped in a low permeability layer (0.1 Darcy) located in the higher permeability of the simulation grid. Two stress periods were simulated. The first stress period consisted of 30 years of no-flow at the extraction well to simulate the natural transport of TCE in the vapor phase via diffusion. Following the diffusive transport period, the extraction well was used to simulate soil vapor extraction under various flow regimes.

The predicted distribution of TCE in soil vapor following a 30-year period of diffusive transport in a homogeneous permeability field of 1 Darcy is shown in Figure 4-2. The simulated source zone was approximately 8,000 ft^3 and contained a residual NAPL saturation of 1.3%. Under these conditions, the equilibrium soil-vapor concentration of TCE in the source zone was estimated as approximately 540 mg/L. As is evident from Figure 4-2, the diffusive transport of TCE in the vapor phase away from the source zone in a fine-grained sediment similar to that in the OU 12 vadose zone is a slow process. After 30 years, TCE concentrations in the soil vapor were less than 1 mg/L at a distance of approximately 100 feet from the source. However, it is important to note the simulations did not consider vapor transport processes occurring in the subsurface due to changes in weather-related events (i.e., barometric pumping). Barometric pressure changes can result in significant viscous flow that can exceed the contribution to flow generated through diffusive flux.

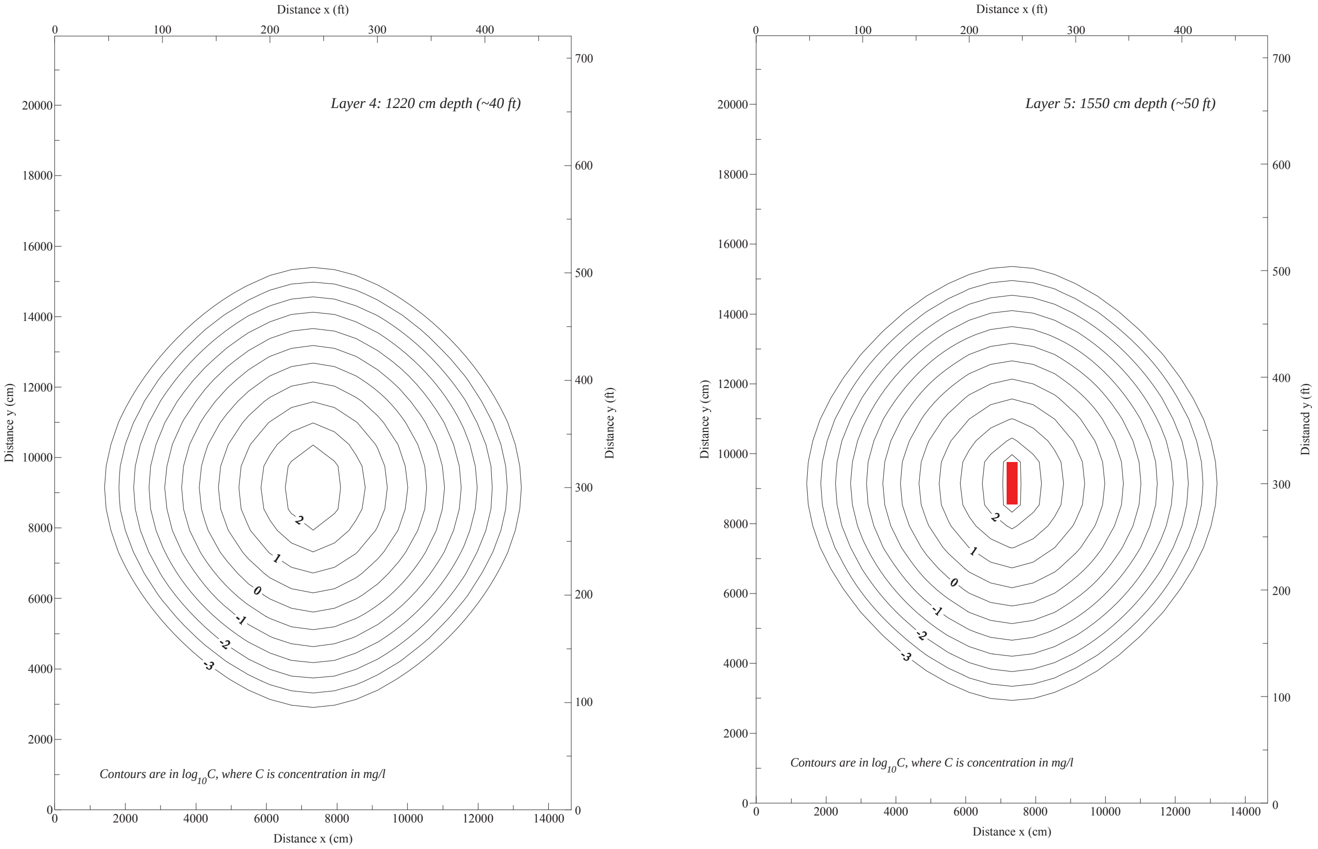


Figure 4-2. Predicted TCE distribution in vapor-phase following 30 years of diffusive transport in a homogeneous permeability field of 1 darcy (source containing 10,000 mg/kg shown in red).

The results of soil vapor extraction from an extraction well centrally located in the simulation grid following the 30-year diffusive stress period are shown in Figure 4-3. The distance of the extraction well from the source was varied from 20 to 60 feet and vapor extraction was varied from 3.5 to 15 standard cubic feet per minute (scfm). The effect of source-zone permeability also was evaluated. The results indicated that the fine-grained sediments of the OU 12 vadose zone would have a significant influence on the expected vapor flow rate and the TCE vapor concentration at the extraction well during short extraction timeframes. Thus, due to the decreased time allotment for the SVE demonstration, monitoring/extraction well spacing was decreased in accordance with the site lithology and predicted TCE response at each extraction well.

4.2 SVE Implementation and Operations

The locations of the soil vapor monitoring/extraction probes were based on the area of contamination inferred from previous site investigation and characterization activities conducted at OU 12 and modified using the data obtained during the Wireline CPT demonstration. A total of seven soil vapor monitoring/extraction probes were installed using a direct push track rig and consisted of 3/4-inch mesh screens connected to 3/4-inch polyvinyl chloride (PVC) risers as shown in Figure 4-4. The probes were

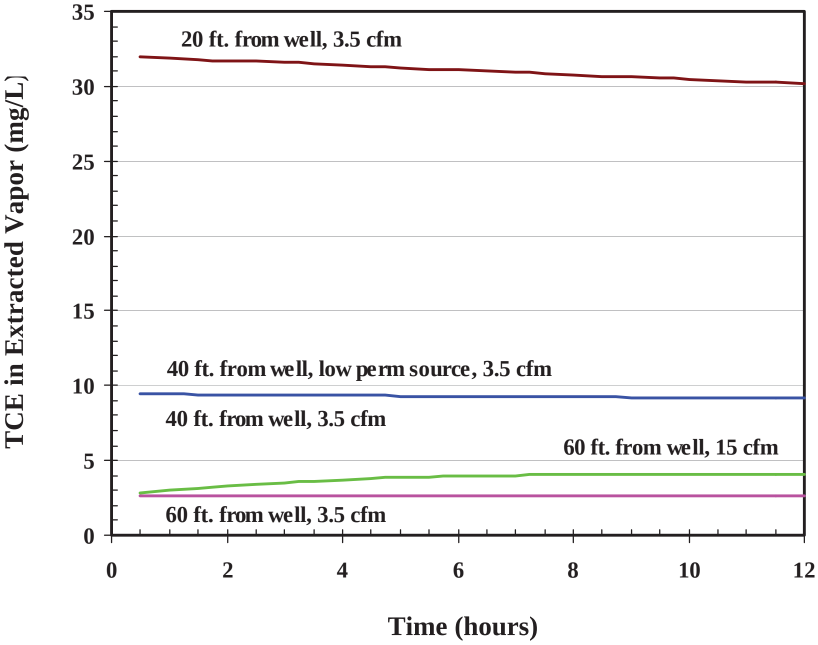


Figure 4-3. Predicted concentration of TCE in extracted soil vapor.

installed from 30 to 60 feet bgs with screened intervals ranging from 15 to 20 feet in length. The extraction/monitoring probes were designed to be finished in a *sandy silt* zone (approximately 30 to 45 feet bgs) and a *silty sand* zone (approximately 45 and 60 feet bgs) at a minimum depth of 30 feet bgs to minimize short-circuiting of air through the upper sandy gravel zone located within the top 20 feet of the ground surface. The specifications of the soil vapor extraction/monitoring probes are shown in Table 4-1.

Each well served as either an extraction well or a monitoring well depending on whether the blower was installed to the well head. During the SVE demonstration, the blower was moved from well to well so that eventually each well served as an extraction well while the other six wells served as monitoring wells.

Table 4-1. Soil Vapor Extraction/Monitoring Well Specifications

Well	Easting[1] (ft)	Northing[1] (ft)	Ground Elevation[2] (ft amsl)	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Screen Length (ft)
U12-VP1	1856098.3	298262.3	4587.4	30.1	50.1	20.0
U12-VP2	1856094.9	298293.7	4587.2	30.1	50.1	20.0
U12-VP3	1856085.7	298351.0	4588.0	39.0	59.0	20.0
U12-VP4	1856102.1	298234.6	4588.1	29.5	48.9	19.4
U12-VP5	1856053.5	298315.7	4587.6	39.6	58.7	19.1
U12-VP6	1856144.4	298293.7	4588.5	30.5	45.4	14.9
U12-VP7	1856056.1	298239.3	4587.3	39.6	54.9	15.3

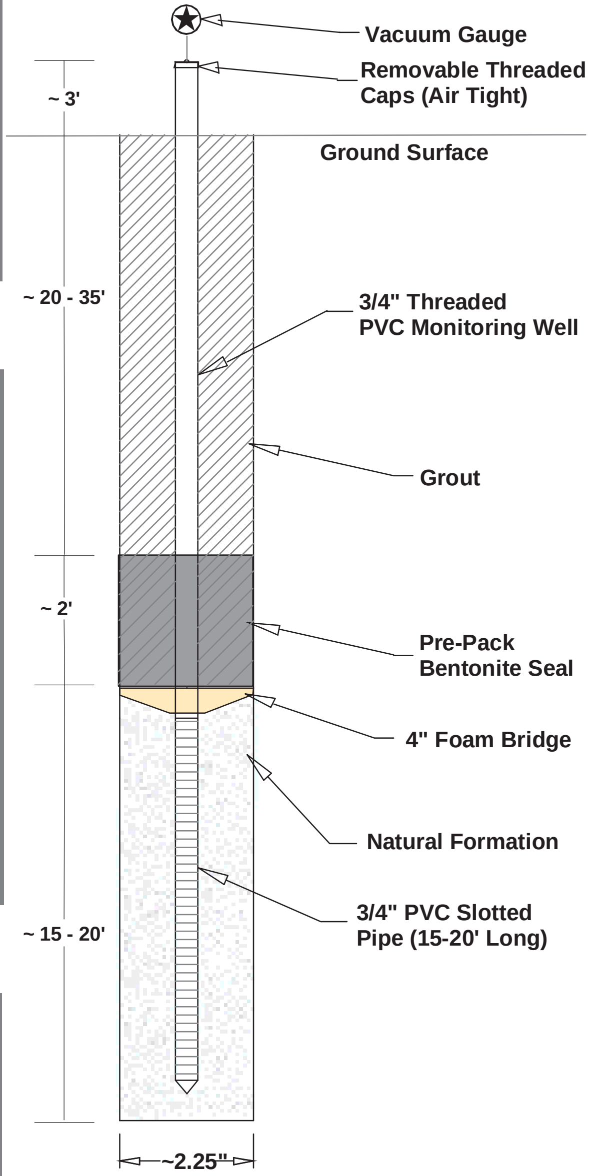
[1] Coordinates measured via GPS survey.

[2] Ground elevations estimated by interpolation using surveyed elevations.

DPT Rig

Pre-Packed Bentonite

Well Installation



Typical Extraction/Monitoring Well

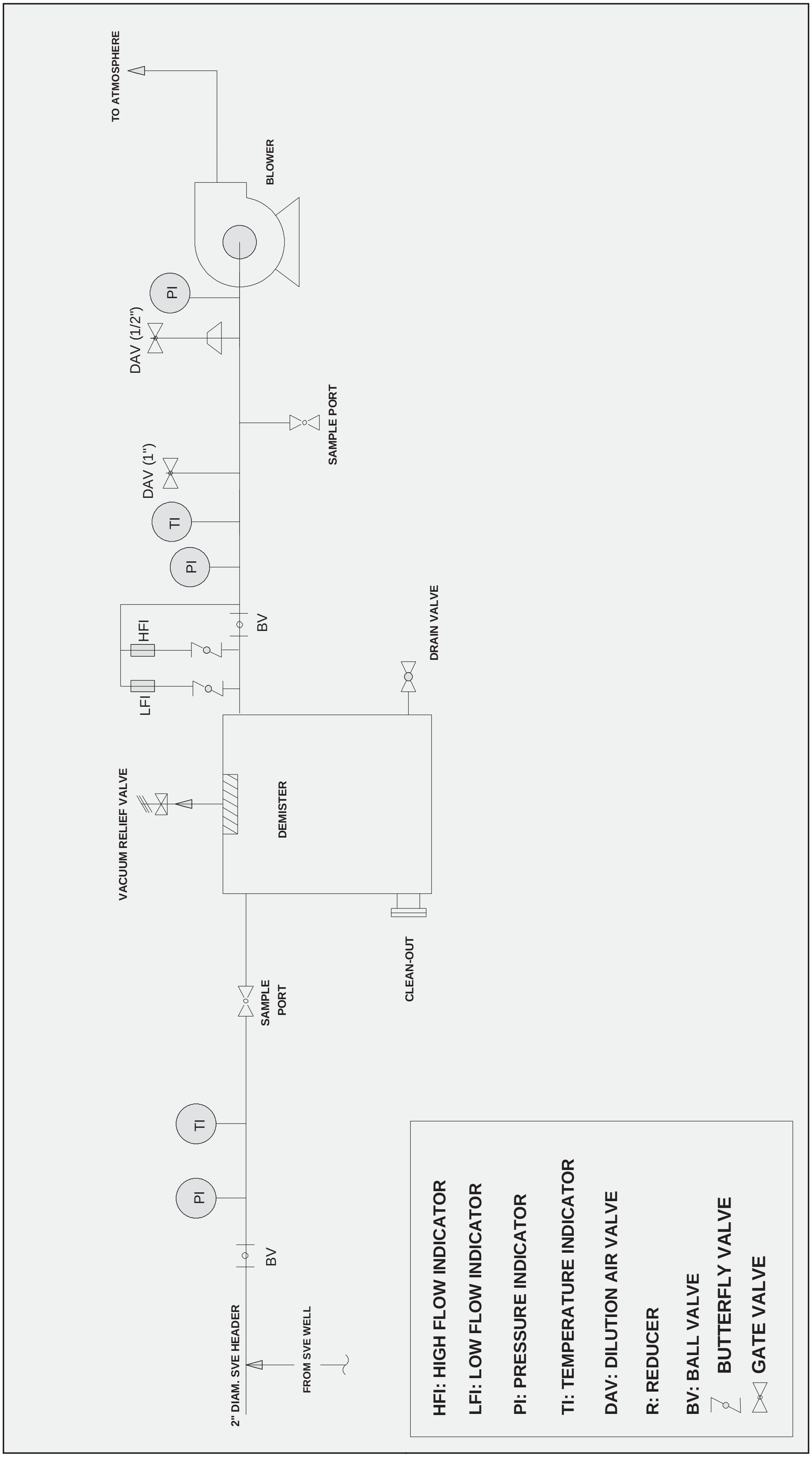
Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE 4-4

The SVE system included piping from the extraction well to a demister tank (called the "wet side" on the field logs) and from the demister tank through the rotometers (called the "dry side" on the field logs) into the blower intake. A demister tank was plumbed into the system in the event that water entrained in the vadose zone was vacuumed to the surface. Sample ports were located on both the wet side and the dry side of the demister tank. Air samples were collected from the wet side of the SVE system to eliminate the potential for TCE to partition to any accumulated water contained in the demister tank resulting in artificially low TCE concentrations measured in the extracted vapor. In the event water was conveyed to the surface, samples would have been collected from the wet side and dry side for comparison purposes. However, water was not encountered during the vapor extraction operations conducted at the OU 12 site during the demonstration. The demister tank was eventually removed during extraction at U12-VP5 when the vacuum relief valve on the demister malfunctioned at a vacuum of 77 inches of water measured at the blower. The demister tank was removed and the SVE process system was re-plumbed with PVC pipe.

Measurements of the effects of SVE on the subsurface were conducted through use of rotometers for measurement of air flow at the extraction well head, use of a vacuum gauge for measurement of vacuum at the well head, and use of differential pressure gauges for measurement of vacuum induced at the monitoring wells. A process and instrumentation diagram of the SVE process system is shown in Figure 4-5. The field-portable SVE process system, extraction/monitoring probe completions, and DSITMS with air module are shown in Figure 4-6. Table 4-2 provides a summary of the instrumentation utilized during the SVE demonstration at the OU 12 site. Prior to field operations, the SVE process system was checked under pressure and vacuum for leaks.

Two blowers were used separately to induce airflow from the extraction well and produce a response at the monitoring wells. The first blower was a 1 horsepower REGENAIR™ blower with a rated (at standard temperature and pressure) free airflow of 92 cubic feet per minute (cfm) and a maximum vacuum of 48 inches of water. This blower was used to sweep vapor from relatively small volumes of the vadose zone to produce chemical data that serve as input to the numerical model. This blower allowed operation at low vacuum that was increased in steps until the pneumatic permeability of the affected area controlled the blower operation. Initially, the air dilution valve was opened to the atmosphere at the start of the operation and the blower was operated at minimum vacuum. The air dilution valve was closed in small increments (steps) and the vacuum/flow was recorded in the SVE header. Eventually, the dilution valve was closed to the atmosphere and full available vacuum (discounting pressure losses in the pipes and the well) was applied to the vadose zone. The step test was continued at higher vacuum and flow using a second 3 horsepower REGENAIR™ blower whose capacity at standard temperature and pressure was rated at a flow of 147 cfm and a vacuum of 90 inches of water. Prior to the start of each step test at the soil vapor extraction points, a low-flow (approximately 200 ml/min) sample pump was used to extraction the soil gas in the immediate vicinity of the well. The sample pump also was used near the completion of each step test to evaluate TCE rebound during periods when the blower was shut down. A summary of the step tests conducted at each soil monitoring/extraction location is shown in Table 4-3.



Soil Vapor Extraction System
Process & Instrumentation Diagram

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE 4-5


SVE Process System and On-Site DSITMS Laboratory


SVE Well Head Completion


SVE Monitoring Well Head Completion


SVE Monitoring Well Vacuum Gauge Calibration


DSITMS with Air Module Installed

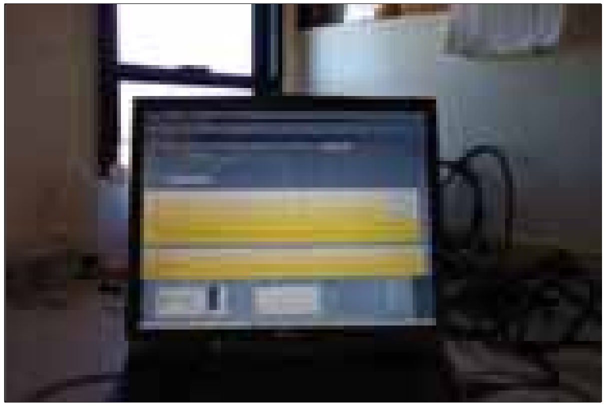

Real-Time DSITMS Spectra of Extracted Vapor

Figure 4-6. Field-Portable SVE Process System, extraction/monitoring well completions, and DSITMS on-site laboratory.

Table 4-2. Instrumentation Utilized During the OU 12 SVE Demonstration

Instrument	Function	Range	Accuracy	Application
Dwyer™ Magnehelic Gauges	Differential pressure (or vacuum) gauge	0 - 0.5 inches 0 - 1 inch 0 - 5 inches 0 - 15 inches	+/- 2% of full scale at 70^{o} F	Used to indicate vacuum at monitoring wells
Noshok™ Vacuum Gauges	Vacuum measurement	0 - 60 inches 0 - 100 inches	1.5% of full scale	Used to indicate vacuum at well head and within SVE system piping
King™ Instrument Rotometer	Air flow meter	1 - 20 inches 2 - 60 inches	+/-2% of full scale	Used in SVE piping to indicate flow induced by application of vacuum to well head
Oakton™ U03316-80 Barometer	Atmospheric pressure indicator	27.9” to 30.9” Hg (945 to1045 mbar)	+/- one mbar @ 0.03” Hg	Used at site to indicate atmospheric pressure changes that could affect vacuum readings
Blower	**Power**	**Max. Vacuum (@STP)**	**Max. Air Flow (@STP)**	**Application**
GAST REGENAIR^{TM} R4	1 HP, 120V, 60 Hz,	48 inches	92 CFM	Low level step test
GAST REGENAIR^{TM} SDR4	3 HP, 240V, 60Hz	90 inches	147 CFM	High level step test

A barometer was used prior to the start of extraction operations at each well and periodically during each test to determine the range of barometric pressure change that occurred over the time frame of the SVE demonstration. There was no significant barometric pressure change (i.e., less than +/- one millibar) that occurred during the demonstration that required adjustment of the differential vacuum readings taken at the monitoring wells.

An example of the step test procedures can be demonstrated by considering the flow tests conducted at U12-VP1. The first blower used, the REGENAIR^{TM} SDR4, the larger of the two blowers was installed to the SVE process system and tested at increments of constant flow as shown in Table 4-3. The blower was started with the dilution air valve in the fully open position. The valve was closed partially to a position that applied enough vacuum to induce flow to greater than 2 cfm (flow was established at 2.75 cfm at the given vacuum) and remained approximately steady at 2.75 cfm for 23 minutes. At that time, the vacuum relief valve was closed further to induce a vacuum of 51.5 cfm and a flow of 5 cfm (approximately doubling the initial flow) at the wellhead. Over the next 14 minutes, vacuum and airflow were monitored at the extraction well and vacuum was monitored at the monitoring wells. The dilution air valve was closed further (but not fully) to apply a vacuum that varied between 52 and 53 inches of water and increasing flow to 7.5 cfm. Monitoring of flow and vacuum at the extraction well and vacuum

Table 4-3. Summary of OU 12 SVE Step Tests

Test	Date	Start Time (min)	End Time (min)	Elapsed Time (min)	Flow Rate (scfm)	Flow Rate (lpm)	Blower	Comments
Vapor Probe 1								
VP1-1	9/1/2002	0.0	3.0	3.0	0.01	0.20	NA	Blower step #1 - sample pump only.
VP1-2	9/1/2002	3.0	23.1	20.1	2.75	77.87	Large	Blower step #2
VP1-3	9/1/2002	23.1	46.4	23.3	5.00	141.58	Large	Blower step #3
VP1-4	9/1/2002	46.4	69.6	23.2	7.50	212.38	Large	Blower step #4
VP1-5	9/1/2002	69.6	89.6	20.0	7.00	198.22	Large	Blower step #5
VP1-6	9/1/2002	89.6	154.1	64.5	0.01	0.20	NA	Blower step #6 - sample pump only.
VP1-7	9/1/2002	154.1	182.3	28.3	8.00	226.53	Large	Blower step #7
VP1-8	9/1/2002	182.3	210.7	28.4	0.01	0.20	NA	Blower step #8 - sample pump only.
Vapor Probe 2								
VP2-1	9/2/2002	0.0	11.5	11.5	0.01	0.20	NA	Blower step #1 - sample pump only.
VP2-2	9/2/2002	11.5	40.0	28.5	8.00	226.53	Large	Blower step #2
VP2-3	9/2/2002	40.0	57.0	17.0	11.00	311.49	Large	Blower step #3
VP2-4	9/2/2002	57.0	68.0	11.0	12.00	339.80	Large	Blower step #4
VP2-5	9/2/2002	68.0	115.5	47.5	17.50	495.54	Large	Blower step #5
VP2-6	9/2/2002	115.5	140.0	24.5	0.01	0.20	NA	Blower step #6 - sample pump only.
VP2-7	9/2/2002	140.0	165.0	25.0	16.50	467.23	Large	Blower step #7
VP2-8	9/2/2002	165.0	187.0	22.0	5.00	141.58	Large	Blower step #8
VP2-9	9/2/2002	187.0	202.4	15.4	0.01	0.20	NA	Blower step #9 - sample pump only.
Vapor Probe 3								
VP3-1	9/4/2002	0.0	31.9	31.9	0.01	0.20	NA	Blower step #1 - sample pump only.
VP3-2	9/4/2002	31.9	66.5	34.6	3.00	84.95	Large	Blower step #2
VP3-3	9/4/2002	66.5	80.0	13.5	0.01	0.20	NA	Blower step #3 - sample pump only.
VP3-4	9/4/2002	80.0	90.3	10.3	3.75	106.19	Small	Blower step #4
VP3-5	9/4/2002	90.3	98.4	8.2	0.01	0.20	NA	Blower step #5 - sample pump only.
Vapor Probe 4								
VP4-1	9/3/2002	0.0	14.6	14.6	0.01	0.20	NA	Blower step #1 - sample pump only.
VP4-2	9/3/2002	14.6	26.2	11.6	3.50	99.11	Large	Blower step #2
VP4-3	9/3/2002	26.2	33.2	7.0	3.00	84.95	Large	Blower step #3
VP4-4	9/3/2002	33.2	42.2	9.0	5.50	155.74	Large	Blower step #4
VP4-5	9/3/2002	42.2	61.2	19.0	8.00	226.53	Large	Blower step #5
VP4-6	9/3/2002	61.2	71.2	10.0	10.50	297.33	Large	Blower step #6
VP4-7	9/3/2002	71.2	81.2	10.0	12.00	339.80	Large	Blower step #7
VP4-8	9/3/2002	81.2	128.2	47.0	14.00	396.44	Large	Blower step #8
Vapor Probe 5								
VP5-1	9/3/2002	0.0	51.0	51.0	0.00	0.00	Large	Sampling port valve problems.
VP5-2	9/3/2002	51.0	62.0	11.0	0.01	0.20	NA	Blower step #1 - sample pump only.
VP5-3	9/3/2002	62.0	70.0	8.0	7.50	212.38	Large	Blower step #2
VP5-4	9/3/2002	70.0	78.2	8.2	0.01	0.20	NA	Blower step #3 - sample pump only.
Vapor Probe 6								
VP6-1	9/4/2002	0.0	7.0	7.0	0.00	0.00	NA	Baseline establishment
VP6-2	9/4/2002	7.0	64.5	57.5	0.01	0.20	NA	Blower step #1 - sample pump only.
VP6-3	9/4/2002	64.5	82.5	18.0	2.25	63.71	Small	Blower step #2
VP6-4	9/4/2002	82.5	88.0	5.5	5.50	155.74	Small	Blower step #3
VP6-5	9/4/2002	88.0	109.0	21.0	7.75	219.46	Small	Blower step #4
VP6-6	9/4/2002	109.0	118.4	9.4	0.01	0.20	NA	Blower step #5 - sample pump only.
VP6-7	9/4/2002	118.4	125.3	6.9	7.50	212.38	Small	Blower step #6
Vapor Probe 7								
VP7-1	9/3/2002	0.0	10.0	10.0	0.01	0.20	NA	Blower step #1 - sample pump only.
VP7-2	9/3/2002	10.0	16.0	6.0	0.00	0.00	NA	Recalibrate.
VP7-3	9/3/2002	16.0	27.0	11.0	0.01	0.20	NA	Blower step #2 - sample pump only.
VP7-4	9/3/2002	27.0	40.0	13.0	2.50	70.79	Large	Blower step #3
VP7-5	9/3/2002	40.0	60.0	20.0	5.00	141.58	Large	Blower step #4
VP7-6	9/3/2002	60.0	77.0	17.0	7.50	212.38	Large	Blower step #5
VP7-7	9/3/2002	77.0	87.0	10.0	8.50	240.69	Large	Blower step #6
VP7-8	9/3/2002	87.0	95.0	8.0	10.00	283.17	Large	Blower step #7
VP7-9	9/3/2002	95.0	110.0	15.0	11.50	325.64	Large	Blower step #8
VP7-10	9/3/2002	110.0	125.0	15.0	16.00	453.07	Large	Blower step #9
VP7-11	9/3/2002	125.0	140.0	15.0	0.01	0.20	NA	Blower step #10 - sample pump only.
VP7-12	9/3/2002	140.0	142.7	2.7	0.00	0.00	NA	Cadet pump off.
Vapor Probe 1 Rerun								
VP1-1R	9/4/2002	0.0	10.0	10.0	0.01	0.20	NA	Sample collection leak.
VP1-2R	9/4/2002	10.0	20.6	10.6	2.00	56.63	Small	Sample collection leak.
VP1-3R	9/4/2002	20.6	46.7	26.1	3.50	99.11	Small	Sample collection leak.
VP1-4R	9/4/2002	46.7	64.7	18.0	0.01	0.20	NA	Blower step #1 - sample pump only.
VP1-5R	9/4/2002	64.7	100.7	36.1	3.50	99.11	Small	Blower step #2

at the monitoring wells was continued for the next 38 minutes during which time samples of air were continuously analyzed by the lab. The blower exhaust was directed away from the working area through a 2-inch PVC pipe approximately 20 feet in length. No organic vapors were detected using the Hnu meter in the workspace during the time of SVE operations.

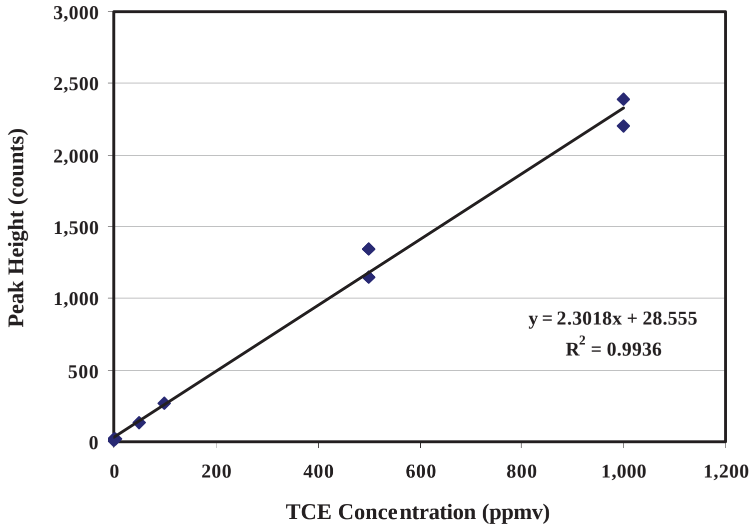
Generally, during implementation of the SVE tests at the seven wells, the vacuum was stepped up in sufficient increments to induce an increase of airflow of two or more cfm. Flow was measured at the rotometers and applied vacuum measured at the wellhead. Vacuum also was measured near to the blower intake to approximate the blower's operating vacuum. Subsurface induced vacuum was measured at each of the monitoring probes by recording vacuum indicated on the differential pressure gauges. All airflow, wellhead vacuum, and monitoring well vacuums were recorded continually. Differential pressure gauges were checked and set to zero at the start of extraction operations at each well.

Because of its operating capacity, the large blower was used preferentially at the extraction wells until it failed to start during a TCE rebound evaluation at U12-VP3. It is surmised that the cause of the failure was associated with a pebble that entered the blower intake during the disconnecting and moving of the blower from one well to another. The smaller of the two blowers (REGENAIR^{TM} R4) was used at U12-VP6 and, for comparison to the large blower performance, at U12-VP1. The pneumatic evaluation and the assessment of the TCE time series data collected during the SVE demonstration are presented in Section 5.0 of this report.

4.3 DSITMS Vapor Analytics

During the SVE demonstration conducted at OU 12, the DSITMS was operated with an air module interface (see Figure 4-6) for real-time analysis of TCE in the extracted vapor. The mass spectral data generated from the DSITMS for each flow test were received in an ASCI format (i.e., comma delimited) and contained peak height counts as a function of time for all mass numbers. A computer code was written to extract the TCE data (mass numbers 130 and 132) from each mass spectral data set and once extracted, the TCE peak height was plotted as a function of time for each individual flow period for each step test. An analysis frequency of one second was used during the SVE demonstration, resulting in thousands of discrete data points for each flow test conducted.

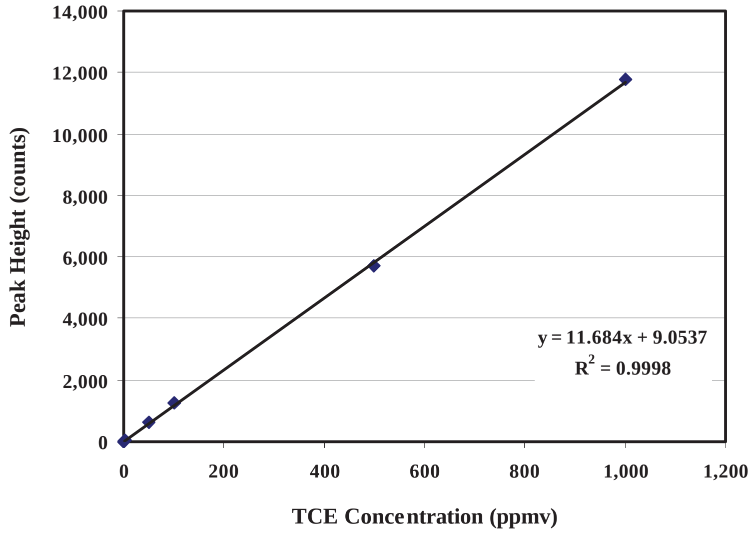
The TCE calibration data were subjected to a regression analysis to produce a response factor for converting peak height counts as a function of time to TCE concentration values. A response factor was produced for each individual flow period for each step test and was based on calibration standards analyzed before and after each flow period. Figure 4-7 provides the results of the regression analysis performed on the TCE calibration data generated during the OU 12 SVE demonstration.



U12-VP1 Calibration Curve

Regression Output	
Constant	28.5554
Std Err of Y Est	80.5392
R Squared	0.99359
No. of Observations	10
Degrees of Freedom	8

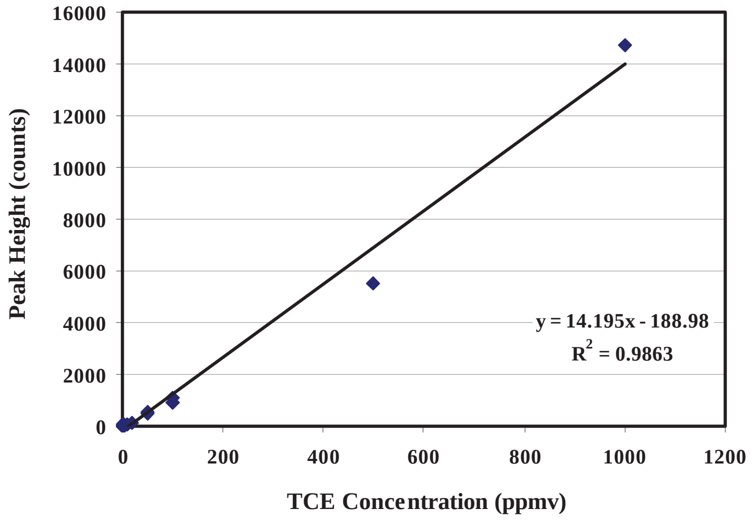
Response factor:
0.4344385 ppmV/(PH count)



U12-VP2 Calibration Curve

Regression Output	
Constant	9.0537
Std Err of Y Est	82.0843
R Squared	0.99976
No. of Observations	6
Degrees of Freedom	4

Response factor:
0.0855876 ppmV/(PH count)

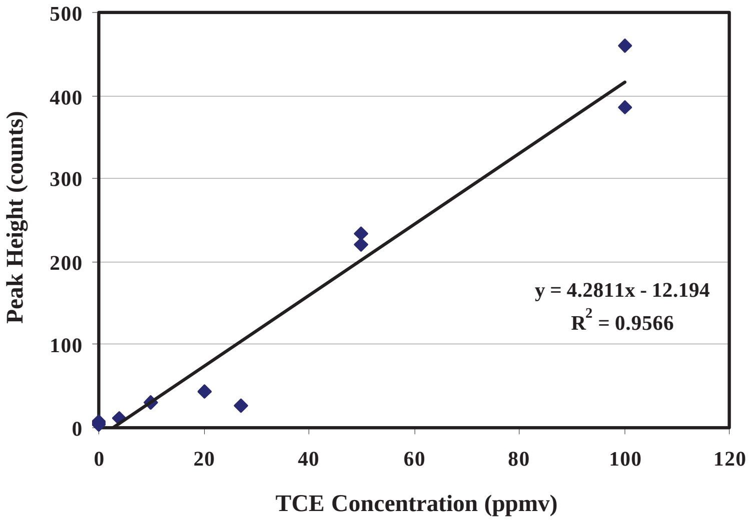


U12-VP4 Calibration Curve

Regression Output	
Constant	-188.976
Std Err of Y Est	509.077
R Squared	0.98626
No. of Observations	13
Degrees of Freedom	11

Response factor:
0.0704466 ppmV/(PH count)

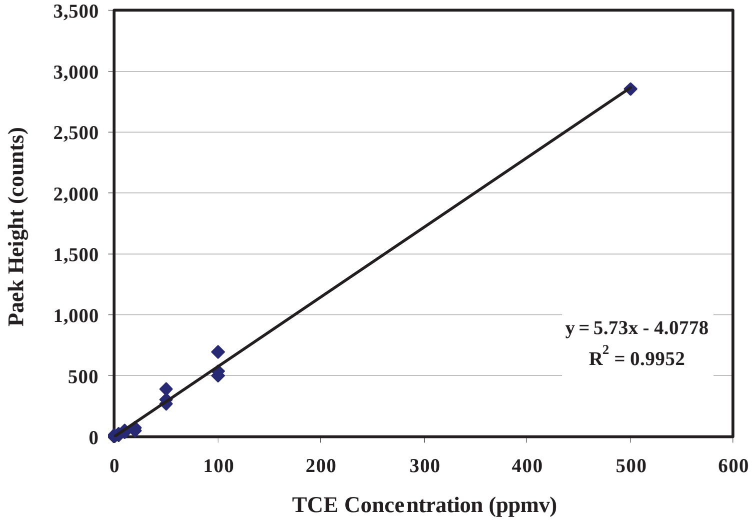
Figure 4-7. Results of the regression analysis performed on the OU 12 SVE calibration data.



U12-VP5 and U12-VP7 Calibration Curve

Regression Output	
Constant	**-12.1937**
Std Err of Y Est	**29.9232**
R Squared	**0.95659**
No. of Observations	**18**
Degrees of Freedom	**16**

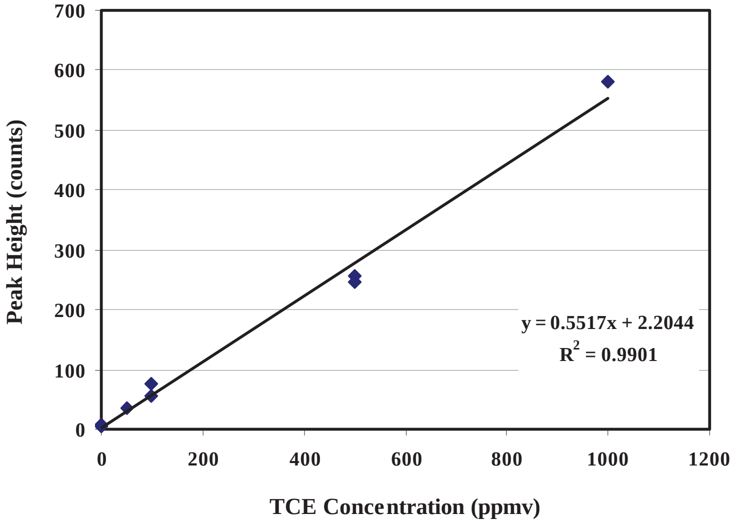
Response factor:
1.8125215 ppmV/(PH count)



U12-VP3 and U12-VP6 Calibration Curve

Regression Output	
Constant	**-4.0778**
Std Err of Y Est	**41.7568**
R Squared	**0.99519**
No. of Observations	**24**
Degrees of Freedom	**22**

Response factor:
0.1745213 ppmV/(PH count)



U12-VP1-D Calibration Curve

Regression Output	
Constant	**2.2044**
Std Err of Y Est	**21.2597**
R Squared	**0.99009**
No. of Observations	**8**
Degrees of Freedom	**6**

Response factor:
1.8125215 ppmV/(PH count)

Figure 4-7. ***continued***

5.0 RESULTS OF SOIL SAMPLING AND SVE DEMONSTRATION

The results from the Wireline CPT soil sampling and SVE demonstrations conducted in the suspected source zone at OU 12 are described in this section.

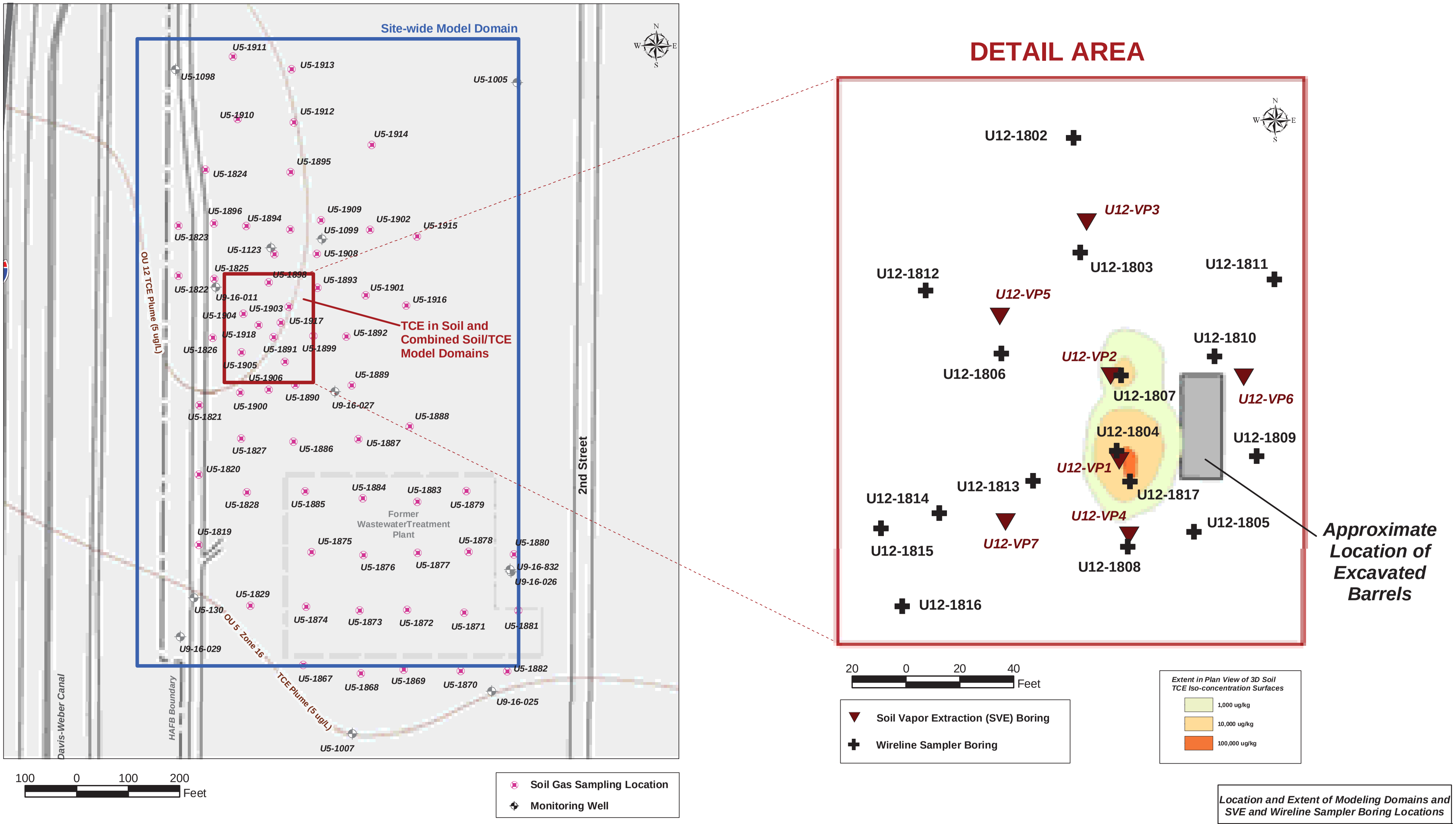
5.1 OU 12 Soil Data Evaluation

During the nine working days of Wireline CPT soil sampling, 599 soil samples were collected from 16 discrete push locations (see Figure 5-1). The depth profiles generated based on the TCE soil concentration data are shown in Figures 5-2 and 5-3 for concentrations less than 350 µg/kg and greater than 1,000 µg/kg, respectively. The analytes PCE, DCE, and vinyl chloride were below the project reporting limits in all soil samples analyzed. A summary of the soil sampling results obtained during the Wireline CPT demonstration is shown in Table 5-1.

Samples were collected using either distilled water or methanol as an extractant and analyzed according to US EPA Method 8265 (see Section 3.3). During the analysis of samples collected from U12-1807, four samples (30 to 33 feet bgs) were observed to contain a light nonaqueous phase liquid (LNAPL) as shown in Figure 5-4. In addition, two samples (27 to 29 feet bgs) from U12-1804 were observed to contain a LNAPL. With the exception of U12-1817, distilled water was used as the extractant during the Wireline CPT demonstration; thus, it is surmised that the measured TCE concentrations in samples containing LNAPL from U12-1804 and U12-1807 are biased low due to incomplete extraction associated with the preferential partitioning of the TCE into the LNAPL. Methanol was used as the extractant for the analysis of soil samples collected from U12-1817, located approximately 10 feet southeast of U12-1804 and adjacent to the excavated drum area. Based on the TCE concentrations observed at U12-1817, an LNAPL/water partitioning factor of approximately 10 was estimated. This factor was used to adjust the TCE soil concentration of two samples (15,400 µg/kg at 27 feet bgs and 7,300 µg/kg at 29 feet bgs) collected at U12-1804 and one sample (14,400 µg/kg at 33 feet bgs) collected at U12-1807.

Inference of the magnitude and spatial extent of TCE contamination in the vadose zone at OU 12 was accomplished using three-dimensional modeling of TCE concentration measured in soil samples retrieved with a the Wireline CPT sampler. Iterative, short-delay modeling of the extent of contamination (the model was expeditiously revised whenever new data were received from the field) provided field personnel with guidance for selecting new wireline sampling locations. The relationship between TCE contamination and soil type was investigated with the benefit of three-dimensional modeling of the architecture of the main soil types in the vadose zone, based on CPT data acquired during previous investigations at OU 12.

All three-dimensional subsurface modeling performed in this investigation was performed using the kriging and visualization algorithms available in the EVS-Pro software system (CTECH, 2002). Ordinary kriging (Isaaks and Srivastava, 1989; Gooevaerts; 1997) was used to model TCE contamination, whereas indicator kriging (Isaaks and Srivastava, 1989; Gooevaerts; 1997) was used to model the distribution of soil types.



Location and Extent of Modeling Domains and SVE and Wireline Sampler Boring Locations

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-1

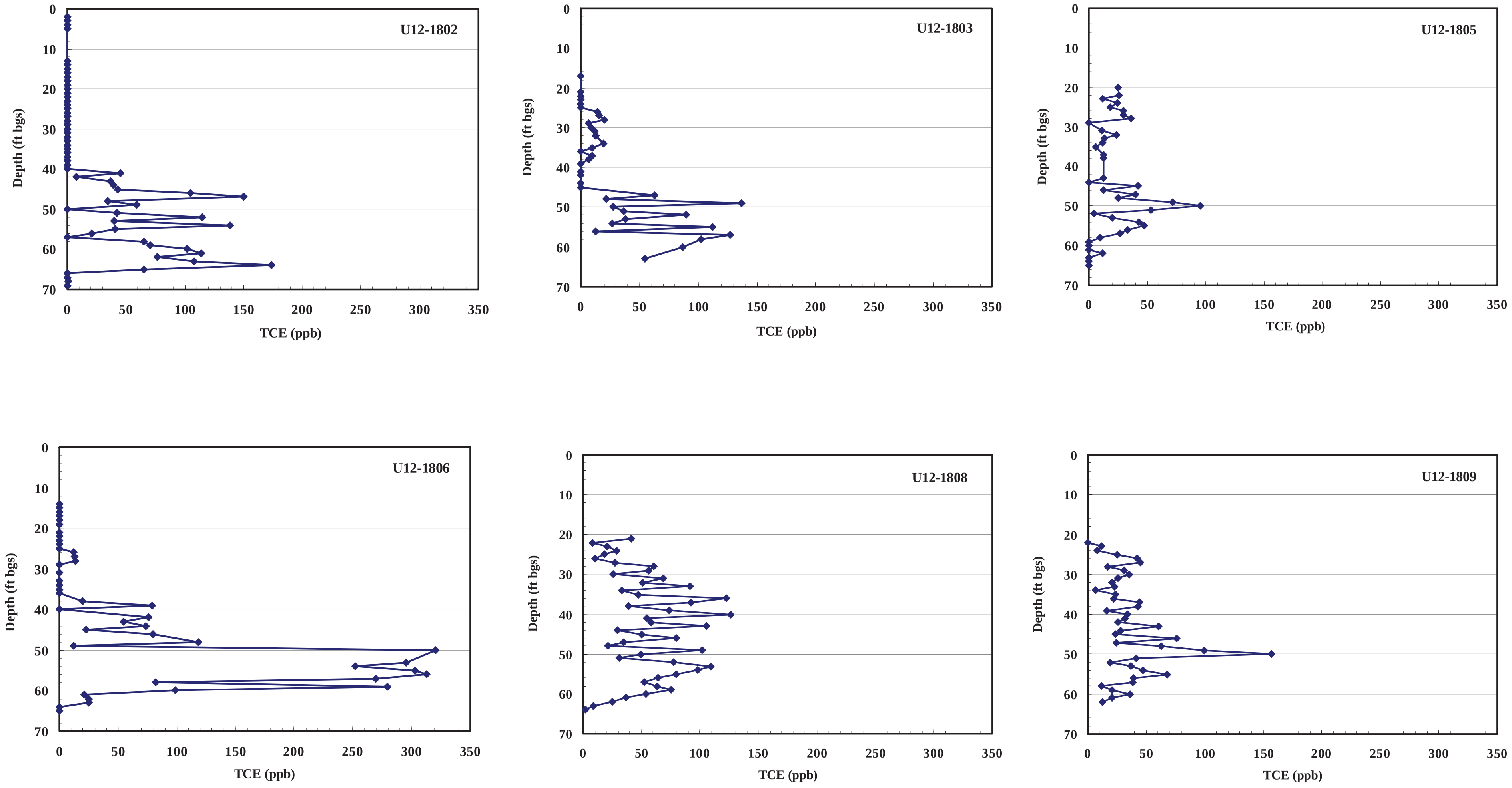


Figure 5-2. TCE concentration depth profiles less than 350 µg/kg for the OU 12 Wireline CPT soil sampling demonstration.

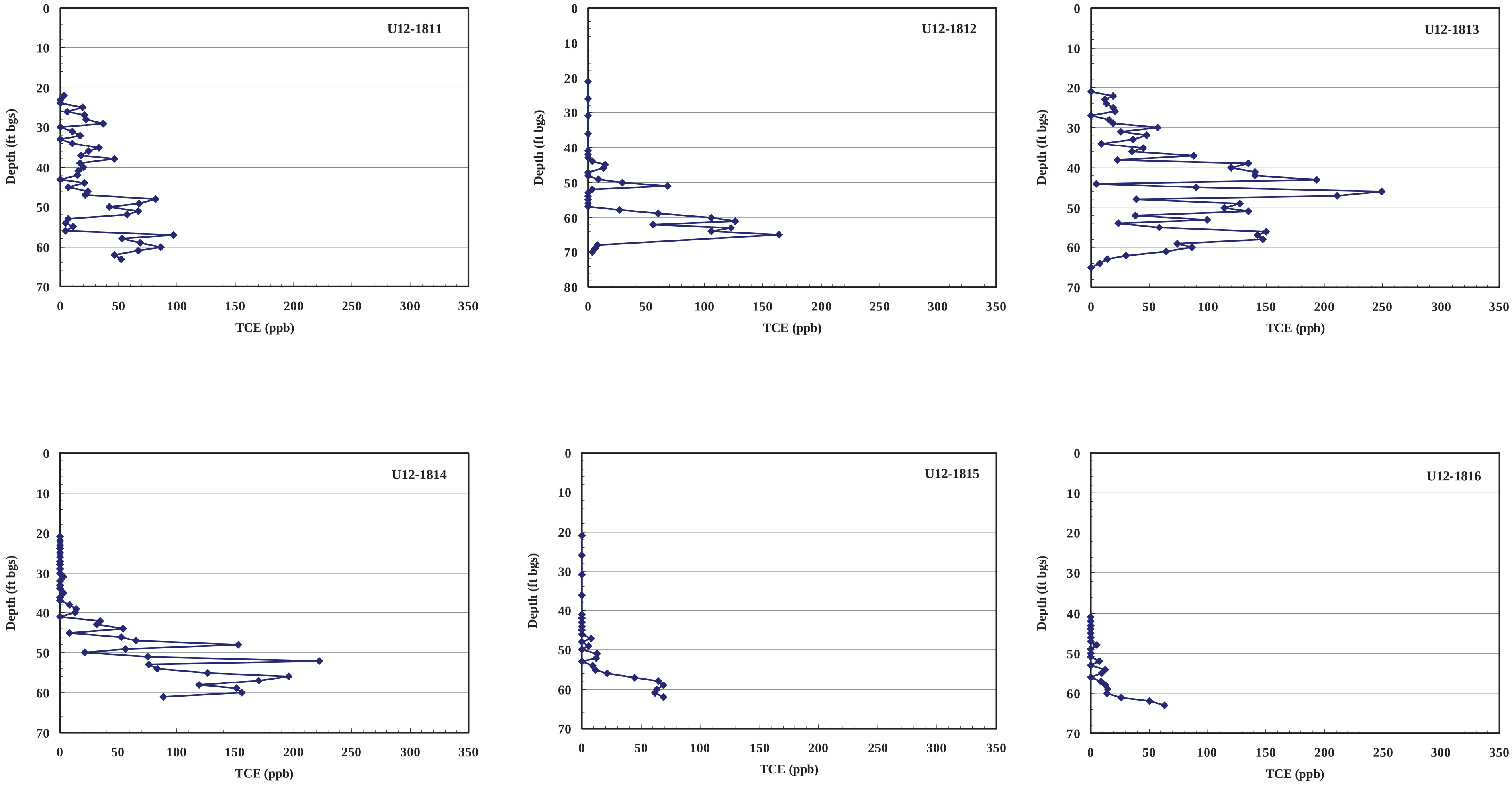


Figure 5-2. *Continued*

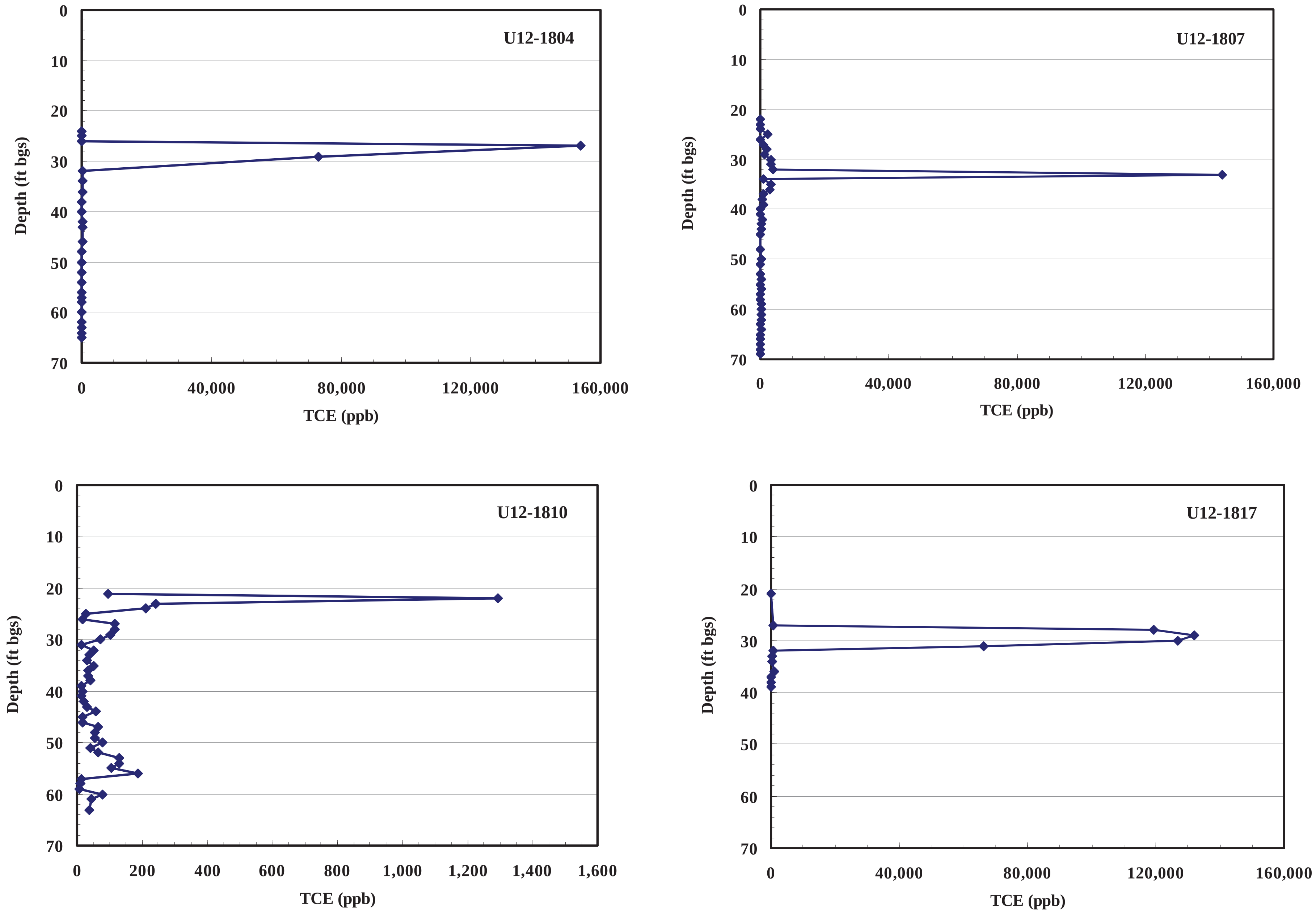


Figure 5-3. TCE concentration depth profiles greater than 1,000 µg/kg for OU 12 Wireline CPT soil sampling demonstration.

Table 5-1. Summary of Wireline CPT Soil Sampling Program

Wireline CPT Push Location	TCE Concentration Range (μg/kg)	Extractant	Beginning Sampling Depth (ft bgs)	Ending Sampling Depth (ft bgs)	Total Soil Samples Collected
U12-1802	0.0 - 174	Water	2.0	69.0	61
U12-1803	0.0 - 137	Water	17.0	63.0	37
U12-1804	3.0 – 154,000[a]	Water	24.0	65.0	25
U12-1805	0.0 – 96	Water	20.0	65.0	39
U12-1806	0.0 – 320	Water	14.0	65.0	44
U12-1807	0.0 – 144,000[b]	Water	22.0	69.0	44
U12-1809	2.0 - 126	Water	21.0	64.0	44
U12-1809	0.0 – 157	Water	22.0	62.0	41
U12-1810	0.0 – 1,295	Water	21.0	63.0	42
U12-1811	0.0 – 97	Water	22.0	63.0	42
U12-1812	0.0 – 164	Water	21.0	70.0	32
U12-1813	0.0 – 249	Water	21.0	65.0	45
U12-1814	0.0 – 222	Water	21.0	61.0	41
U12-1815	0.0 – 69	Water	21.0	62.0	26
U12-1816	0.0 – 63	Water	41.0	63.0	23
U12-1817	0.0 – 131,900	Methanol	21.0	39.0	13

[a] It is surmised that the aqueous extraction was incomplete in two samples collected from this push location due to the presence of LNAPL; thus, the concentrations for these samples (7,300 and 15,400 μg/kg) were adjusted by a factor of 10 based on the partitioning factor calculated from U12-1817.

[b] It is surmised that the aqueous extraction was incomplete in one sample collected from this push location due to the presence of LNAPL; thus, the concentration for this sample (14,400 μg/kg) was adjusted by a factor of 10 based on the partitioning factor calculated from U12-1817.

5.1.1 Magnitude and Spatial Extent of TCE Contamination in Soil

Characterization of the spatial extent and magnitude of TCE contamination in the vadose zone was concurrent with field sampling efforts. This was possible because of the on-site analyses of the wireline soil samples, timely electronic delivery of new analytical results to the modeler, and punctual modeling of the newly acquired data obtained from the field. A revised model was typically available in the field within approximately 4 hours after the receipt of new data, enabling field personnel to consider the revised model when selecting new sampling locations. In addition, the close proximity of the wireline sampler borings to each other, together with the large number of soil samples obtained from each boring and the comparatively small depth increment between samples, yielded an uncommonly dense spatial distribution of data for modeling. The result is a nearly complete characterization of the extent of TCE contamination above 100 μg/kg in the vadose zone of the investigative area at OU 12.

Figure 5-4. Soil samples collected from U12-1807 (30 to 33 feet bgs) containing LNAPL.

Modeling of TCE contamination in soil was performed within the region illustrated in Figure 5-1. The figure also includes the approximate location of several drums excavated during trenching activities just prior to the start of the field investigation. The region depicted in Figure 5-1 is the areal extent of the modeling domain for the third and final iteration of the TCE contamination model. Earlier models of TCE contamination utilized domains of smaller areal and vertical extent; however, all of the various modeling domains share consistent areal and vertical discretization increments. All iterations of the model are presented within the final modeling domain in order to describe how the modeling was used to aid the selection of new wireline boring locations, and to illustrate how the understanding of soil contamination evolved as newly acquired data were used to revise the model. The geometry and discretization of the modeling domain is summarized in Table 5-2.

Table 5-2. Modeling Domain for TCE Contamination and Combined Soil/TCE Modeling

Coordinate Direction	Minimum[4]	Maximum	Discretization Interval (ft)	Number of Grid Blocks[5]	Length (ft)
x[1]	1,856,000	1,856,168	$\Delta_x = 4$	$N_x = 42$	168
y[2]	298,200	298,400	$\Delta_y = 4$	$N_y = 50$	200
z[3]	4,515	4,600	$\Delta_z = 1$	$N_z = 85$	85

[1] Easting (feet)
[2] Northing (feet)
[3] Elevation (feet above mean sea level)
[4] Corresponds to the model origin (lower left corner of the model)
[5] There are $N_x \, N_y \, N_z = 178{,}500$ grid blocks in the model

The initial TCE contamination model, developed using the concentration of TCE measured in the 294 soil samples from the first seven CPT wireline sampler borings, is represented in plan-view in Figure 5-5 by the 100 µg/kg iso-concentration surface, and in Figure 5-6 by the 1,000 µg/kg iso-concentration surface. In this view the three-dimensional surfaces are projected onto a horizontal plane, so their three-dimensional character is lost except for the shadow effect in the rendering. Each wireline sampler boring is posted with a colored circle. The color of a particular circle will, in general, differ from the others because the circle represents the projection onto the horizontal plane of a sphere, color-coded by measured TCE concentration and posted at the upper-most soil sample extracted from the boring. These two iso-surfaces illustrate the size and shape of the inferred region of soil contamination based on the data from the first seven boring locations, and provide a basis for comparison with subsequent models. It should be noted that the extent of the modeling domain shown in these figures, which is determined by the spatial configuration of the boring locations, is smaller than the extent of the final modeling domain.

The truncation of the 100 µg/kg iso-concentration surface along the western, southern, and eastern boundaries of the initial model indicates that insufficient data are available in these regions to characterize the spatial configuration of the iso-surface. For example, on the eastern boundary of the initial model the kriging algorithm extrapolated TCE concentrations greater than 100 µg/kg to the east of borings U12-1804 and U12-1807, because soil samples from these borings did not provide the data needed to constrain interpolation of the 100 µg/kg iso-surface. The extrapolation would have continued eastward had the modeling domain been larger to the east. Analogous truncations are evident along the western and southern boundaries of the model; in each case, there are insufficient data to achieve closure of the 100 µg/kg iso-surface within the limits of the modeling domain. Although the 1,000 µg/kg iso-surface (Figure 5-6) is fully contained within the domain, it is constrained to the northwest only by U12-1803 and U12-1806, and to the southeast by U12-1805 and U12-1808. The bulge to the east and the elongation to the southwest are the result of extrapolation. Partly on the basis of Figures 5-5 and 5-6, the next three wireline sampler borings (U12-1809, U12-1810, and U12-1811) were located to the east of the first seven borings. The decision to step out to the east also was influenced by the location of the drums unearthed during trenching activities shortly before the field investigation began.

A second model of TCE contamination of soil was constructed after receiving the analytical results for the three new borings. The revised model, shown in Figure 5-7 (100 µg/kg iso-surface) and Figure 5-8 (1,000 µg/kg iso-surface), is based on 10 borings and the analytical results from 419 soil samples. The additional borings provide sufficient spatial control to more fully characterize the eastern extent of 100 µg/kg iso-surface: it no longer extends to (and, by implication, beyond) the model boundary, but is closed to the east. Along the western and southern boundaries of the model, however, the 100 µg/kg iso-surface remains poorly characterized. The effect of the additional borings on the 1,000 µg/kg iso-surface is less dramatic, but still significant. The extent of the iso-surface to the north and east has been reduced, whereas to the southwest the extent (by extrapolation) of the iso-surface has actually increased. Five additional wireline sampler borings were placed to the west and southwest to address the clear lack of spatial control. In addition, a sixth boring was placed within the 1,000 µg/kg iso-surface to provide more complete characterization of the region of highest TCE contamination.

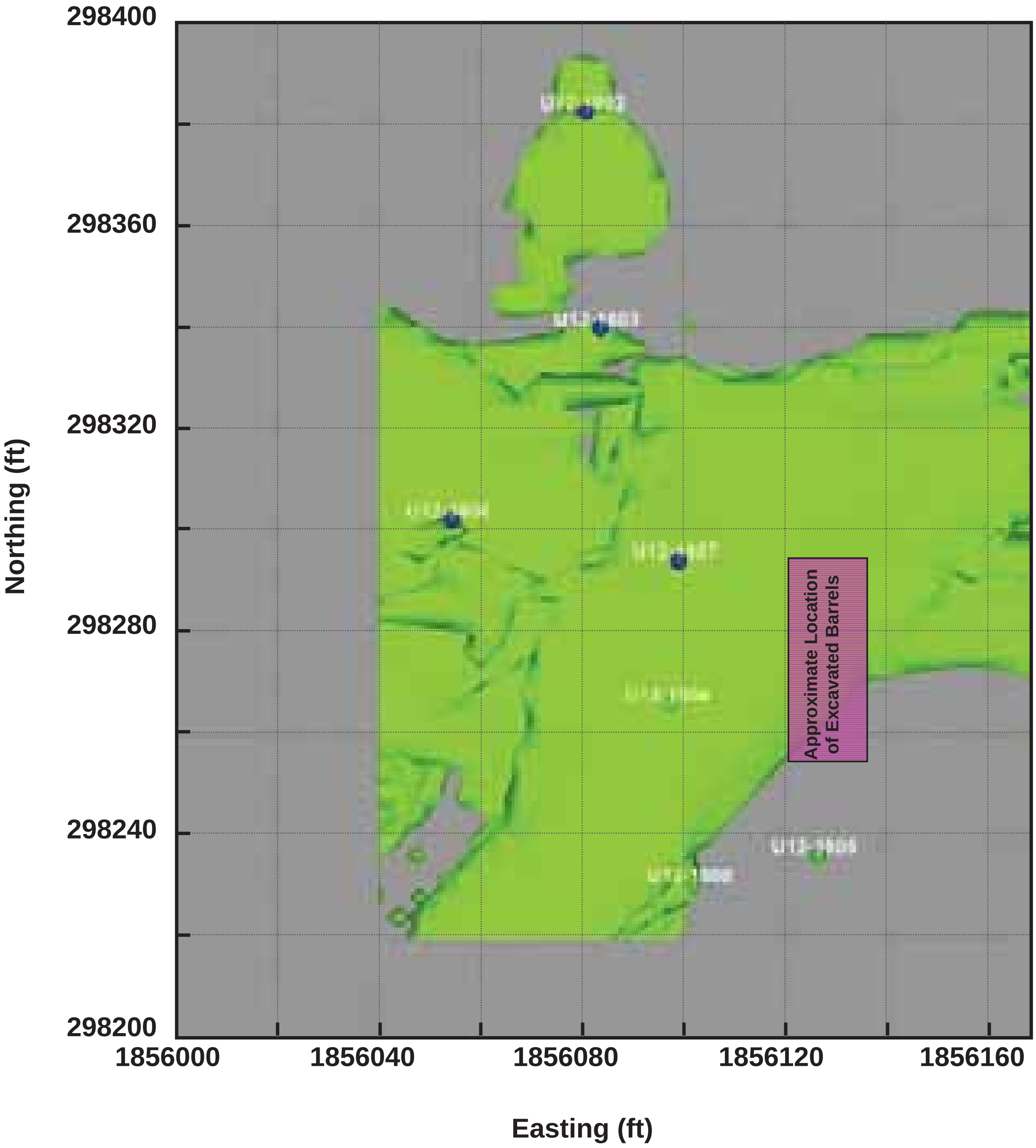


Figure 5-5. Initial model of TCE contamination in soil, 100 μg/kg iso-concentration surface, constructed using 294 wireline soil samples from seven borings.

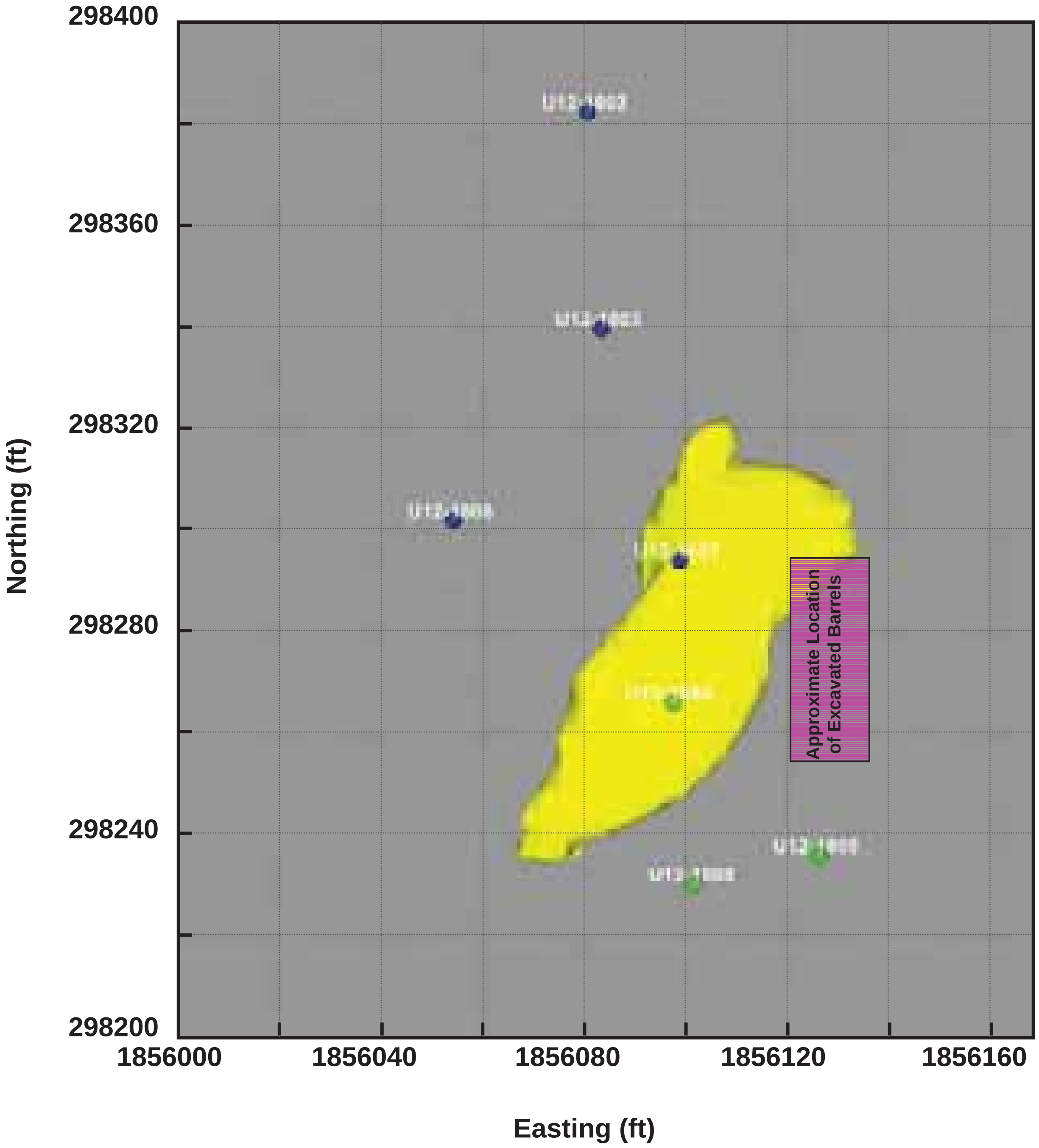


Figure 5-6. Initial model of TCE contamination in soil, 1000 μg/kg iso-concentration surface, constructed using 294 wireline soil samples from seven borings.

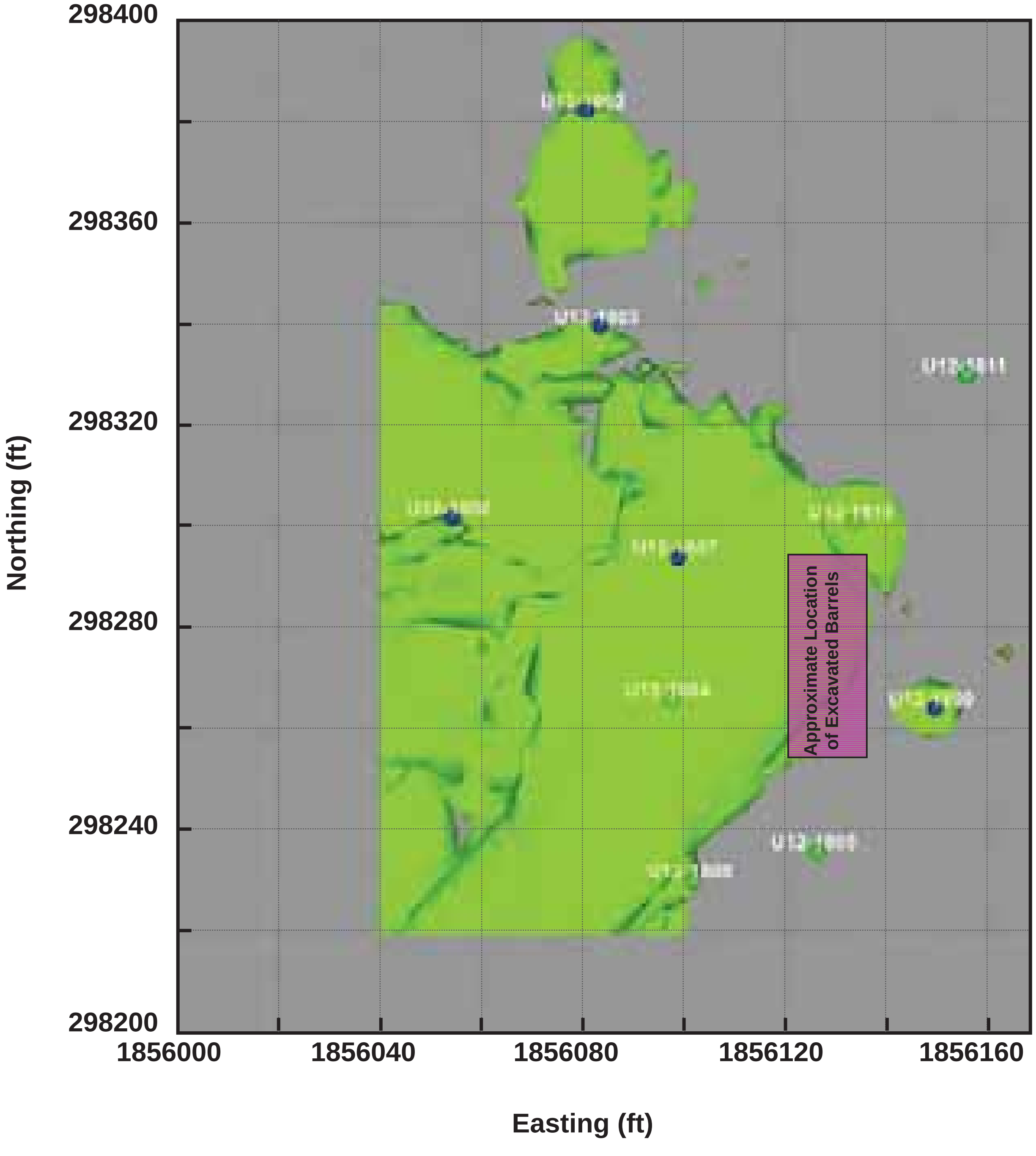


Figure 5-7. Revised model of TCE contamination in soil, 100 μg/kg iso-concentration surface, constructed using 419 wireline soil samples from 10 borings.

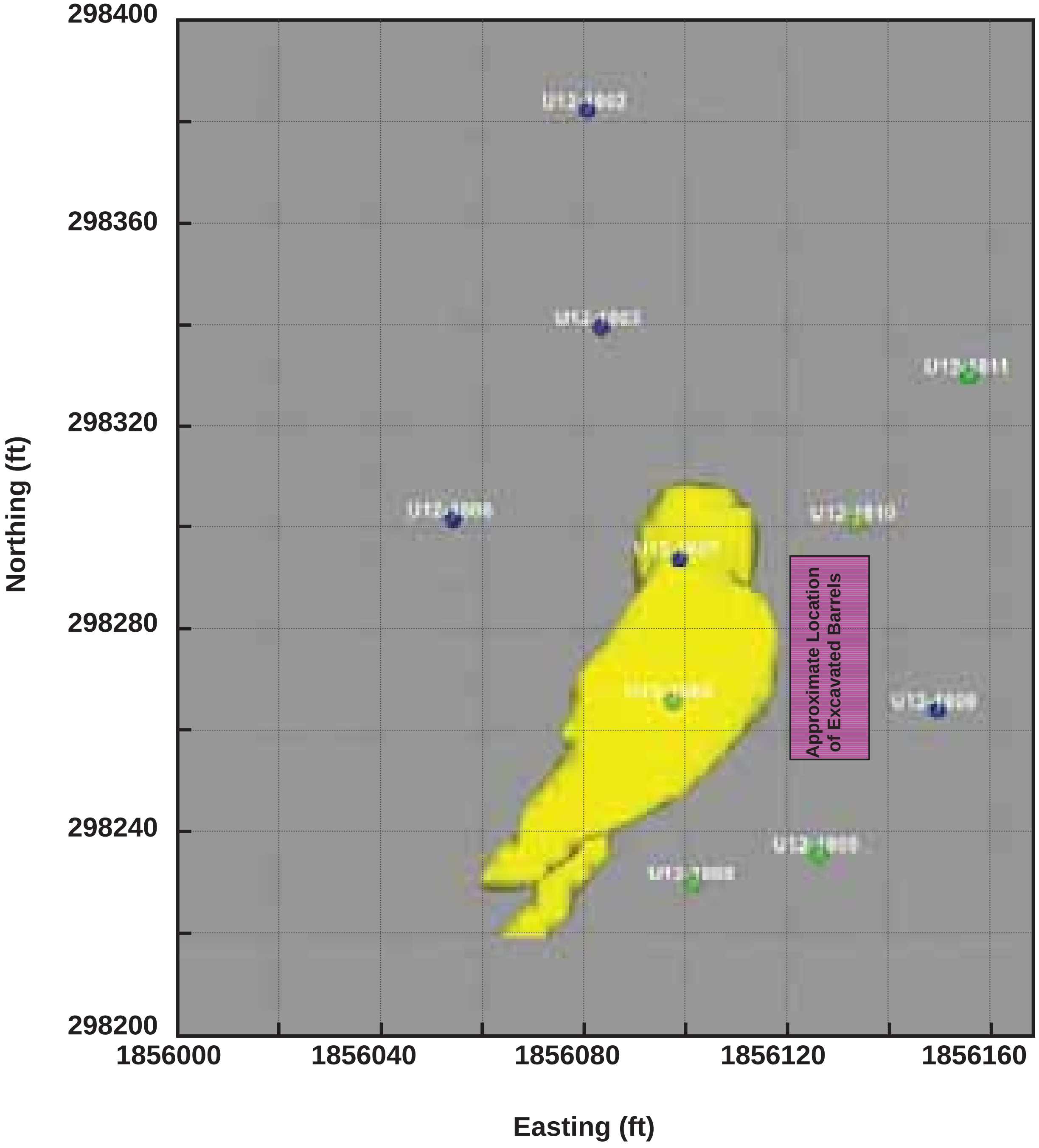


Figure 5-8. Revised model of TCE contamination in soil, 1000 μg/kg iso-concentration surface, constructed using 419 wireline soil samples from 10 borings.

The final TCE soil contamination model, shown in Figure 5-9 (100 µg/kg iso-surface) and Figure 5-10 (1,000 µg/kg iso-surface), is based on the analytical results of 599 soil samples taken from the 16 wireline sampler borings advanced during this investigation. The improved characterization of the 100 µg/kg iso-surface to the west and southwest is clearly evident. To the south, however, more data are needed to refine the delineation of the 100 µg/kg iso-surface, which apparently extends beyond the southern boundary of the model. Two additional borings to the south of U12-1808 would have established the southern extent of the 100 µg/kg iso-surface, but time constraints unfortunately precluded the wireline sampler contractor from acquiring additional data. The two additional borings would also have augmented the characterization of the isolated 1,000 µg/kg iso-surface on the southern model boundary. Although data from U12-1817 and additional control to the southwest have eliminated the southwestward trend from the 1,000 µg/kg iso-surface enclosing (in plan view) U12-1804, U12-1807, and U12-1817, the portion of the iso-surface on the southern boundary is unsupported by data. It is likely an extrapolation artifact, and thus should be discounted as a real indicator of soil contamination.

The inferred 10,000 µg/kg iso-surface displayed in Figure 5-11 further illustrates the extent of TCE contamination in soil as delineated by the final model. This iso-surface encloses the soil samples with the highest measured concentration of TCE. These samples are: from U2-1804, 154,000 µg/kg at a depth of 27 feet below ground surface and 73,000 µg/kg at 29 feet; from U2-1807, 144,000 µg/kg at 33 feet; and from U2-1817, 131,900 µg/kg at 29 feet. In contrast, surrounding borings yielded no soil samples with a measured TCE concentration greater than 10,000 µg/kg.

Figure 5-12 is an isometric view of the 100 µg/kg iso-concentration surface from the final three-dimensional model of TCE contamination in soil. The view is from the southwest corner of the model domain, looking to the northeast. The spheres on each of the borings represent soil sample locations, color-coded according to the measured concentration of TCE. The most striking aspect of this representation of the soil contamination is its layered character of the soil contamination. Broad, layered areas of soil contamination, connected vertically by narrow throat-like regions, occur at various elevations.

This attribute of the soil contamination is described in more detail in the next section of this report, where the co-development of models of the extent of TCE contamination and vadose zone soil architecture is discussed.

5.1.2 Soil Architecture of the Vadose Zone

Modeling of the distribution of soil types in the vadose at OU 12 was performed at two scales (see Figure 5-1). The first and larger model was made to establish the architecture of soil types (soil lithology) in the vadose zone over a large portion of the suspected OU 12 source area, and is denoted the site-wide model in subsequent discussions. The smaller model is spatially coincident with the previously described model of TCE concentration in soil, and was built for the purpose of understanding the relationship between

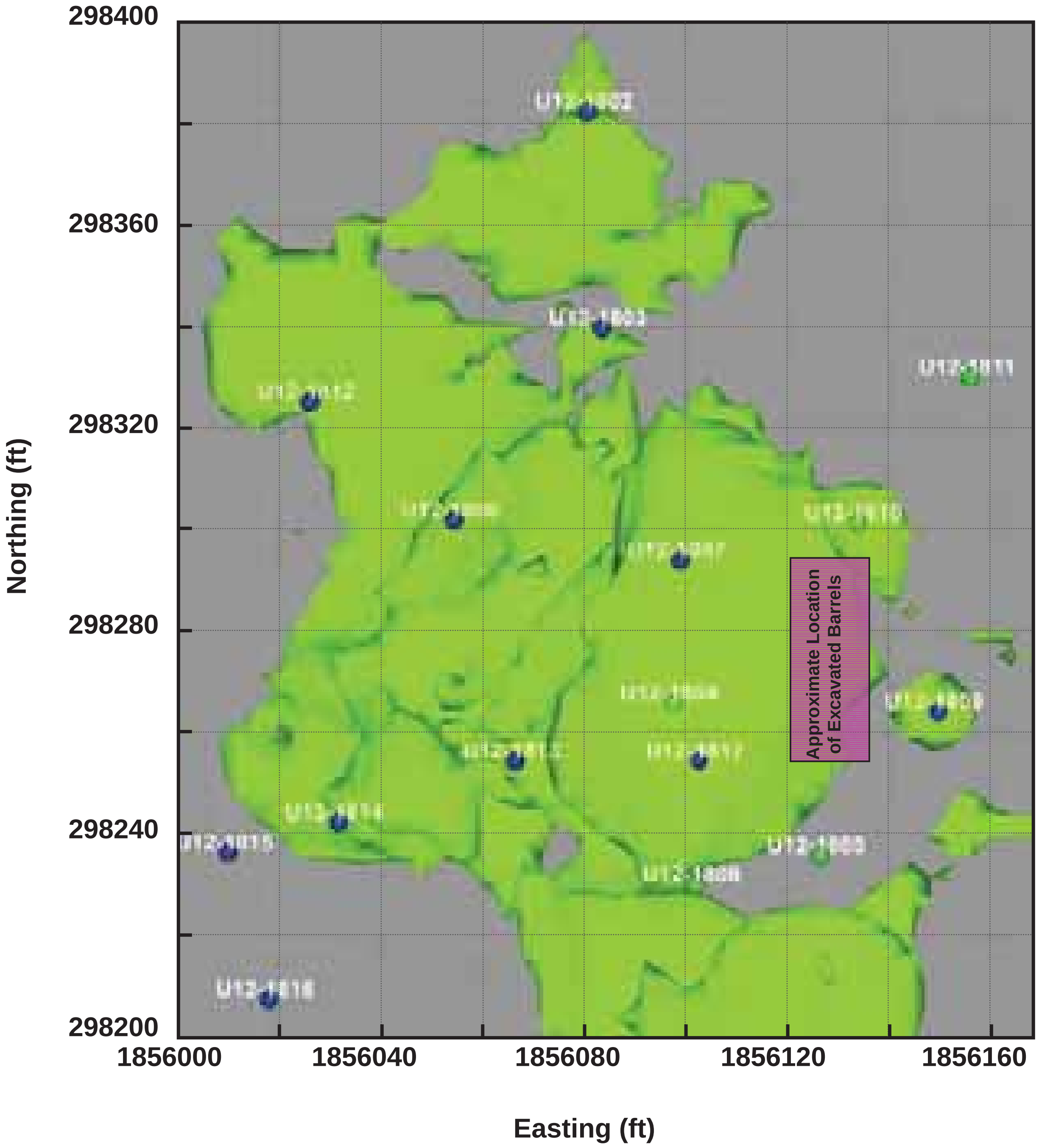


Figure 5-9. Final model of TCE contamination in soil, 100 µg/kg iso-concentration surface, constructed using 599 wireline soil samples from 16 borings.

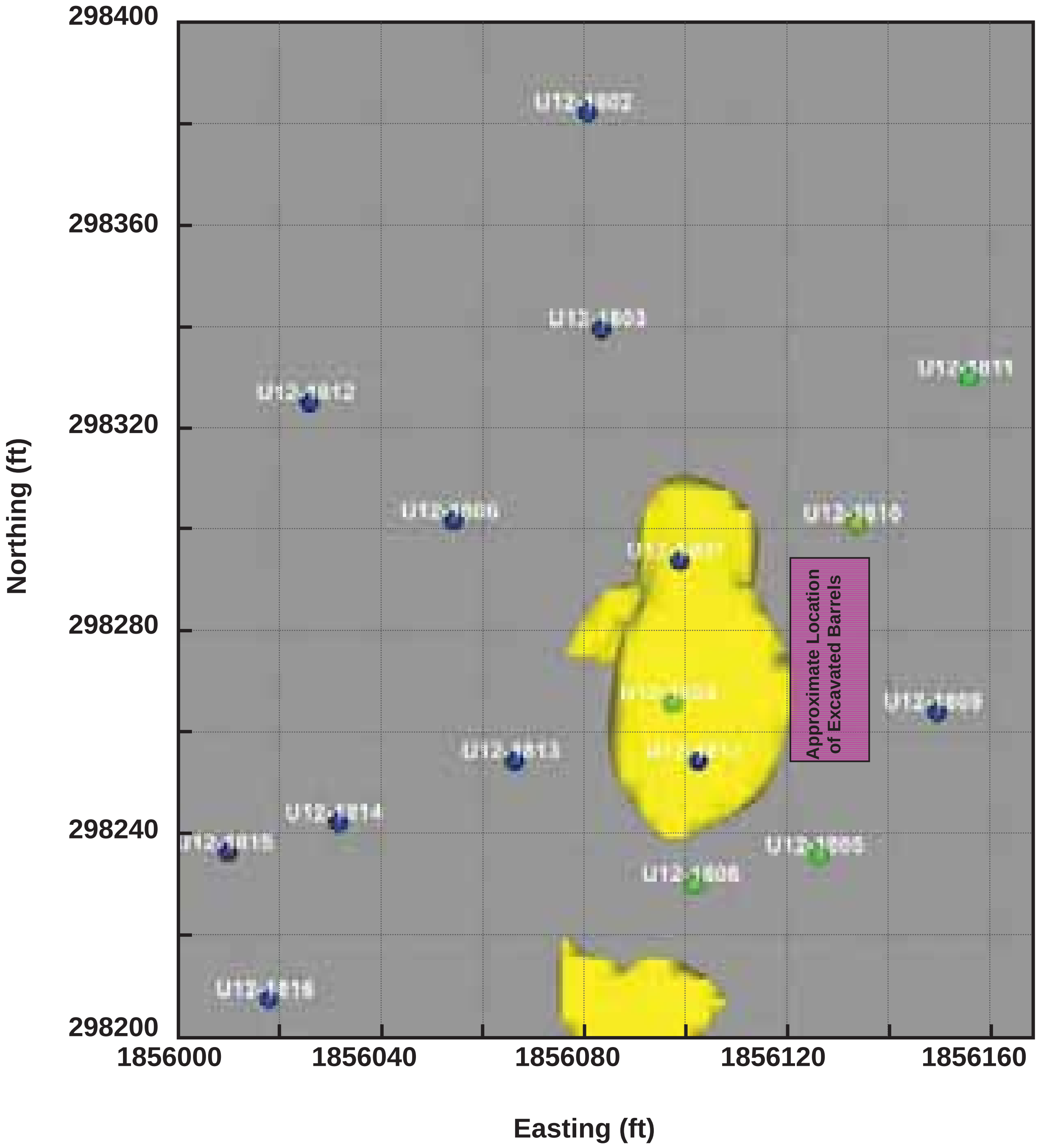


Figure 5-10. Final model of TCE contamination in soil, 1000 μg/kg iso-concentration surface, constructed using 599 wireline soil samples from 16 borings.

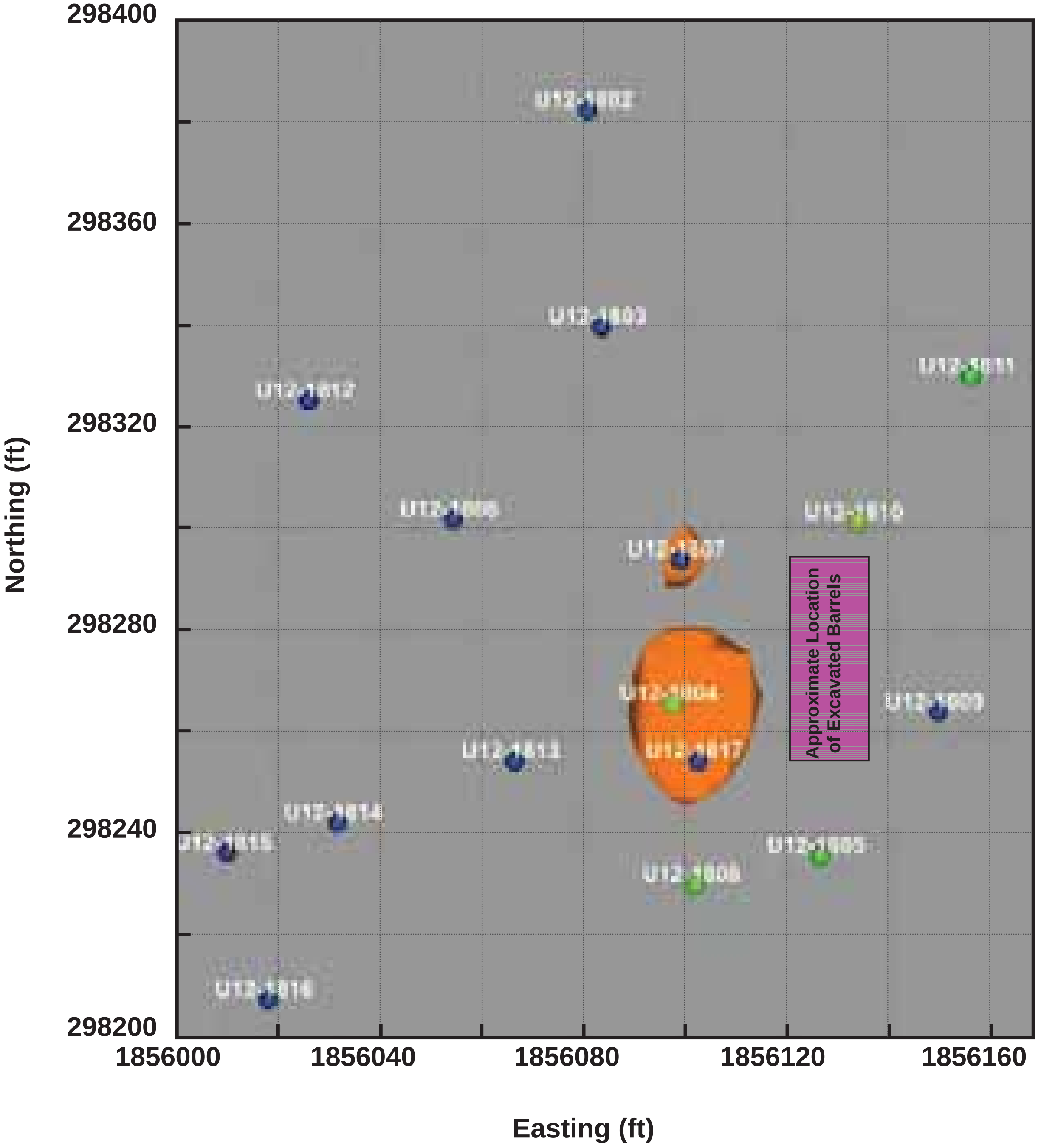


Figure 5-11. Final model of TCE contamination in soil, 10,000 μg/kg iso-concentration surface, constructed using 599 wireline soil samples from 16 borings.

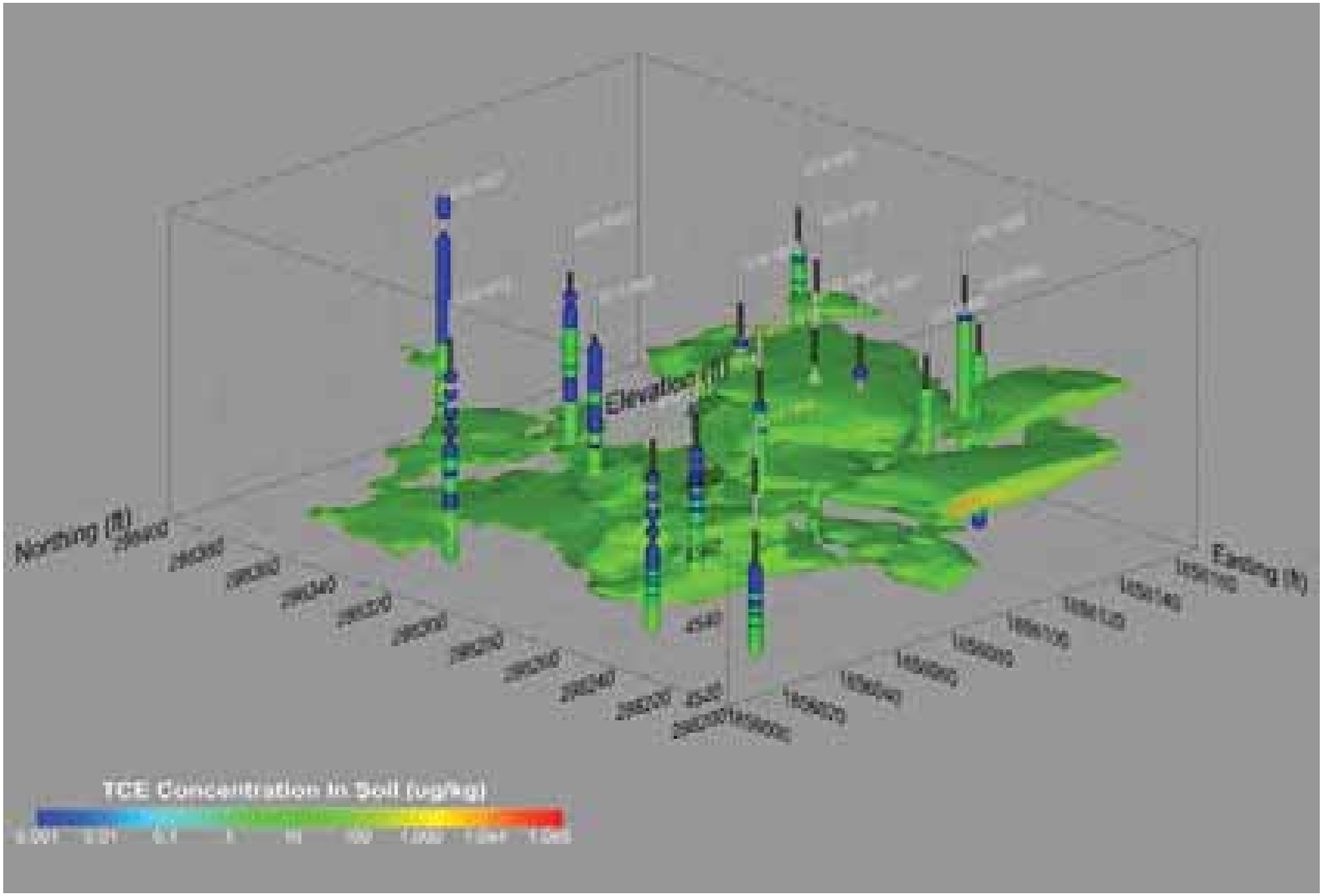


Figure 5-12. Isometric view, looking northeast of the final model of TCE contamination in soil, 100 μg/kg iso-concentration surface, constructed using 599 wireline soil samples from 16 borings.

TCE contamination and soil type. Because the spatial distribution of soil types is considered in conjunction with the previously modeled TCE contamination in soil, the smaller model is denoted the combined soil/TCE model. A description of the modeling domain for the site-wide model, including discretization parameters, is provided in Table 5-3. The modeling domain for the combined soil/TCE model was previously described in Section 5.1.1 (see Table 5-2).

Table 5-3. Modeling Domain for Site-Wide Soil Model

Coordinate Direction	Minimum[4]	Maximum	Discretization Interval (ft)	Number of Grid Blocks[6]	Length (ft)
x^1	1,855,850	1,856,600	$\Delta_x = 12.5$	$N_x = 60$	750
y^2	297,600	298,850	$\Delta_y = 12.5$	$N_y = 100$	1250
z^3	4,500	4,620	Variable[5]	$N_z = 60$	Variable[5]

[1] Easting (feet)

[2] Northing (feet)

[3] Elevation (feet above mean sea level))

[4] Corresponds to the model origin (lower left corner of the model)

The model is limited above by the ground surface and below by the groundwater elevation in May 2002, so the model thickness varies. The thickness in z of the bounding coordinate frame is 120 ft, yielding ~2 ft grid blocks in z.

[6] There are $N_x N_y N_z$ = 360,000 grid blocks in the site-wide soil model

Both the larger site-wide and the combined soil/TCE models are based on the inferred soil-type data for 64 CPT borings from previous investigations (Montgomery Watson Harza, 2002); these data reside in the Hill AFB ERPIMS database, where the inferred soil types are identified in the ASTMCODE and LITHCODE fields. The depth increment (layer thickness) between successive soil-type data in the ERPIMS database is variable and often small, on the order of 0.25 foot or less. To enable three-dimensional numerical modeling on the scale of a few hundred feet, the soil-type data were upscaled to a larger depth increment using a computer program written expressly for this project. The program operates on the data from each individual CPT boring by accumulating individual layer thicknesses and soil-types until a total thickness of between 2 and 4 feet is reached. The accumulated thickness is then assigned an upscaled soil type corresponding to the major soil type within the combined interval (i.e., the largest thickness-weighted proportion within the accumulated interval). The process is repeated until the bottom of the boring is reached. An exception to this procedure occurs when a contiguous interval of a single soil type is encountered; then the entire thickness of the contiguous interval is used. As a result of this upscaling procedure, 6,658 soil-type data were reduced to 1,063 data.

In addition to upscaling soil-type thickness, the twelve distinct soil types present in the data extracted from ERPIMS were reduced to four main (silt, sandy silt, silty sand, and sand) for purposes of numerical modeling. Soils that occurred rarely and over very small thicknesses were filtered out simply as a consequence of the upscaling procedure described above. Further grouping of soil types was accomplished after upscaling by lumping thin, infrequently occurring types with more predominant types. Thus “sand” represents not only clean sand, but also conglomerate, sand and gravel, and very fine sand. Similarly, “silt” represents silt, clayey silt, silty clay, clay, and organic materials. No grouping was done in the “silty sand” and “sandy silt” soil types.

An isometric view of the upscaled and grouped soil data is shown Figure 5-13. Each of the 64 CPT locations is represented as a vertical string of spheres, with spheres color-coded by soil type, each sphere located at the bottom of an (upscaled) interval. The groundwater surface inferred from May 2002 soundings and the ground surface are also shown in Figure 5-13. Data for both surfaces were extracted from ERPIMS. These two surfaces are used to vertically limit the extents of the larger, site-wide model of vadose-zone soil architecture. The coordinate axes in the figure depict the spatial extent of the larger, site-wide model.

A few comments about the limitations numerical soil models are warranted. A numerical model of vadose zone soil architecture can only partly reflect the true complexity of the subsurface at OU 12. Moreover, the details lost in the modeling process due to the linked operations of upscaling, soil-type lumping, and modeling domain discretization may be key to understanding DNAPL migration pathways to groundwater. Thin, alternating beds of silty-sand and sandy-silt are very common in the raw data from CPT borings. The model, however, does not account for architectural features thinner than the thickness of a gridblock (2 feet, in the case of the larger soil model and 1 foot in the smaller model), such as thin lenses of clay or sand. Thus, an upscaled interval of silty sand may include a thin layer of silt or clay that impedes contaminant migration. Similarly, upscaled sandy-silt layers may include lenses of clean sands that may permit migration of contaminants. In addition, transitions between soil types are modeled as abrupt contacts, which in all likelihood do not occur in the subsurface. Smooth, gradational changes between soil types are also likely to occur, however, but are not reflected in the model.

Finally, the sedimentary fabric of soil, imparted to the soil by depositional processes, occur on a continuum of nested scales. Individual soil laminae are on the scale of approximately 0.10 inches or less, much too small to be correctly captured by a numerical model, because even the comparatively small depth increments between CPT measurements are too large to capture the detail of laminae-scale soil fabric. Yet this fabric may have a strong impact on the migration of percolating groundwater containing dissolved DNAPL. Because of the position of OU 12 on the ancestral Weber River delta deposited into Lake Bonneville, the mean dip direction of depositional laminae is likely to the west, but with some variability due to unsteady current directions during sediment deposition. The laminae may thus drive the movement of dissolved DNAPL to the west as the contaminant makes its way vertically through the vadose zone to the water table, resulting in a lateral offset between DNAPL sources in the vadose zone and the area of highest contaminant concentration in groundwater.

5.1.2.1 *Site-Wide Soil Architecture Model*

The site-wide model of vadose zone soil architecture, obtained by applying indicator kriging (Isaaks and Srivastava, 1989; Gooevaerts; 1997) to the upscaled and grouped soil-type data, is shown in isometric view in Figure 5-14. The view is looking to the northeast. Visual inspection of this limited view of the model suggests a complex architecture of interbedded soil types consistent with a deltaic depositional environment. Sand is common, but is present mainly in the upper part of the vadose zone. Silty sand is ubiquitous throughout the vadose zone, and appears to be the dominant soil type. Sandy silt is common, and present mainly in the lower part of the vadose zone. Silt is uncommon.

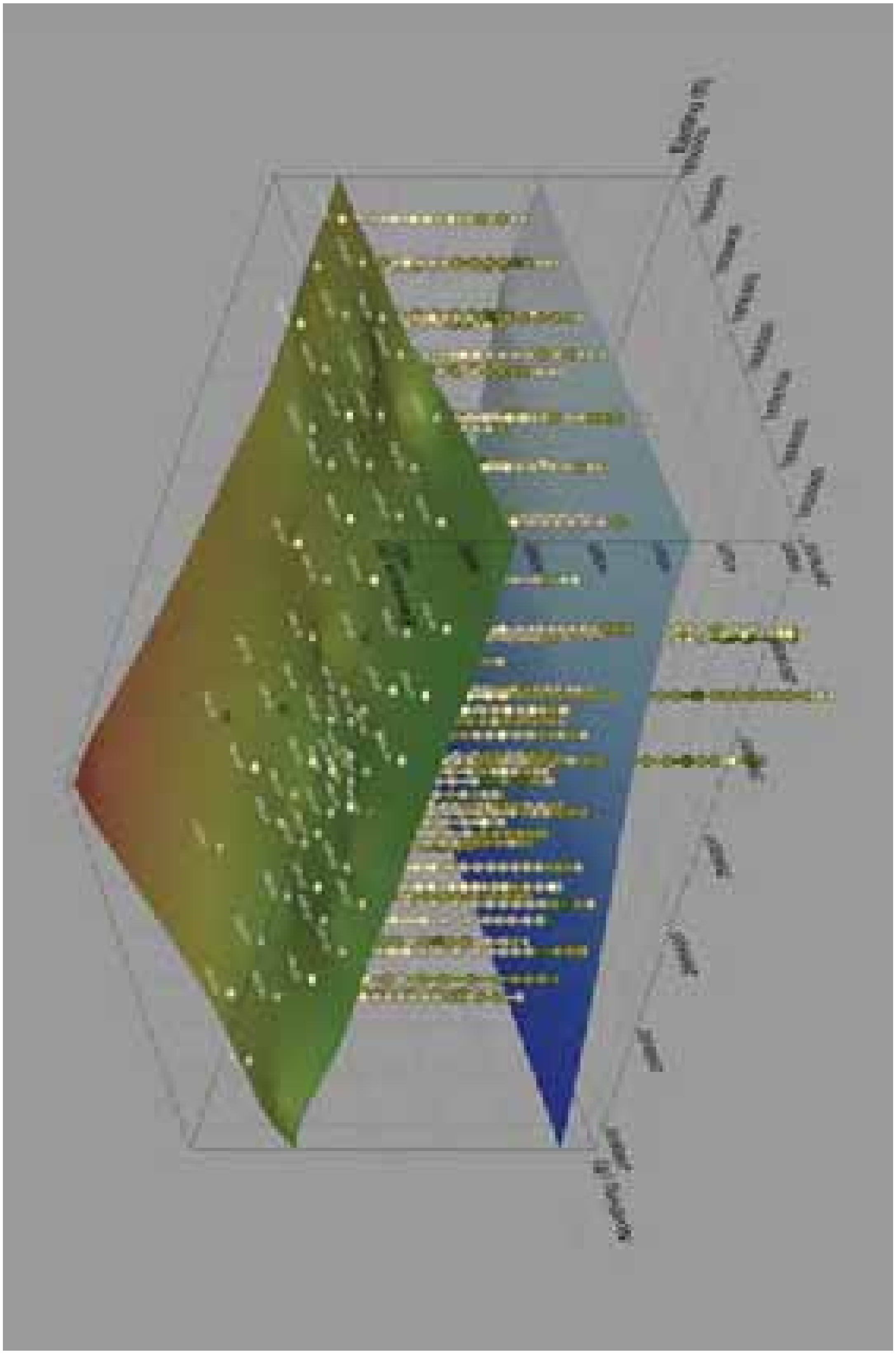


Figure 5-13. Isometric view, looking northeast, of the soil-type data used to model the site-wide vadose zone soil architechture at OU 12. Threre are 1063 data (upscaled from 6658 data) in 64 CPT borings.

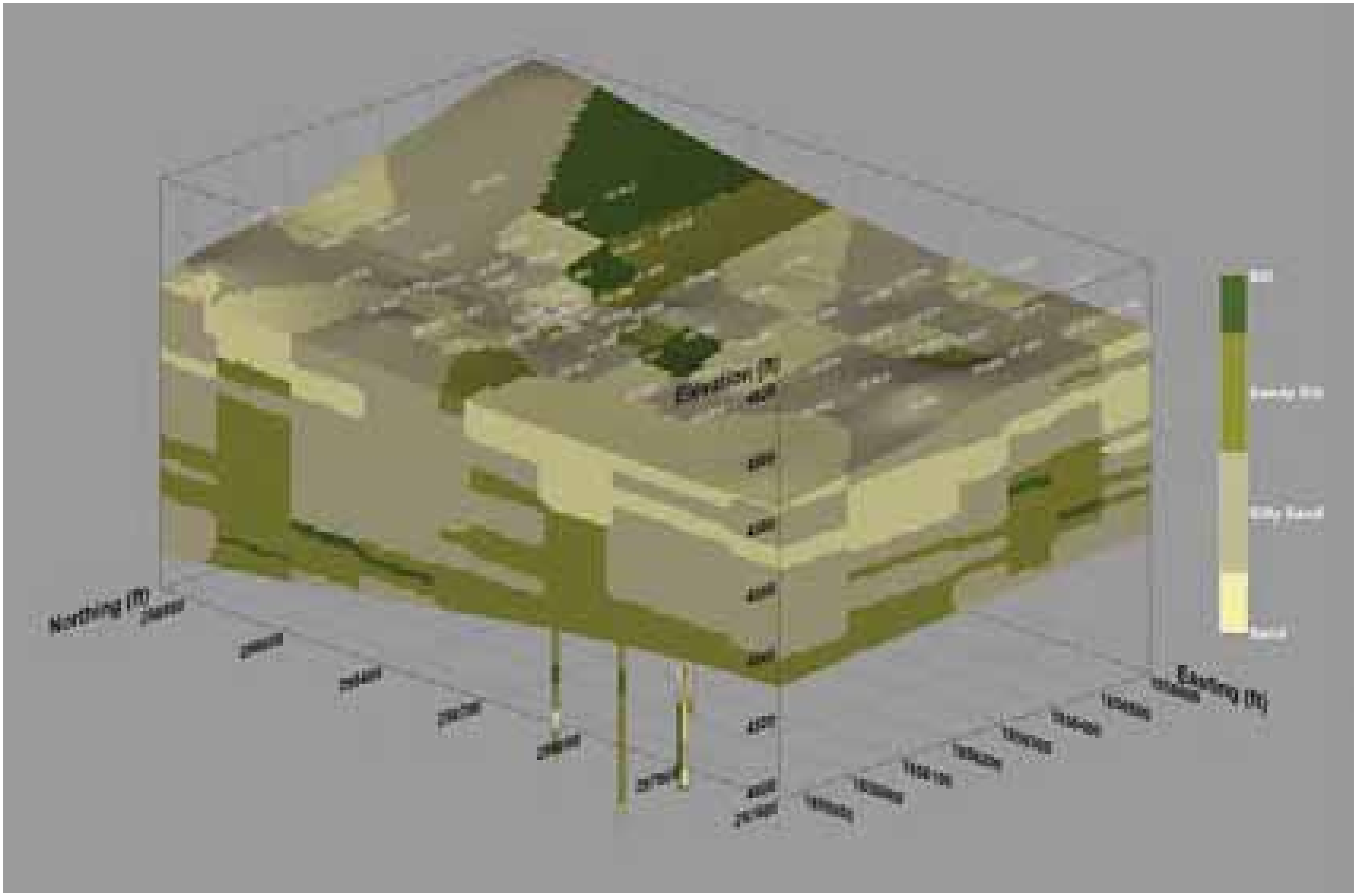


Figure 5-14. Isometric view, looking northeast, of a block diagram of the site-wide vadose zone soil architecture model.

A series of vertical, east-west cross sections through the model illustrate the complex, interbedded, and spatially variable nature of the soil architecture at OU 12. Figure 5-15 shows a cross section near the southern end of the model at a northing of 297,800 ft. The position of the cross section is approximately one-fifth the distance to the northern end of the model, as illustrated by the inset on the figure. Prominent lenses of sand occur in the upper part of the section, especially to the west, but the lenses are not connected across the entire width of the cross section. Minor, isolated sand lenses occur deeper in the section. Sandy silt and silt are uncommon in comparison to silty sand and sand. A cross section 400 feet to the north, at a northing of 298,200 feet, roughly midway between the northern and southern ends of the model, is shown in Figure 5-16. Prominent sand bodies continue to occur in the upper part of the section, but the largest of these is now on the east rather than the west. Larger, more numerous isolated sand lenses occur at depth. There is no connection between sand lenses across the width of the section. Sandy silt and silt remain minor in comparison to silty sand and sand. Note that the thickness of the section has increased by approximately 10 feet, due mainly to the northward dip of the groundwater surface. The relative size of sand lenses diminishes near the northern end of the model (northing of 298,600 ft), as shown in Figure 5-17. In addition, the sand lenses appear to be somewhat more isolated than in the south. The fraction of sandy silt is much higher, dominating the lower two-thirds of the section on the west. The thickness of the vadose zone has increased, again by about 10 feet, primarily because of the northward dip of the groundwater surface, but also due in part to increased elevation of the ground surface.

A north-south vertical cross section, roughly bisecting the model (easting of 1,856,150 ft), is shown in Figure 5-18, and reinforces the character of soil architecture observed on the east-west cross sections. Again, the most salient features of the architecture are the occurrence of larger, connected sand lenses in the upper and southern part of the section, isolated sand lenses at depth, and the tendency for the sand lenses to become smaller and more isolated to the north. Sandy-silt and silt are most common in the lower part of the section, especially to the north. The continuity of the sand body north-to-south and its position in the upper part of the stratigraphic section, together with the position of OU 12 on the ancestral Weber River delta, suggests barrier or foreshore beach deposits underlain by lagoonal or possibly delta front deposits (note the increasing thickness of the vadose zone to the north).

The modeled architecture has apparent implications for DNAPL movement through the vadose zone and ultimately to groundwater at OU 12. Based on the results of the Wireline soil sampling demonstration, it is unlikely that free-phase DNAPL is migrating to groundwater. Instead, it is probable that surface water infiltrates and percolates through the vadose zone, passing through regions of contaminated soil. As it travels through these zones, contaminant in the soil dissolves into the percolating water and is transported to groundwater. Gravity is thus the main force driving dissolved contaminant mass through the vadose zone, and the preferred migration pathways are through higher permeability sands, such as the inferred beach deposits in the upper part of the vadose zone. Capillary forces, however, also wield influence on the movement of percolating water. When lower permeability materials are encountered migration pathways are deflected, and the fluid seeks to establish routes with the least capillary resistance. At OU 12, the vertical pathways are likely to be tortuous, because there are no large sand bodies spanning the entire thickness of the vadose zone; the larger sand bodies occur in the upper reaches of the vadose zone and are better connected laterally than vertically.

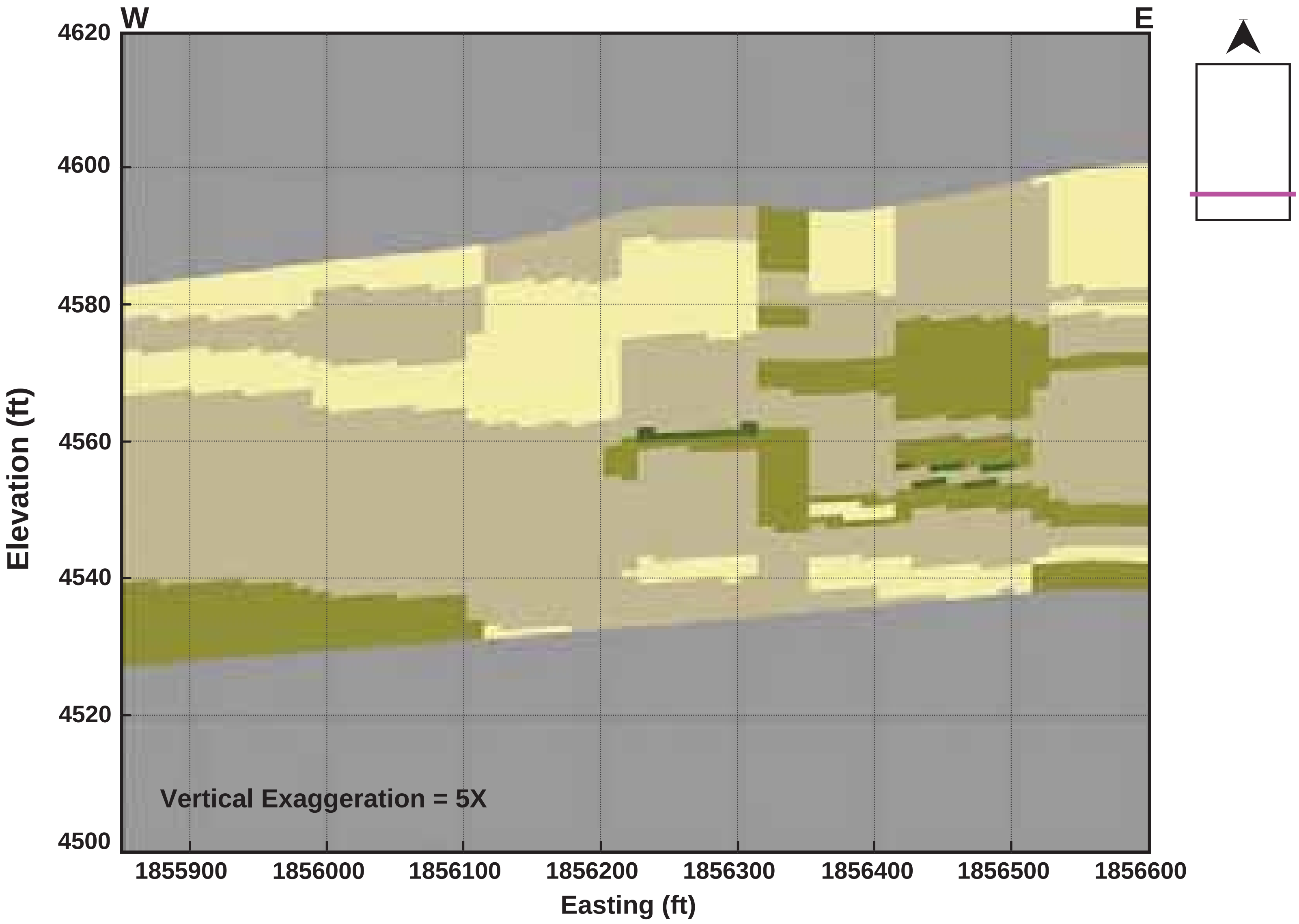


Figure 5-15. East-west vertical cross-section through the site-wide soil architecture model at a northing of 298,000 ft.

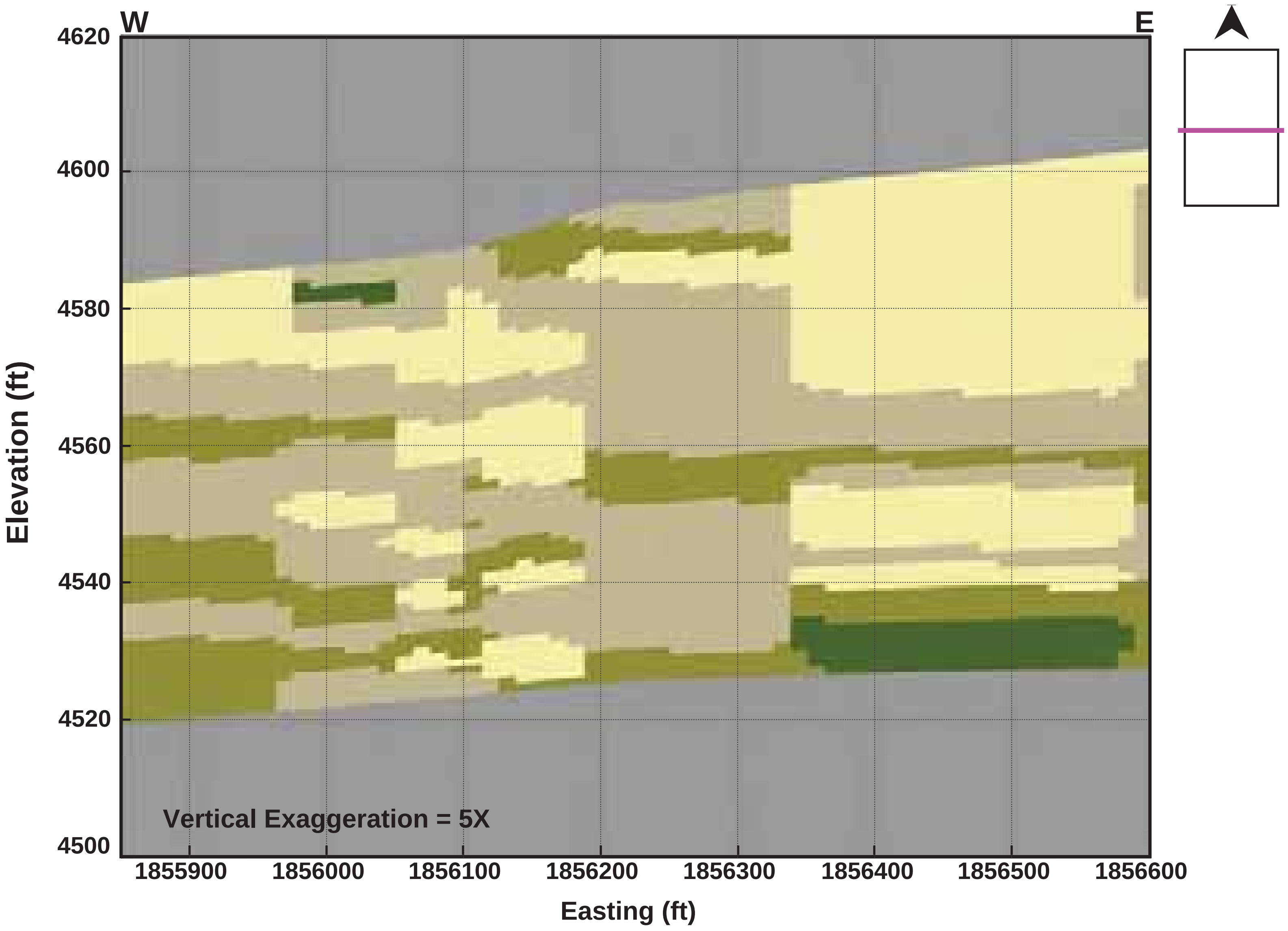


Figure 5-16. East-west vertical cross-section through the site-wide soil architecture model at a northing of 298,200 ft.

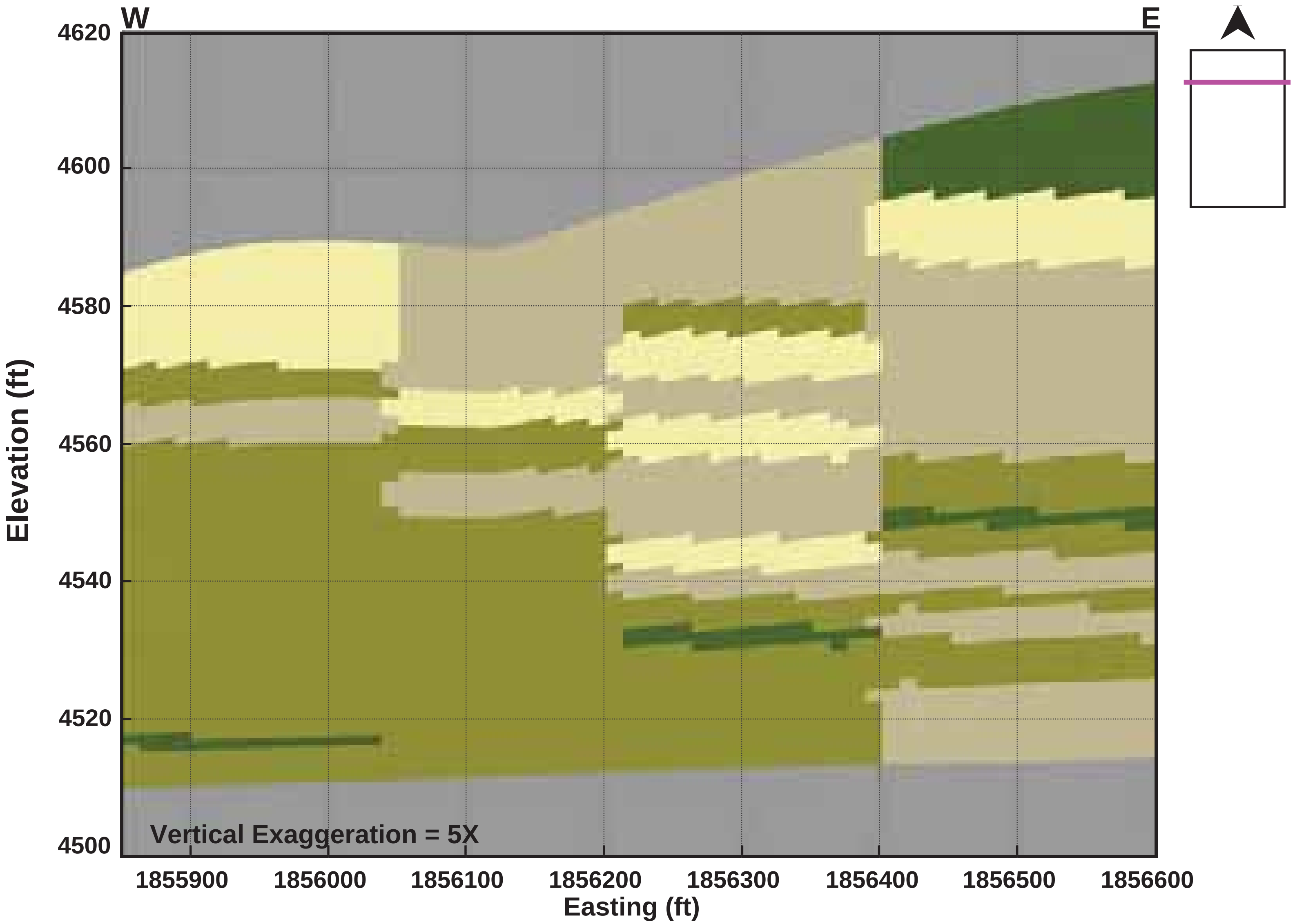


Figure 5-17. East-west vertical cross-section through the site-wide soil architecture model at a northing of 298,600 ft.

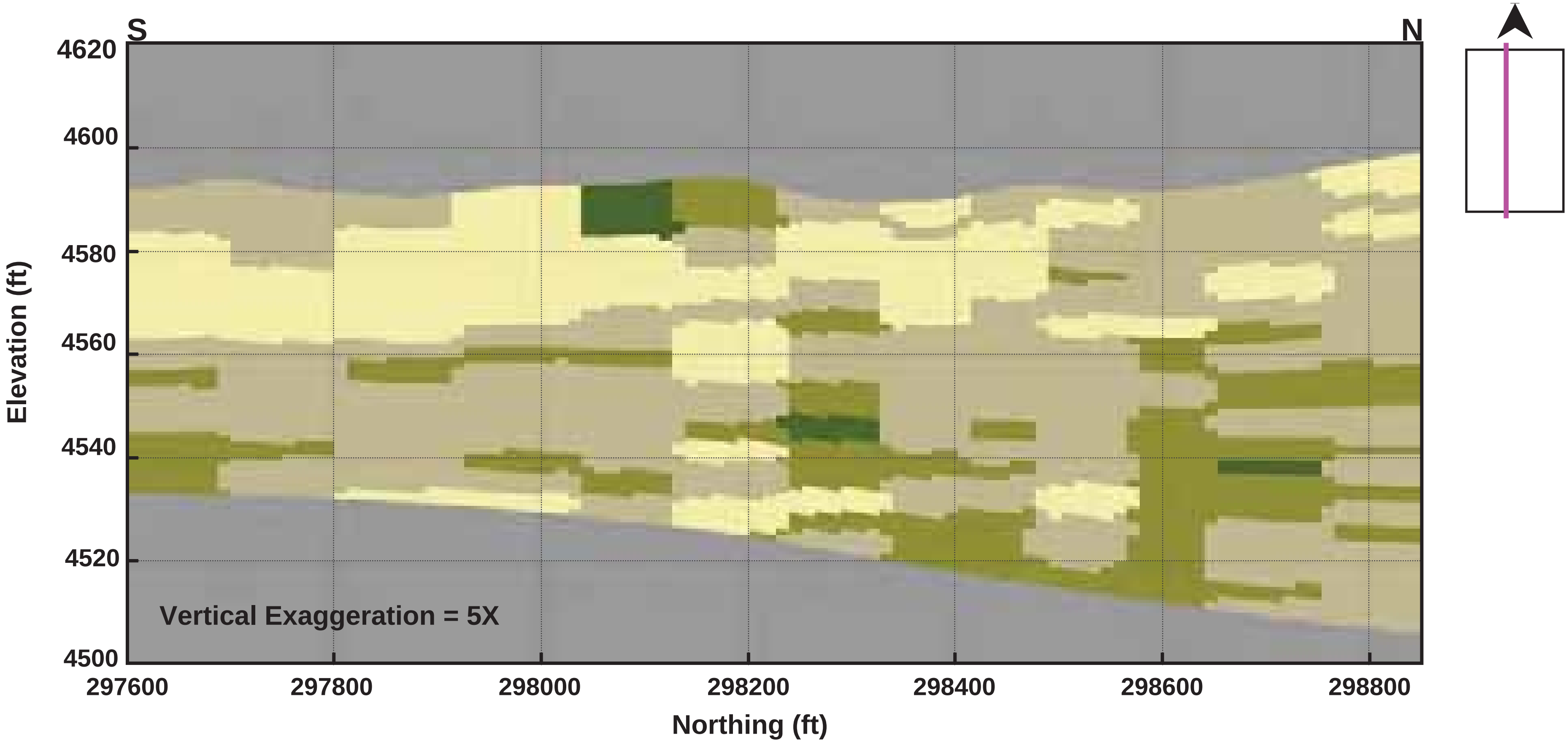


Figure 5-18. North-south vertical cross-section through the site-wide soil architecture model at an easting of 1,856,150 ft.

Volumetric calculations yield an estimated 12,533,000 yd^3 of soil in the portion of the OU 12 vadose zone considered in the site-wide model. This volume is approximate, and varies depending on the elevation of the underlying groundwater surface. The calculations also confirm previously described visual observations: silty sand is the most predominant soil type (53%), followed by sandy-silt (23%), sand (21%), and silt (3%).

5.1.2.2 *Combined Modeling of Soil Architecture and TCE Contamination*

The domain of the smaller model of vadose zone soil distribution is identical to the domain of the final model of TCE concentration in soil, both in terms of domain extent and discretization. The areal extent of the domain was shown previously in Figure 5-1, and the discretization described in Table 5.2. The objectives of modeling soil architecture and TCE concentration using coincident domains are to understand the distribution of TCE by soil type, to provide qualitative insight regarding the movement of TCE through the vadose zone, and to obtain quantitative estimates of the mass of TCE residing in each type of soil.

The same set of upscaled soil-type data from the 64 CPT locations used to construct the site-wide model were also used to construct the combined soil/TCE model. As a practical matter, however, only those wells within and in the vicinity of the modeling domain contribute to the inference of soil type. Note that data from outside the modeling domain will contribute to the inference of soil type.

An east-west vertical slice through the combined soil/TCE model at a northing of 298,270 ft is shown in Figure 5-19. The inset shows the location of the cross section in the modeling domain. The iso-concentration contours shown in the figure are 100 μg/kg (green), 1,000 μg/kg (yellow) and 10,000 μg/kg (red), and are the intersection of the plane of the section with the corresponding iso-concentration surface. The region between contours is colored for clarity. Although the shape of the 100 μg/kg contour suggests the sinuous movement of TCE through the vadose zone, contours are not equivalent to migration pathways. It is unlikely that a small volume of contaminant originating in the region of highest TCE concentration remains confined to the plane of the figure as it makes its way downward to the water table.

Nonetheless, the shape of the 100 μg/kg contour does provide insight to the general nature of contaminant movement. There is a clear tendency for movement to the west, perhaps due to the sedimentary fabric imparted to the soil during deltaic deposition, as discussed previously. Locally there is a suggestion of migration to the east, as indicated by the portions of the 100 μg/kg contour between an easting of approximately 1,856,065 feet and 1,856,110 feet and an elevation between about 4540 feet and 4550 feet. The eastward component of migration may be due to pathways smaller than the scale of the model. This displays only one component of transport, however: an intersecting, orthogonal cross section, discussed presently, suggests a component of transport from north to south. Also, note the layered structure of the 100 μg/kg contour, with three distinct, laterally spreading bodies of TCE contamination at approximately 4530 feet, 4545 feet, and 4555 feet. These may be due to the presence of fine-grained lenses, thinner than the scale of the model, that impede the vertical migration of TCE. Contaminant spreads laterally as a consequence, seeking a downward pathway with less capillary resistance.

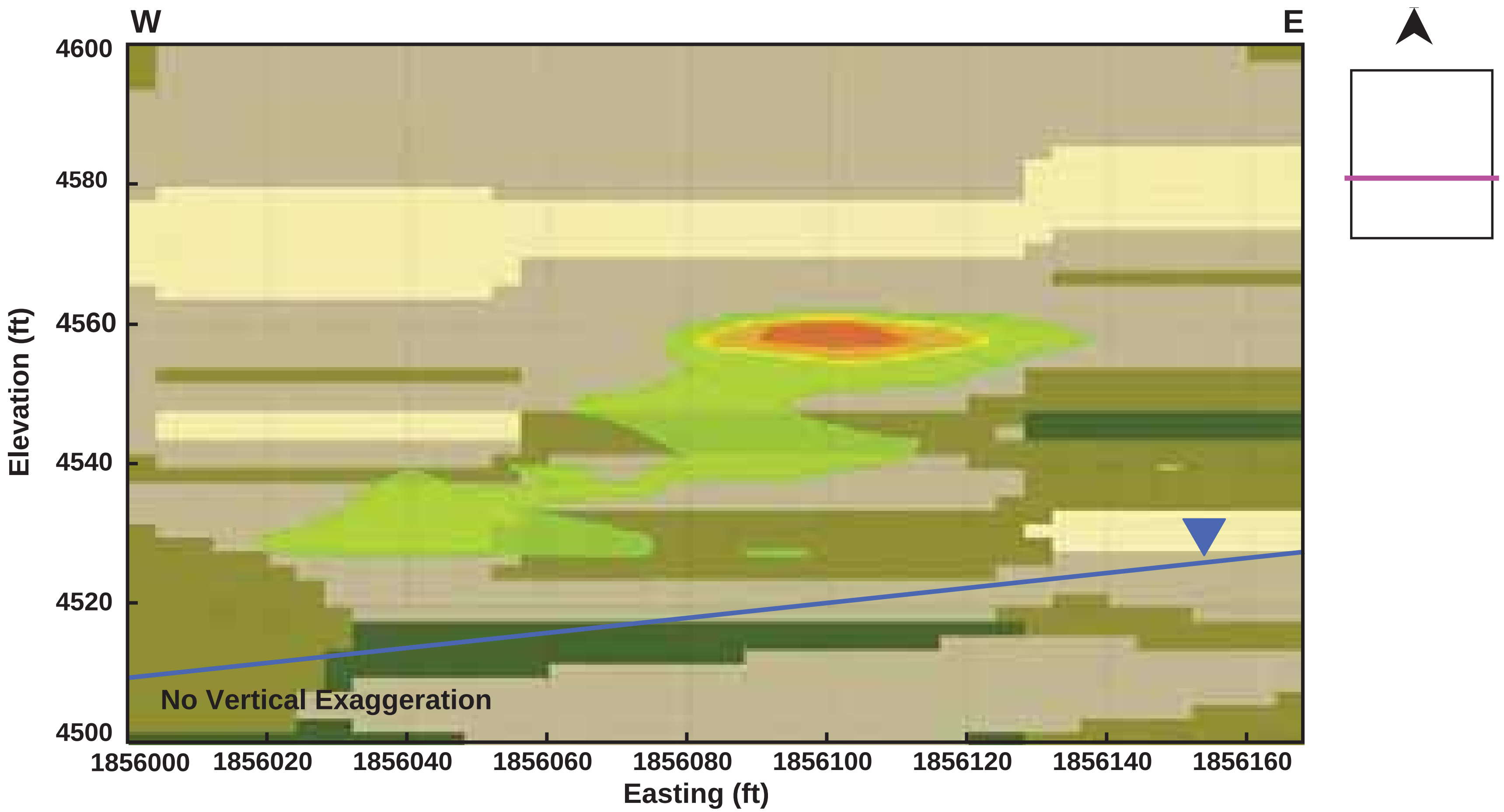


Figure 5-19. East-west vertical cross-section through the combined TCE/soil model at a northing of 298,270 ft.

The position of the water table in May 2002 is shown on Figure 5-19 for reference. It is about 15 to 20 feet lower than the lowest level of the 100 μg/kg contour. Although the magnitude of water table fluctuations over the past several decades are unknown, it seems unlikely they are in the range of 15 to 20 feet. Thus the fluctuation of the groundwater surface through soils contaminated with TCE at a level above 100 μg/kg does not appear to be a mechanism for contamination in the saturated zone, at least at the location of this particular cross section.

Figure 5-20 is a north-to-south vertical cross section at an easting of 1,856,100 feet, and orthogonal to Figure 5-19. The elongate character of contamination is evident. Note the shape of the 100 μg/kg between northings of approximately 298,250 feet and 298,270 feet, and elevations of about 4540 to 4550 feet. This tongue-shaped contour indicates transport to the south, and connects to a previously described contour suggesting an easterly component of transport on the east-west cross section at a northing of 298,270 feet (see Figure 5-19). Some of the smaller, isolated regions of TCE contamination enclosed by the 100 μg/kg contour may be interpolation artifacts and should be interpreted with discretion (e.g., the region at an elevation of approximately 4,525 feet between a northing of 298,360 feet and 298375 feet). Clearly connected migration pathways are less visible, although there is an apparent southward component of migration direction from the main region of contaminated soil.

Volumetric calculations of soil type indicate that the proportions of soil types in the combined soil/TCE model are very similar to those in the site-wide model. Of the 124,444 yd^3 of soil in the combined soil/TCE model, 17% is sand, 53% is silty-sand, 27% is sandy-silt, and 3% is silt. More detailed calculations describing the relationship between TCE contamination and soil type are summarized in Table 5-4. The calculations are based on the region enclosed by the 10 μg/kg iso-concentration surface. 30,472 yd^3, or 24.5% of the model volume, is enclosed by the 10 μg/kg iso-concentration surface. The average concentration of TCE within this volume is 131.93 μg/kg, yielding a mass of 12.5 lb and a volume of 0.202 ft^3 TCE. The bulk of the TCE is in silty-sand; 21.9% of the silty-sand is contaminated by TCE at a concentration higher than 10 μg/kg, with an average concentration of 343.8 μg/kg, for a total of 10.62 lb TCE (85% of the total). Analogous results for the other modeled soil types are listed in Table 5-4.

Table 5-4. Distribution of TCE Greater Than 10 μg/kg by Soil Type

Soil Type	Volume (yd^3)	Percent of Soil-Type (%)	TCE Volume (ft^3)	TCE Mass (lb)	Average TCE Concentration (μg/kg)
Sand	1,124	5.3	0.0013	0.08	34.05
Silty-Sand	14,450	21.9	0.1715	10.62	343.80
Sandy-Silt	13,895	41.6	0.0275	1.72	57.88
Silt	1,003	24.8	0.0013	0.08	38.97
TOTAL	**30,472**	**24.5**	**0.2016**	**12.50**	**131.93**

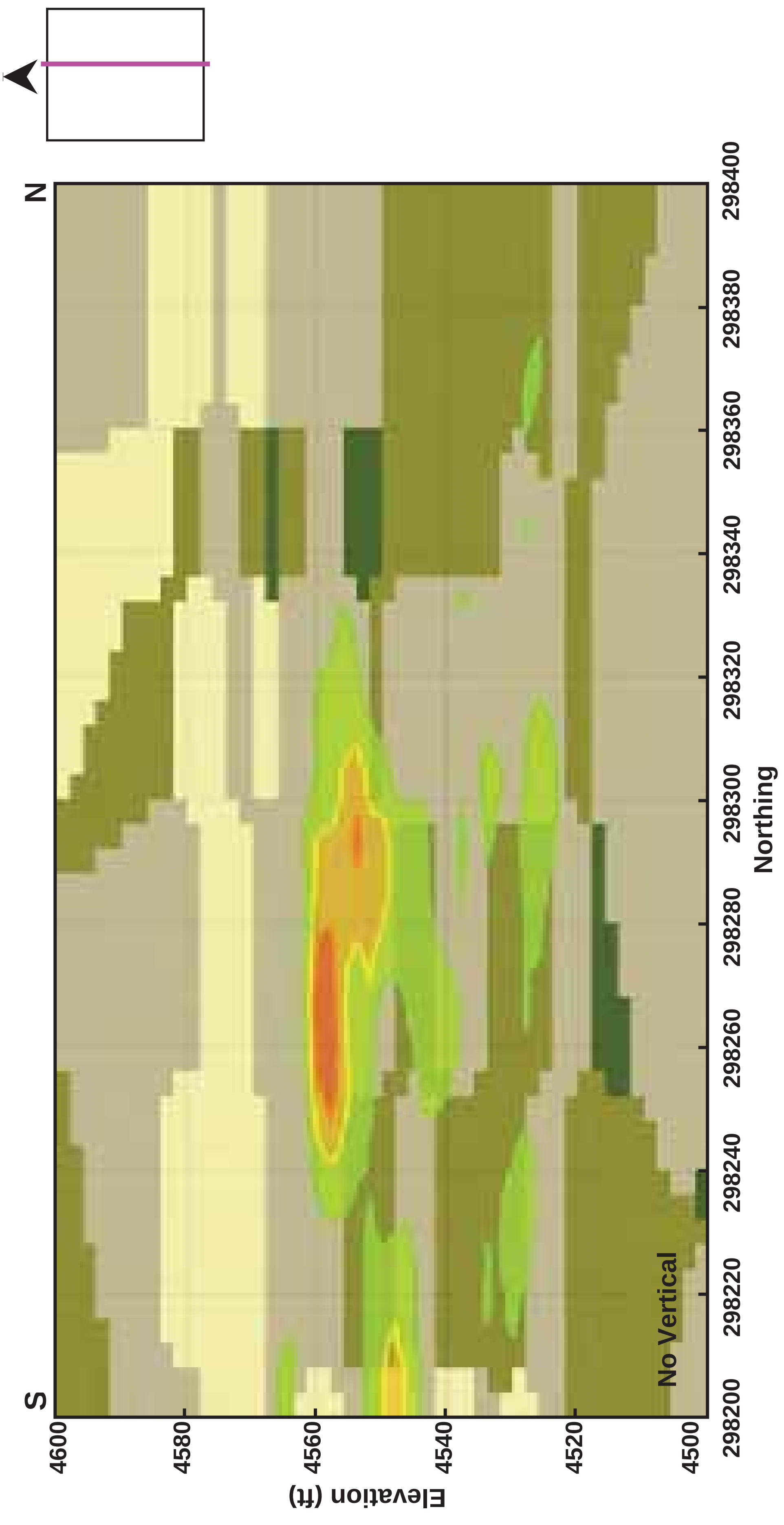


Figure 5-20. North-south vertical cross-section through the combined TCE/soil model at an easting of 1,856,110 ft.

5.2 OU 12 SVE Evaluation

The OU 12 SVE demonstration was primarily conducted to obtain additional vadose zone characterization data for estimating TCE distribution in the suspected source zone at OU 12 using a multiphase, multicomponent numerical model. Step tests were conducted under constant vapor flow conditions and not necessarily constant pressure as is normally performed during SVE pilot-scale studies. TCE time series data were obtained in real-time via DSTIMS and used to make decisions on when to adjust pumping operations at each extraction well. Although the step tests were optimized to assess contaminant distribution within the vadose zone of the investigative area, the data also provide an indication of the pneumatic response of the subsurface at OU 12 during vapor extraction operations.

5.2.1 Pneumatic Evaluation

5.2.1.1 *Zone of Pneumatic Influence*

The pneumatic data generated during the OU 12 SVE demonstration was used to estimate the zone of pneumatic, or pressure, influence observed during vapor extraction operations in the vadose zone at OU 12. Although rather misleading, the zone of pneumatic influence is generally referred to as the radius of influence (ROI), where ROI testing involves evaluating the maximum radial extent of induced subsurface vacuum to some arbitrarily specified level (typically 0.01 inch of water) in single well tests. The ROI is determined by plotting vacuum as a function of logarithmically transformed radial distance and applying linear regression to extrapolate to the distance at which a specified vacuum would be observed. Alternatively, nonlinear regression techniques can be used to estimate the ROI from the measured pressure versus distance data. Vacuum monitoring points are often located significant distances from vapor extraction wells in an attempt to "physically" locate ROIs for given flow rates and to compensate for the possible geologic variations in the subsurface.

Historically, ROIs have been used as the basis of design for extraction well networks. The zone of vacuum influence around a well also has been interpreted as corresponding to the "capture zone" of the extraction well. By subsequently selecting an arbitrary distance within this zone of vacuum influence (e.g., the radius at which the vacuum equals 0.01 inch of water vacuum), designers have established well spacings for SVE well networks. Unfortunately, the zone of vacuum influence does not necessarily correspond with the capture zone of the extraction well. Vacuum profiles are typically very curvilinear, especially under conditions of high leakance of air from the surface and radial-to-vertical gas permeability (k_r /k_z) ratios greater than 1.0. As shown in Figure 5-21, vacuum profiles do not consist of a series of concentric cylinders surrounding the well screen of the vapor extraction well as predicted based on a ROI design. Additionally, a ROI-based SVE design, can result in subsurface pore-gas velocities too low for optimal gas circulation especially at low leakance values and high k_r /k_z ratios. The suitability of using vacuum levels such as 0.01 inch of water, typical of ROI testing and ROI-based designs, to ensure adequate gas circulation decreases with increasing k_r /k_z ratios and decreasing leakance values. ROI-based designs are more likely to be appropriate as k_r /k_z ratios approach 1.0 or less and when significant leakance occurs (EPA, 2001).

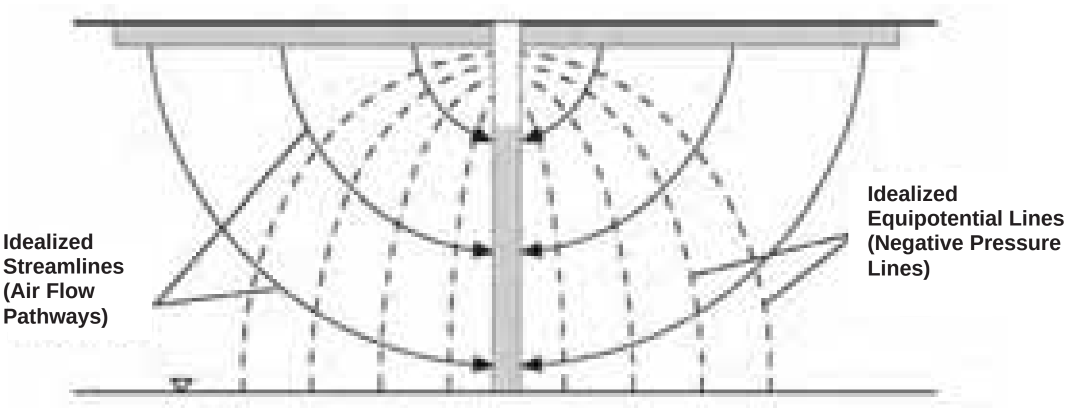


Figure 5-21. Idealized streamlines and vacuum distribution during SVE operations.

Typically, most vacuum dissipation and the highest pressure gradients occur within 15 feet of the vapor extraction well. Thus, SVE designs should be based on pore gas velocities or the rates of pore gas exchange, which, are a function of both the vacuum distribution around the vapor extraction point and the associated soil air permeability. Ideally, information on spatial variability of radial and vertical gas permeability should be utilized in support of three-dimensional numerical gas flow modeling. Since gas permeability is a function of moisture content, spatial variability of gas permeability for any given geologic environment will be significantly greater than for saturated hydraulic conductivity determined for groundwater investigations.

Although limitations are associated with using the ROI as the final SVE design basis, the zone of pneumatic influence does provide the basic information for the initial design of vapor extraction well spacing. The vacuum distribution measured during the last flow period as a function of distance for each vapor extraction well during the OU 12 SVE demonstration is shown in Figure 5-22. The data were subjected to nonlinear regression analyses to obtain an estimate of the zone of pneumatic influence for each extraction well. Based on a maximum radial extent of induced subsurface vacuum of 0.01 inch of water, the zone of pneumatic influence observed during the OU 12 SVE demonstration ranged from approximately 50 to 80 feet in the southern section (U12-VP1, U12-VP4, and U12-VP7) of the investigative area to over 100 feet in the northern section (U12-VP2, U12-VP3, and U12-VP5). The average zone of pneumatic influence within the investigative area was approximately 85 feet.

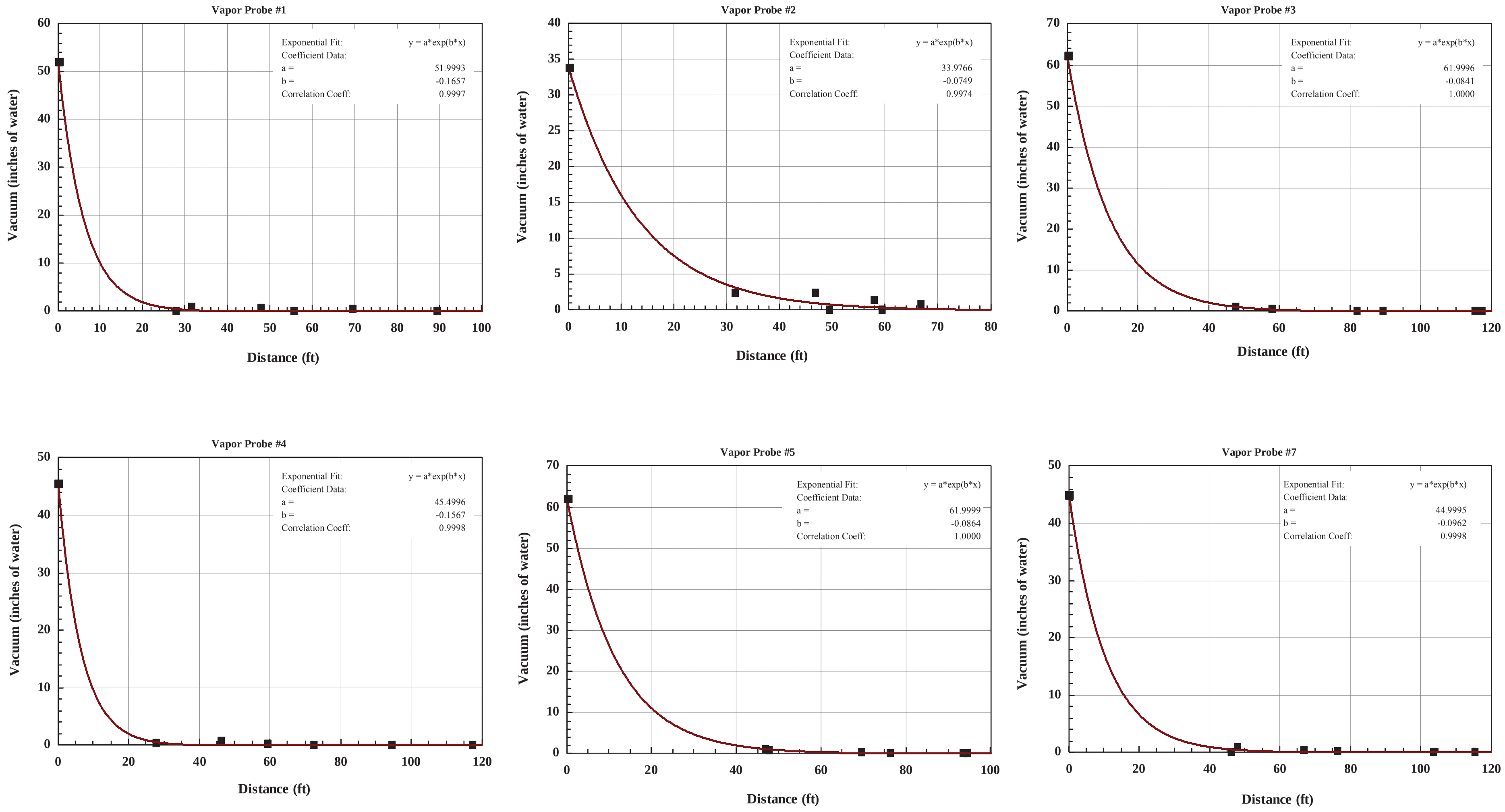


Figure 5-22. Vacuum distribution as a function of distance measured during the OU 12 SVE demonstration.

5.2.1.2 *In Situ Permeability*

The transient pressure distribution measured at a site during soil vapor extraction can be used to estimate the soil permeability to vapor flow. The change in the subsurface pressure distribution with time $P^{?}(r,t)$ is given by (Bear, 1979; Johnson et al., 1990):

$$P' = \frac{Q}{4pm\left(\frac{k}{\mu}\right)} \int_{\frac{r^2 e\mu}{4kP_{atm}t}}^{\infty} \frac{e^{-x}}{x}\,dx \tag{1}$$

The behavior of the integral is such that for ($r^2\varepsilon\mu/4kP_{atm}t$) less than 0.001, its value is very close to the asymptotic limit, and for ($r^2\varepsilon\mu/4kP_{atm}t$) less than 0.1, equation (1) can be approximated by:

$$P' = \frac{Q}{4pm\left(\frac{k}{\mu}\right)}\left[-0.5772 - \ln\left(\frac{r^2 e\mu}{4kP_{atm}}\right) + \ln(t)\right] \tag{2}$$

where

P' = gauge pressure measured at distance r and time t (g/cm-s^2);
m = vent well screen interval (cm);
r = radial distance from the vapor extraction well (cm);
k = soil permeability to air flow (cm^2);
μ = viscosity of air (1.8×10^{-4} g/cm-s at 18 °C);
ε = air-filled soil void fraction;
t = time (s);
Q = volumetric vapor flow rate from the extraction well; and
P_{atm} = ambient atmospheric pressure (where 1 atm is equal to 1.013×10^6 g/cm-s^2).

Equation (2) predicts that a semilog plot of the pressure (P') as a function of time will yield a straight line with slope A and y-intercept B equal to:

$$A = \frac{Q}{4pm\left(\frac{k}{\mu}\right)} \tag{3}$$

$$B = \frac{Q}{4pm\left(\frac{k}{\mu}\right)}\left[-0.5772 - \ln\left(\frac{r^2 e\mu}{4kP_{atm}}\right)\right] \tag{4}$$

Thus, the *in situ* air permeability and its variability throughout the site can be determined from soil gas pressure or vacuum data collected over time at various vapor probe locations following initiation of pumping at an extraction well using the following equation:

$$k = \frac{r^2 e\mu}{4P_{atm}} \exp\left(\frac{B}{A} + 0.5772\right) \tag{5}$$

The governing equations for vapor flow through porous media described above assume that the vapor behaves as an ideal gas and that flow is radially symmetric from the extraction well. In addition, it is assumed that changes in the permeability or vapor-filled porosity caused by liquid removal can be neglected. This is a reasonable assumption based on the short duration of vapor extraction operations conducted at OU 12. Since the observed LNAPL and water are anticipated to be wetting fluids relative to vapors and because vapors preferentially flow through macropores, removal of the LNAPL or water is not expected to significantly increase the permeability in the vadose zone at OU 12. However, permeability changes may be appreciable for soil vapor extraction operations conducted for extended periods of time due to LNAPL removal and/or the drying of the soil.

The pressure decrease (vacuum increase) measured at each vapor monitoring probe as a function of logarithmically transformed time during vapor extraction from U12-VP1, U12-VP2, U12-VP3, U12-VP5, and U12-VP7 is shown in Figures 5-23 through 5-27, respectively. Using the results of the regression analysis conducted on these data and equation (5) shown above, the average *in situ* air permeability between the vapor extraction well and the monitoring probes were determined and are provided in Table 5-5. With the exception of well pairs U12-VP3/U12-VP1 and U12-VP3/U12-VP7, the average *in situ* air permeabilities ranged from 5 to 20 Darcy with a geometric mean of approximately 10 Darcy.

Predicted steady-state flow rates per unit well screen thickness as a function of soil permeability for a 2-inch radius vapor extraction well (R_W) and a 40-foot zone of pneumatic influence (R_I) is shown in Figure 5-28 for various applied vacuum (P_W). During the OU 12 SVE demonstration, flow rates ranged from 0.05 to 0.08 m^3/m-min with an applied vacuum of approximately 0.82 atm. This corresponds to an estimated soil permeability of approximately 1 Darcy for R_W and R_I equal to 2 inches and 40 feet, respectively (see highlighted region shown on Figure 5-28). Since the flow rate shown in Figure 5-28 is proportional to $k/\ln(R_W/R_I)$, the estimated soil permeability based on the OU 12 SVE conditions (i.e., 0.375-inch radius vapor extraction well and an estimated average zone of pneumatic influence of 85 feet) is approximately 2 Darcy. Although this value is slightly less than the 10 Darcy estimated using the vacuum distribution as a function of the logarithmically transformed time, both values are in the general range expected for the fine-grained material observed in the vadose zone at OU 12.

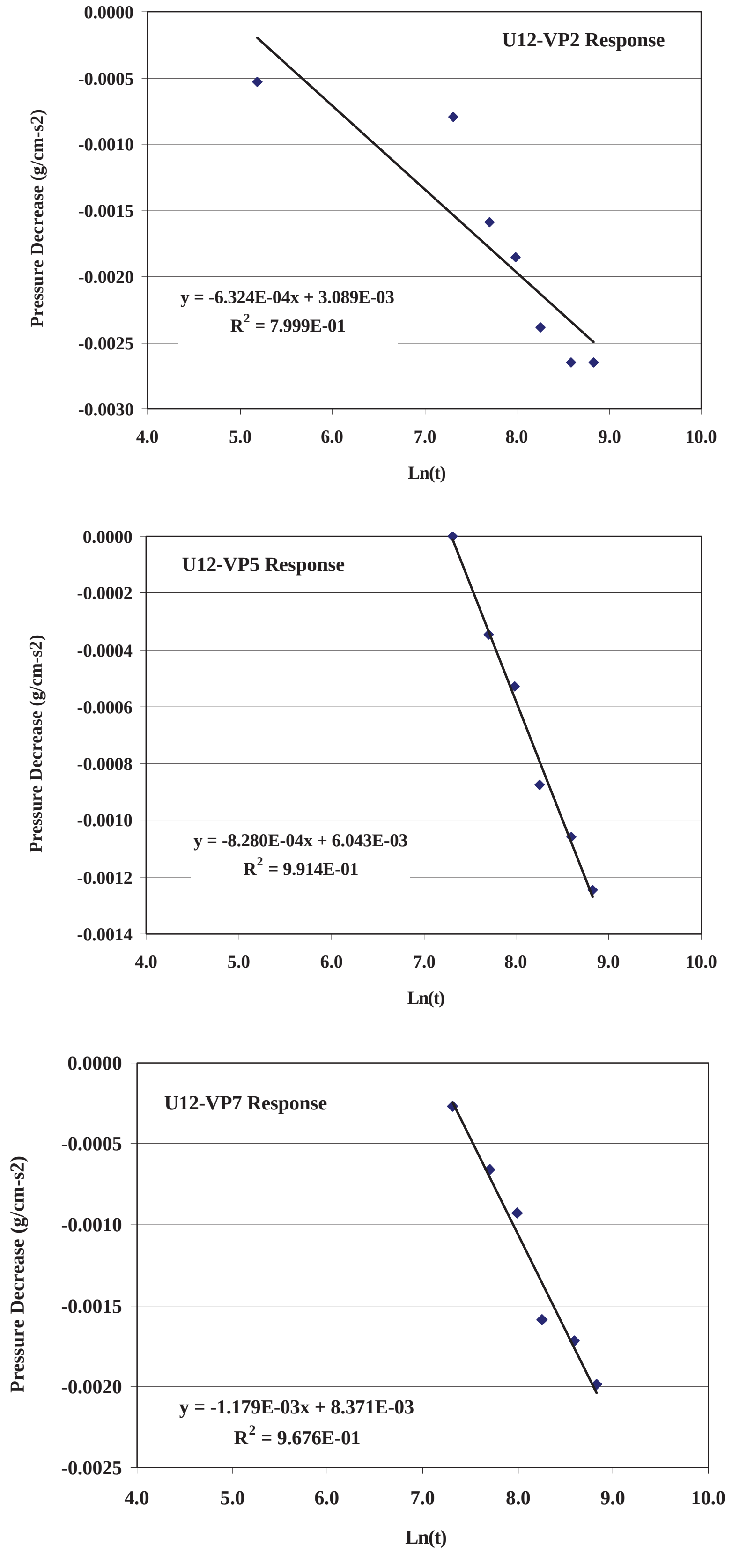


Figure 5-23. Pressure decrease as a function of time during vapor extraction at U12-VP1.

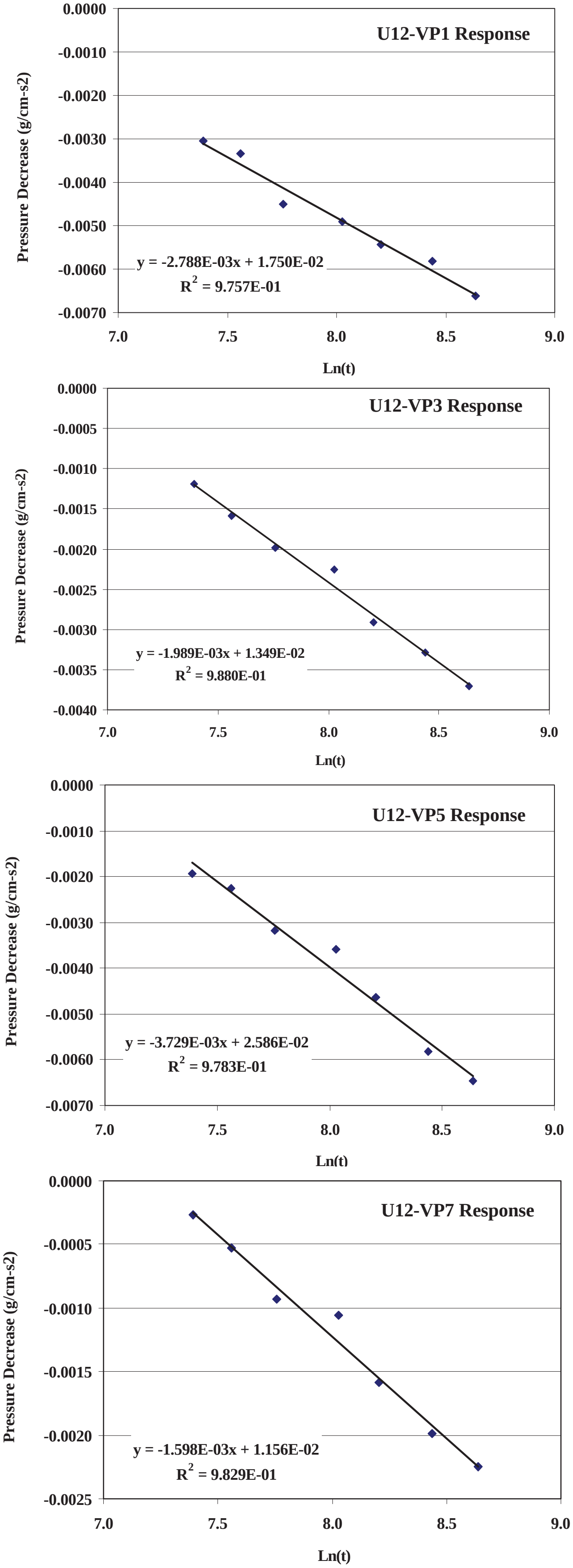


Figure 5-24. Pressure decrease as a function of time during vapor extraction at U12-VP2.

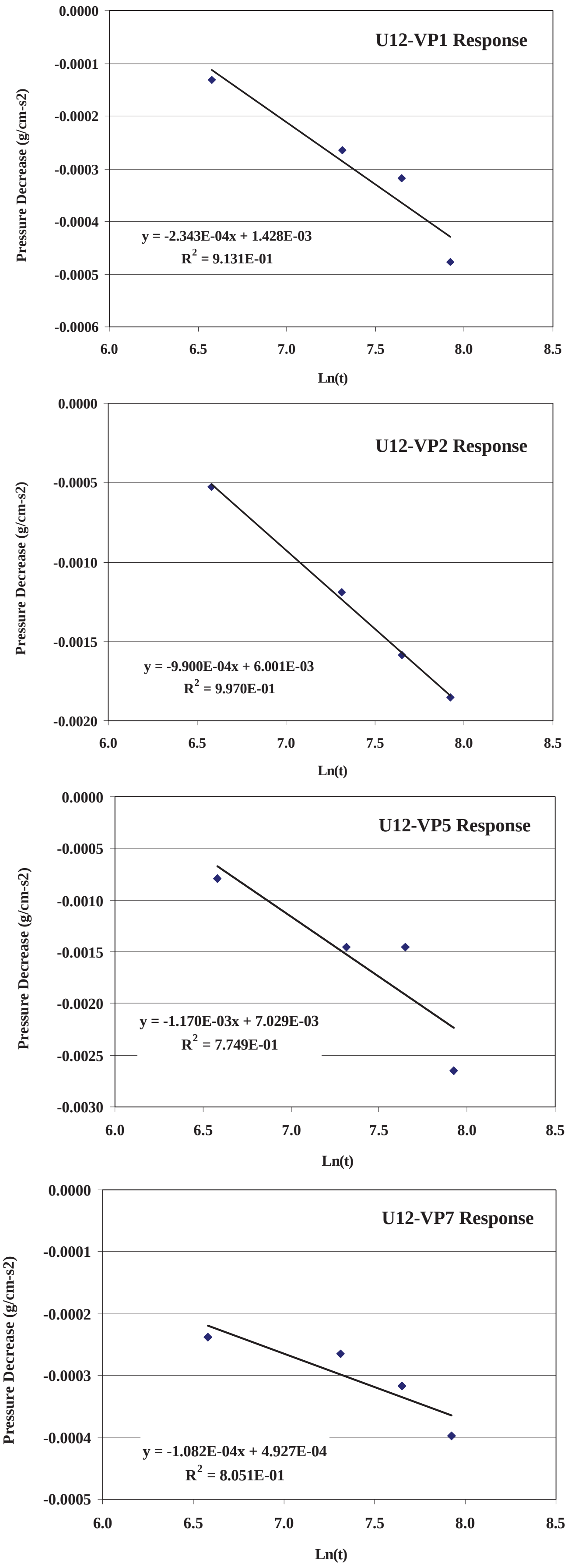


Figure 5-25. Pressure decrease as a function of time during vapor extraction at U12-VP3.

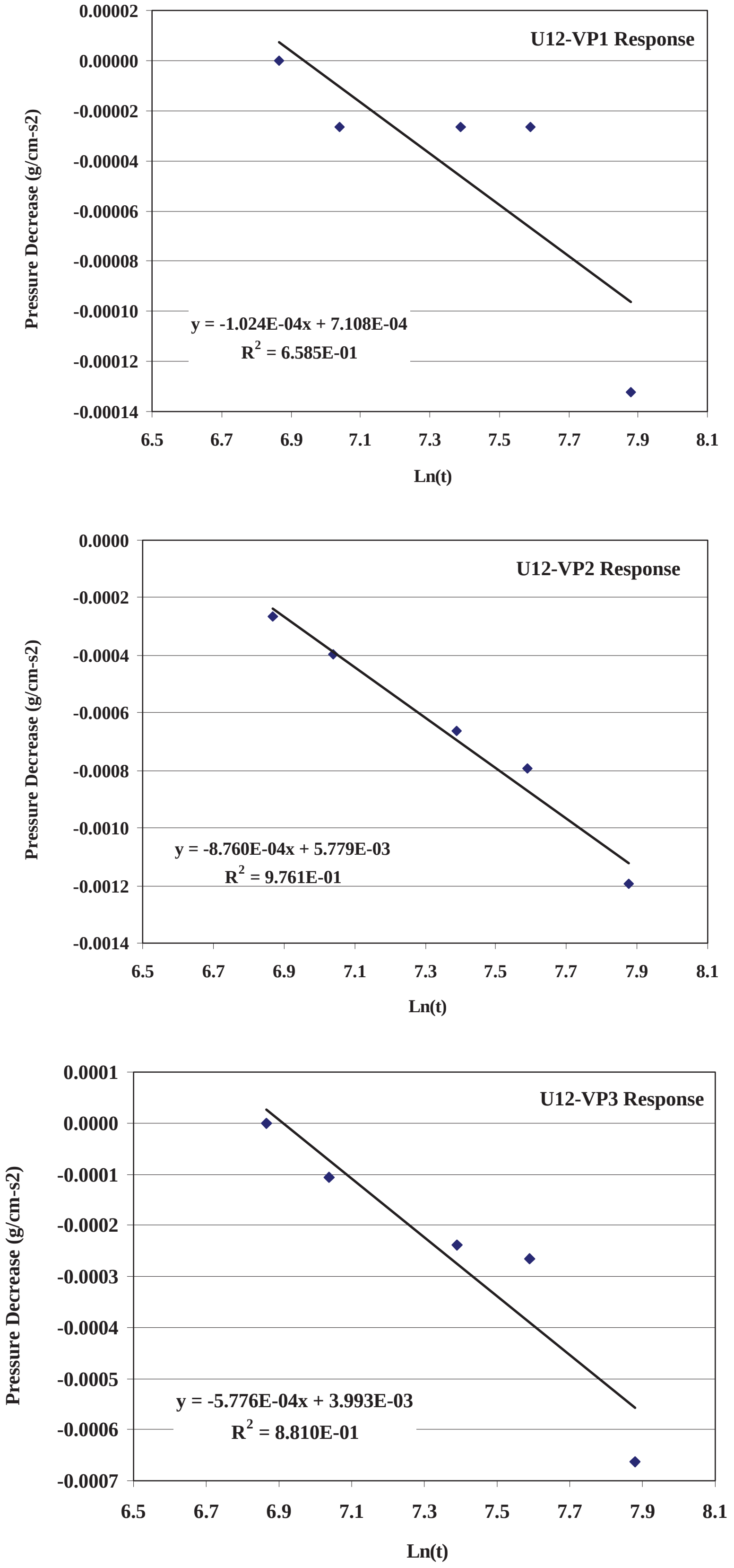


Figure 5-26. Pressure decrease as a function of time during vapor extraction at U12-VP5.

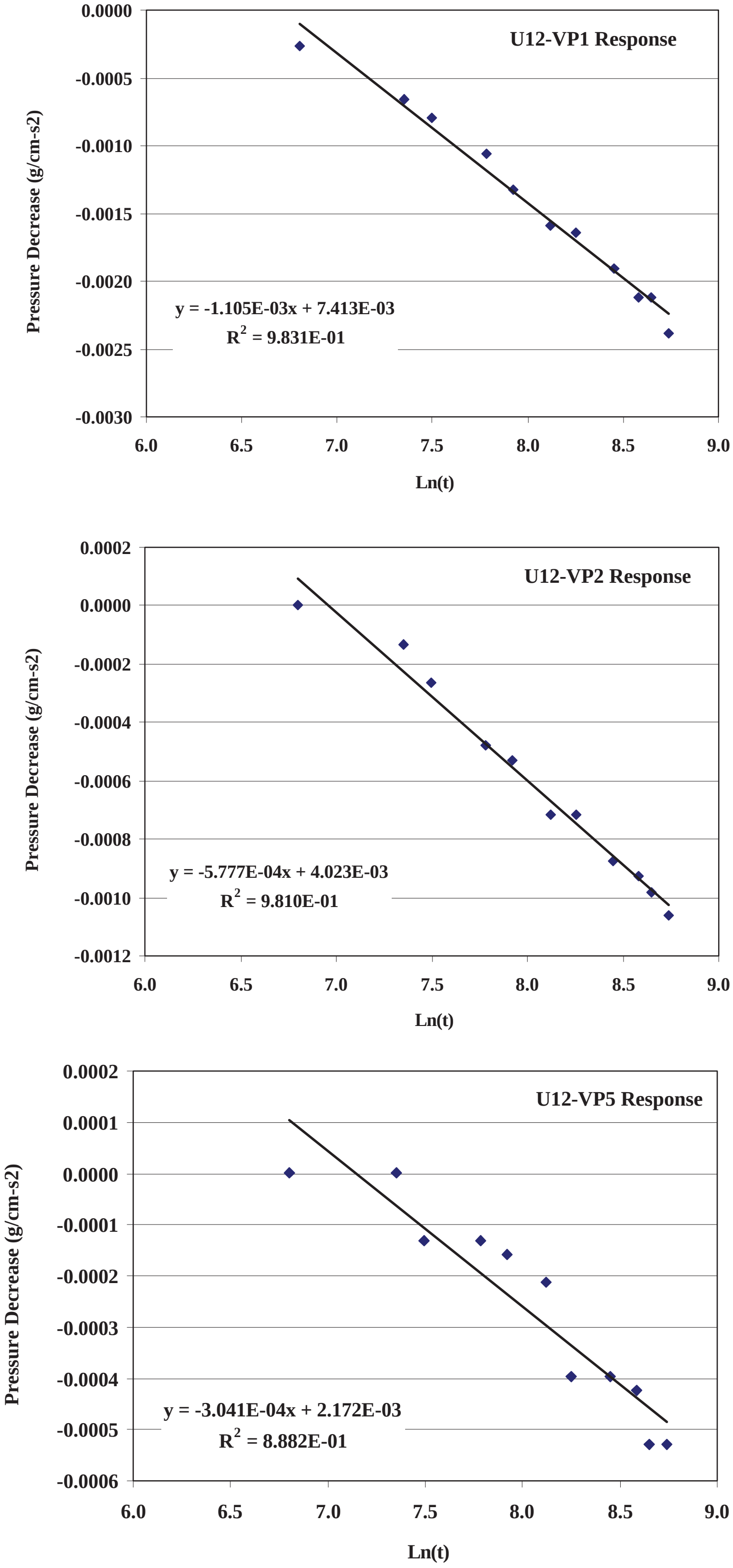


Figure 5-27. Pressure decrease as a function of time during vapor extraction at U12-VP7.

Table 5-5. Estimated *In Situ* Air Permeability

Extraction Well	Monitoring Well	Permeability (Darcy)	Geometric Mean Extraction Well Permeability (Darcy)
U12-VP1	U12-VP2	19	9
	U12-VP5	8	
	U12-VP7	5	
U12-VP2	U12-VP1	5	7
	U12-VP3	10	
	U12-VP5	6	
	U12-VP7	8	
U12-VP3	U12-VP1	46	46
	U12-VP2	20	
	U12-VP5	14	
	U12-VP7	356	
U12-VP5	U12-VP1	12	8
	U12-VP2	8	
	U12-VP3	6	
U12-VP7	U12-VP1	7	10
	U12-VP2	11	
	U12-VP5	12	
Geometric Mean			**12**
Geometric Mean[a]			**9**

[a]Two highest values censored.

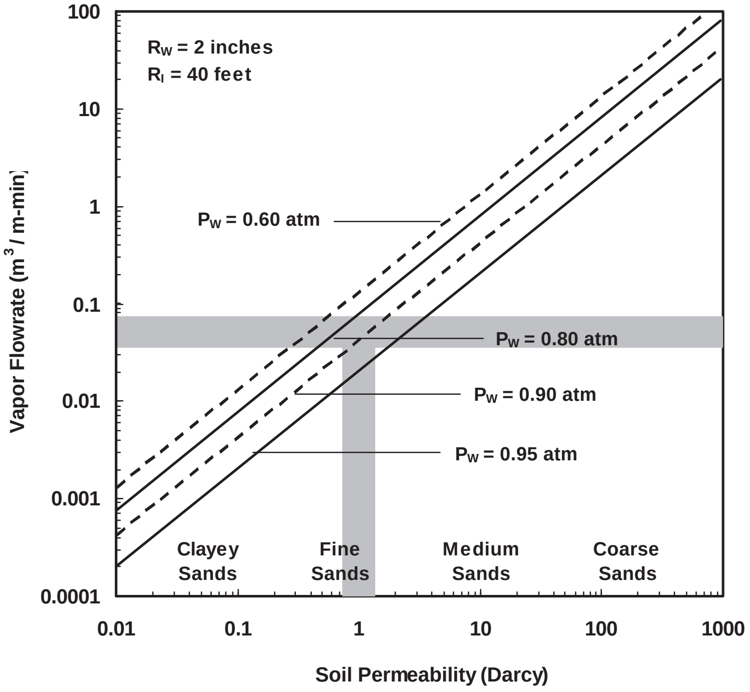


Figure 5-28. Predicted steady-state flow rates (per unit well screen thickness) as a function of soil permeability for various applied vacuum P_W (modified from Johnson et al., 1990).

5.2.1.3 *Blower Comparison*

To compare the effects of blower size on the pneumatic response in the subsurface at OU 12, two different blowers were used during vapor extraction operations at U12-VP1. The first blower (REGENAIR^{TM} SD 4) was a three horsepower blower capable of exerting a vacuum of approximately 78 inches of water (at the elevation of Hill AFB) measured at the blower intake. The second blower (REGENAIR^{TM} R4) was a one horsepower blower capable of exerting a vacuum of approximately 48 inches of water measured at the blower intake. The response of induced airflow as a function of applied vacuum (vacuum measured at the well head to which the blower intake is attached) for both blowers is shown in Figure 5-29. Vacuum was stepped up in increments during testing and flow and vacuum were recorded over time. The dilution attenuation valve was fully opened to the atmosphere at the start of each step test and was gradually closed to apply more vacuum to the well head. Air entering the dilution attenuation valve entered downstream (i.e., adjacent to the blower intake) of the rotometer and thus, had no impact on the measured airflow from the well head.

As can be seen in Figure 5-29, a vacuum of approximately 25 to 29 inches of water applied to the well head was necessary to induce approximately two cfm of airflow through the vadose zone. As the vacuum applied to the well head was increased to the maximum of the small blower's capacity (38 inches of water at the well head and 48 inches of water at the blower intake), airflow increased to approximately 3 to 4 cfm. The difference between the observed vacuum at the well head and the blower intake was associated with friction losses primarily through the rotometer whose rated friction loss is approximately 10 inches of water. The pneumatic response in the vadose zone responded similarly when the large, three horsepower blower was used to induce flow at U12-VP1. At 36 inches of applied vacuum, the airflow was approximately 2.75 to 3 cfm. The maximum steady airflow observed during the test was approximately 8 cfm at 52 to 53 inches of applied vacuum measured at the well head (62 to 63 inches of vacuum measured at the blower) using the three horsepower blower. There was one transient reading at the well head when the vacuum reached 55 inches of water and flow was recorded at 9 cfm.

The airflow as a function of applied vacuum was reproducible up to 3 cfm using both blowers. At an airflow rate of 3 cfm, the one horsepower blower had reached its full vacuum of 48 inches of water at the blower intake. Based on the response at U12-VP1, the one horsepower blower appears to be vacuum-limited under the site-specific conditions at OU 12. However, as discussed above, permeability changes may be appreciable for soil vapor extraction operations conducted for extended periods of time due to LNAPL removal and/or the drying of the soil.

A blower curve was not overlain with the system curve (i.e., pneumatic response of the vadose zone) to generate an “operating point” because the applied vacuum was high for the limited flow observed at U12-VP1. This resulted in a limited range of the blower curve at which airflow could be plotted as a function of applied vacuum. However, it is expected that the approximate operating point of the blower would extend slightly above 53 inches of applied vacuum because airflow was still increasing in proportion to applied vacuum (see Figure 5-29).

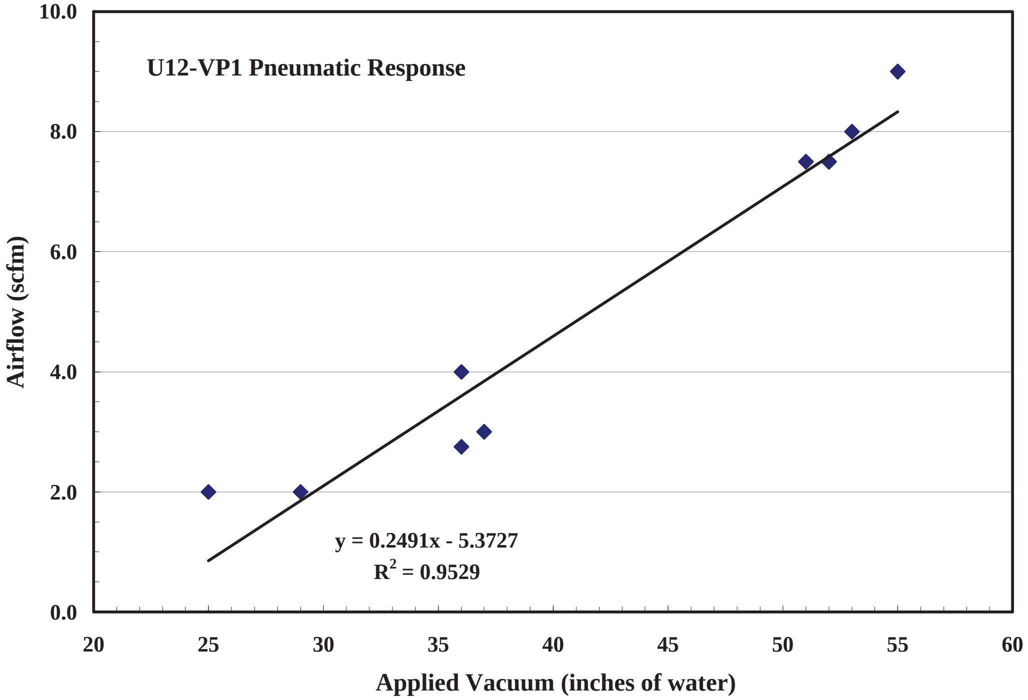


Figure 5-29. Induced airflow at U12-VP1 as a function of applied vacuum for both blowers.

5.2.2 TCE Vapor Concentrations

The SVE demonstration conducted in the suspected source zone at OU 12 focused on step tests for estimating TCE distribution within the vadose zone of the investigative area using a multiphase, multicomponent numerical model. During the step tests, the concentration of TCE in time was monitored via the on-site laboratory using DSITMS. Concentration data were obtained during each flow period on one-second intervals, resulting in thousands of discrete data points for each flow test conducted. A TCE time series plot was generated for each vapor extraction well by combining the individual data sets from each flow period for each extraction well as shown in Figures 5-30 through 5-36. The cumulative TCE removal during each step test and the corresponding extraction rate used during each flow period also are shown on Figures 5-30 through 5-36.

The cumulative mass of TCE removed from the vadose zone during the vapor extraction operations at OU 12 was estimated using the molar volume of an ideal gas pressure-corrected according to the following equation:

$$\frac{V}{n} = \frac{RT}{P} \qquad (6)$$

where

V = volume (L);
n = number of moles of gas ;

T = temperature (°C);
P = pressure (atm) ; and
R = ideal gas constant (0.08206 L-atm/mol-K).

Assuming a pressure of 0.85 atm at Hill AFB and a measurement temperature of 25 °C, the molar volume was estimated to be approximately 28.78 L/mol. This value was used in conjunction with the molecular weight of TCE to convert the TCE vapor concentration obtained from the DSITMS in parts-per-million by volume (ppmv) to mg/L. The vapor extraction rate was then used to integrate the TCE vapor concentration (in mg/L) curve as a function of time to obtain a cumulative TCE mass removal at each vapor extraction well.

The highest TCE vapor concentration was observed at U12-VP1 located approximately 20 feet west of the southern end of the drum excavation area (see Figure 5-1). The concentration of TCE in the extracted vapor from this location appeared to reach a quasi-steady state at approximately 1,000 ppmv and then increased to approximately 1,150 ppmv at the end of the fourth flow period when the blower was shut down to assess contaminant rebound (see Figure 5-30). During this period, the sample pump was extracting from the extraction well at roughly 200 ml/min. The total time of testing at U12-VP1 was approximately 3.7 hours during which time approximately 72 grams of TCE were removed from the vadose zone. The next highest concentration of TCE was observed at U12-VP2, located approximately 35 feet north of U12-VP1 and 20 feet west of the north end of the drum excavation area. The maximum concentration of TCE in the extracted vapor at U12-VP2 during testing was approximately 500 ppmv (see Figure 5-31). The concentration profile at this location was similar to that observed at U12-VP1, reaching a quasi-steady state at approximately 400 ppmv and then increasing to approximately 500 ppmv at the end of the fourth flow period when the blower was shut down to assess contaminant rebound. The total time of testing at U12-VP2 was approximately 3.6 hours during which time approximately 90 grams of TCE were removed from the vadose zone. Although the TCE concentrations were less at U12-VP2 as compared with U12-VP1, the cumulative mass removal was greater due to the rapid TCE decline that occurred during the blower shut down period and the extended time of high extraction rates at U12-VP2.

A similar response in the TCE vapor concentration profile was observed at U12-VP3 and U12-VP6 although total concentrations were significantly less than those measured at U12-VP1 and U12-VP2 (see Figures 5-32 and 5-35). The maximum concentration of TCE in the extracted vapor at U12-VP3 and U12-VP6 during testing was approximately 70 ppmv and 50 ppmv, respectively. The highest TCE vapor concentrations at these wells generally corresponded with increased extraction rates; however, as the extraction rate at U12-VP6 was increased from approximately 2 scfm to 8 scfm, the TCE concentration decreased from 50 ppmv to less than 40 ppmv.

The TCE vapor-phase response was markedly different at U12-VP4, U12-VP5, and U12-VP7 as shown in Figures 5-33, 5-34, and 5-37. The highest concentration of TCE measured at these locations occurred during periods of low-flow sampling when the blower was shut down. This is probably associated with dilution effects due to streamtube convergence in the flow pattern established by the extraction well and subsequent mixing in the extraction system (Jackson and Mariner, 1995). The convergence of these

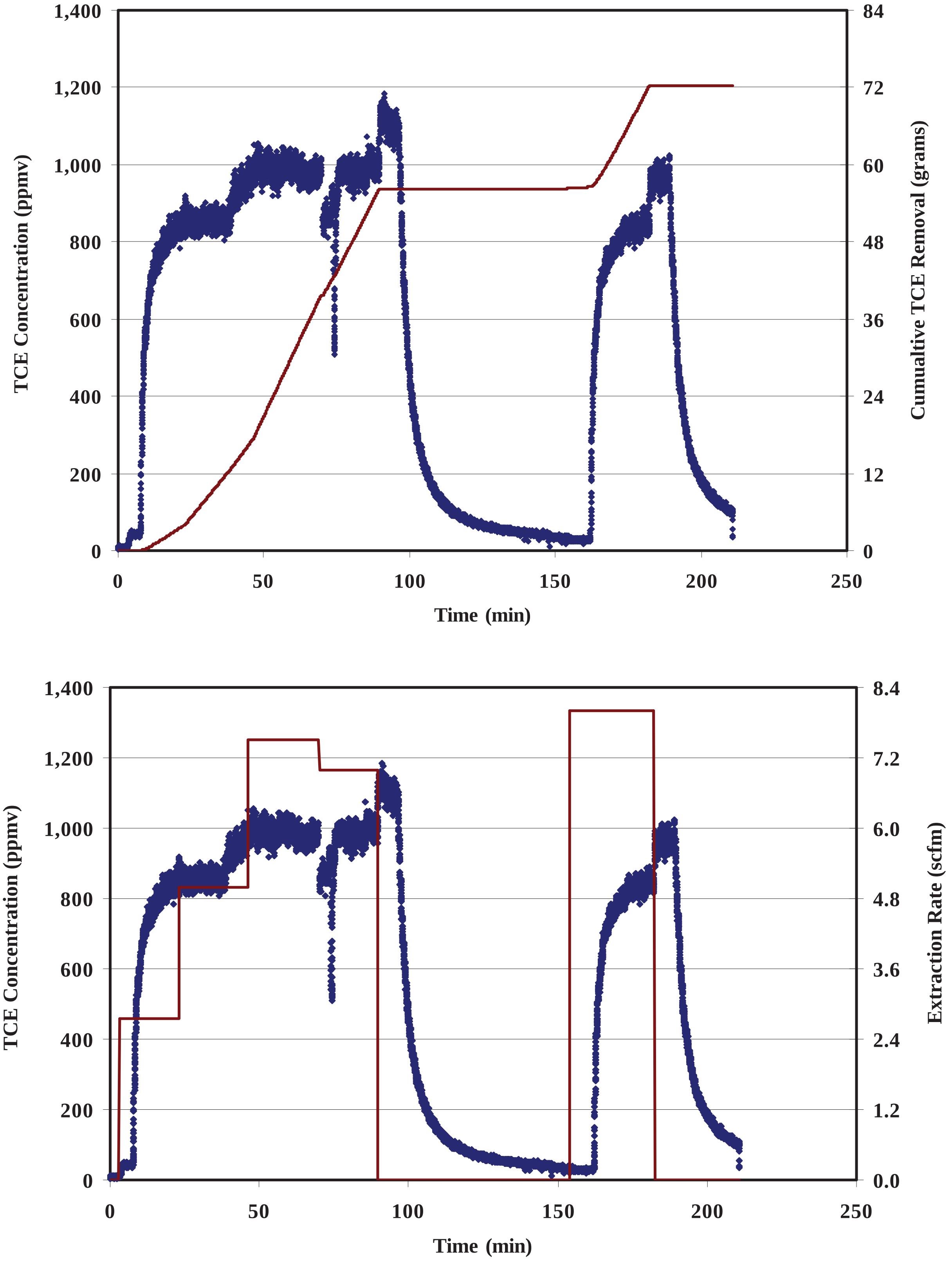
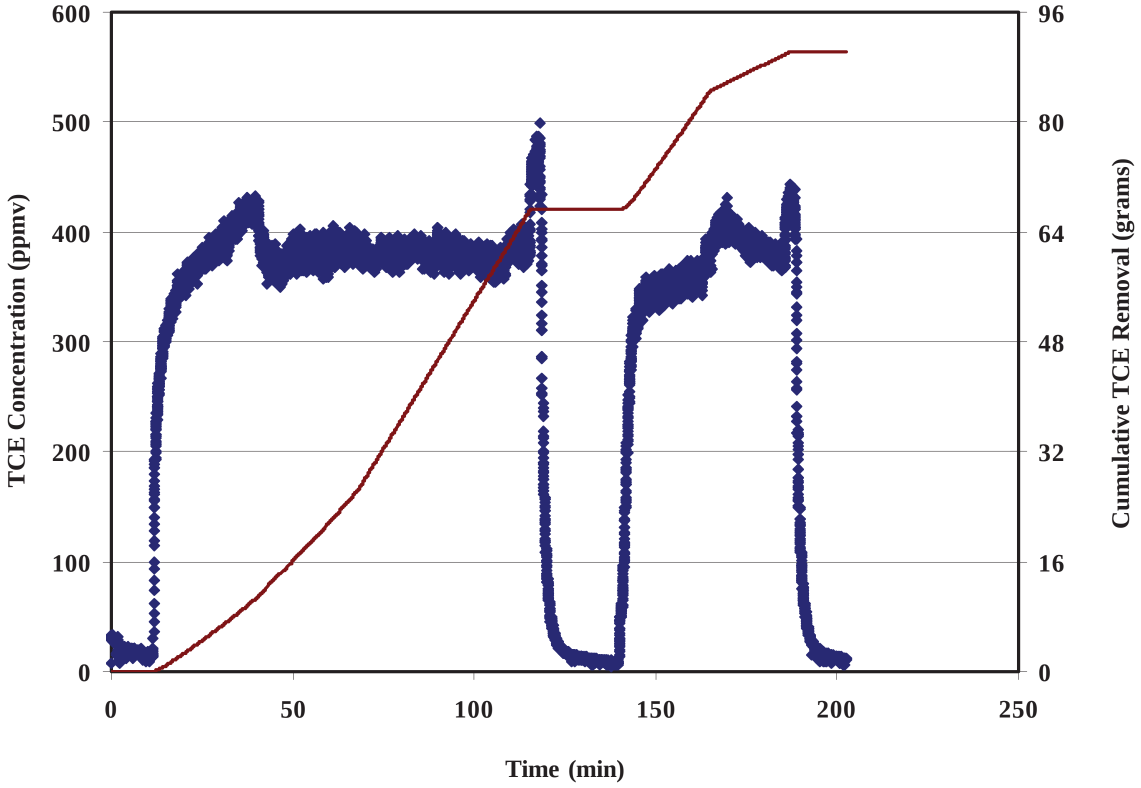


Figure 5-30. TCE vapor data obtained at U12-VP1 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).



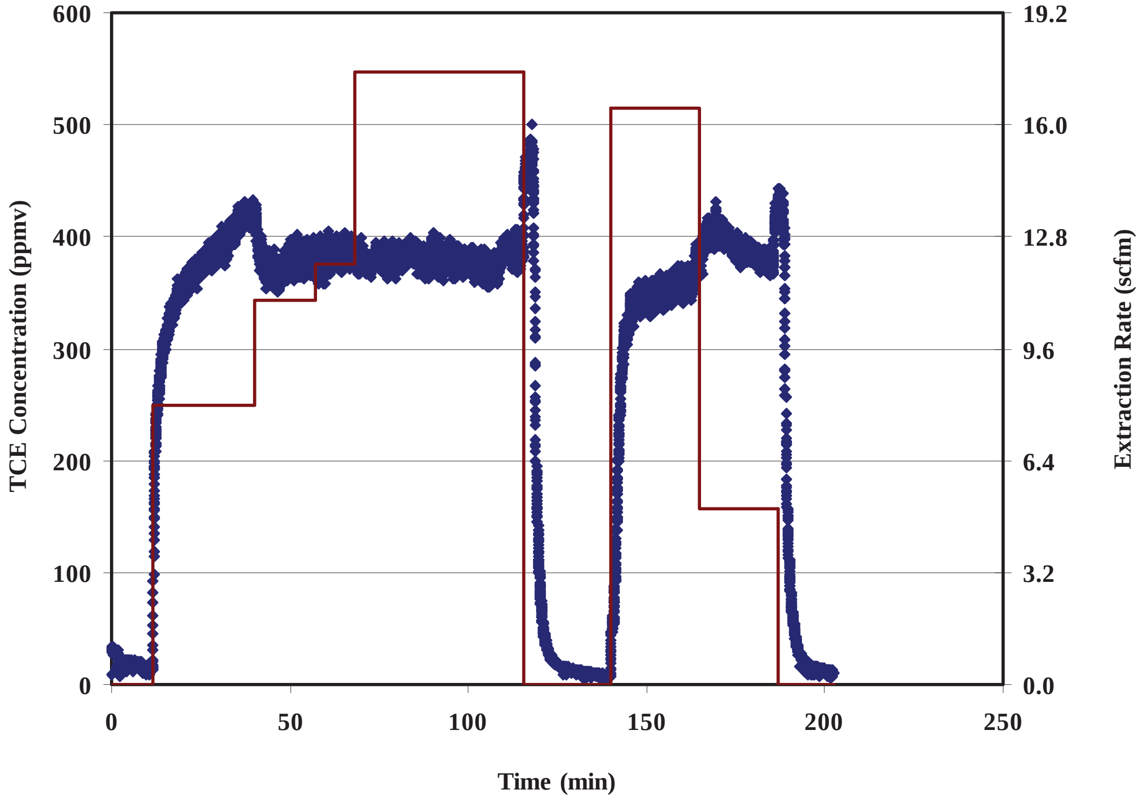


Figure 5-31. TCE vapor data obtained at U12-VP2 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).

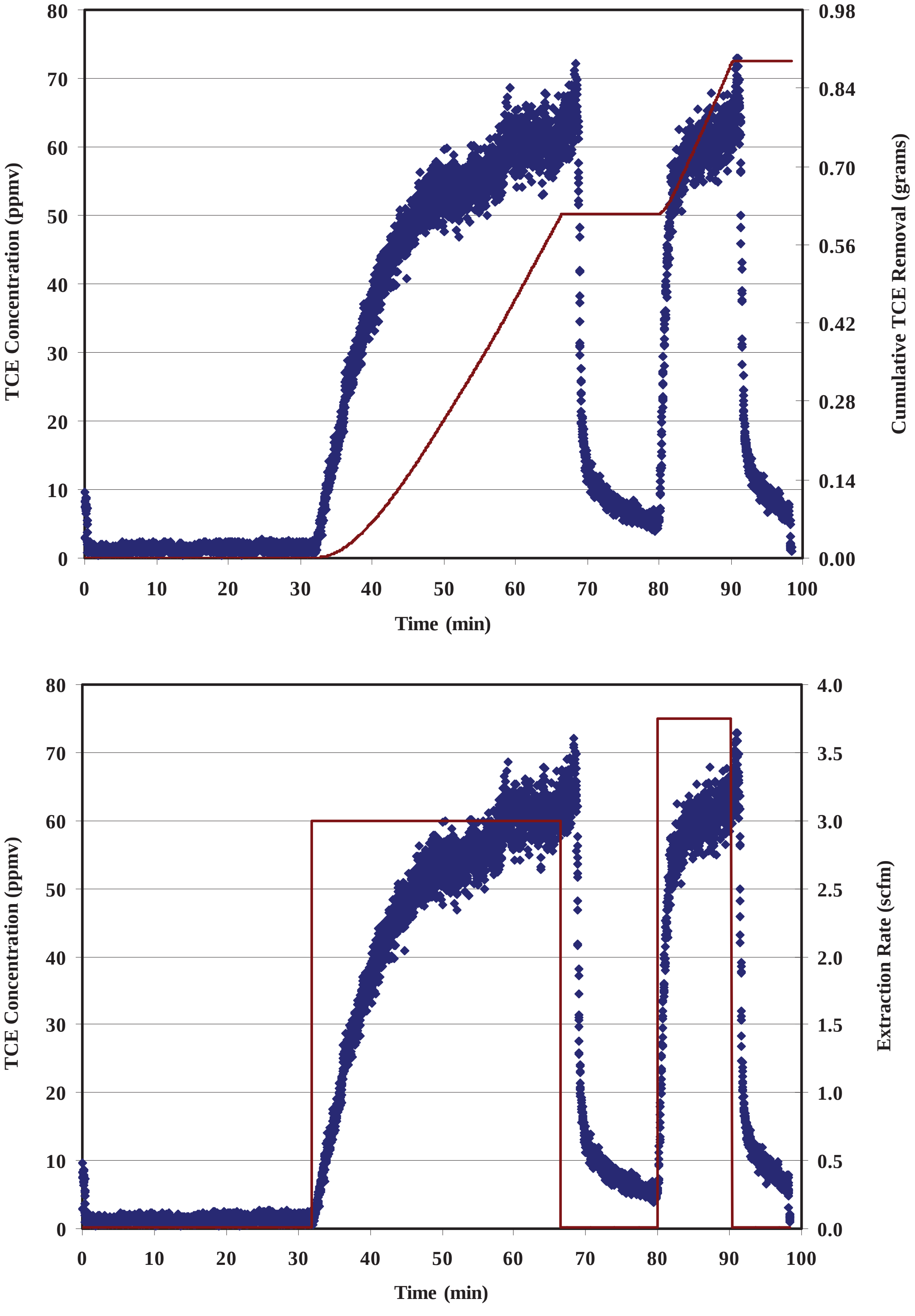
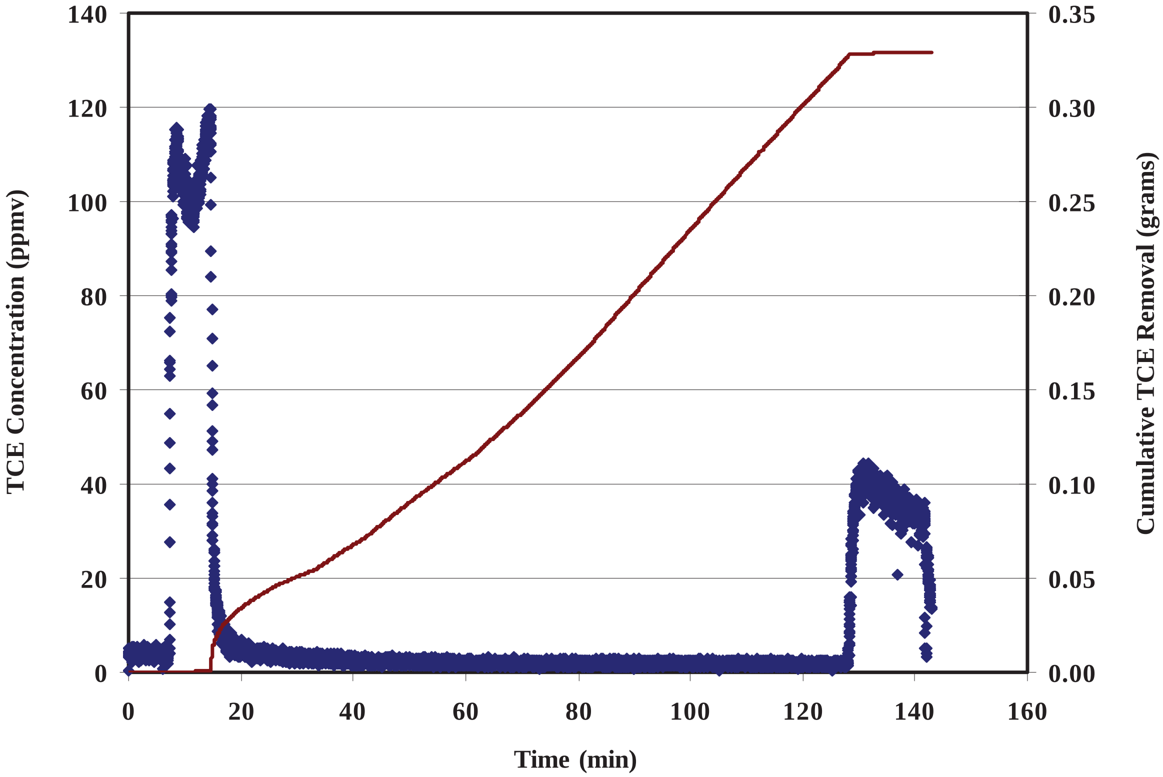


Figure 5-32. TCE vapor data obtained at U12-VP3 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).



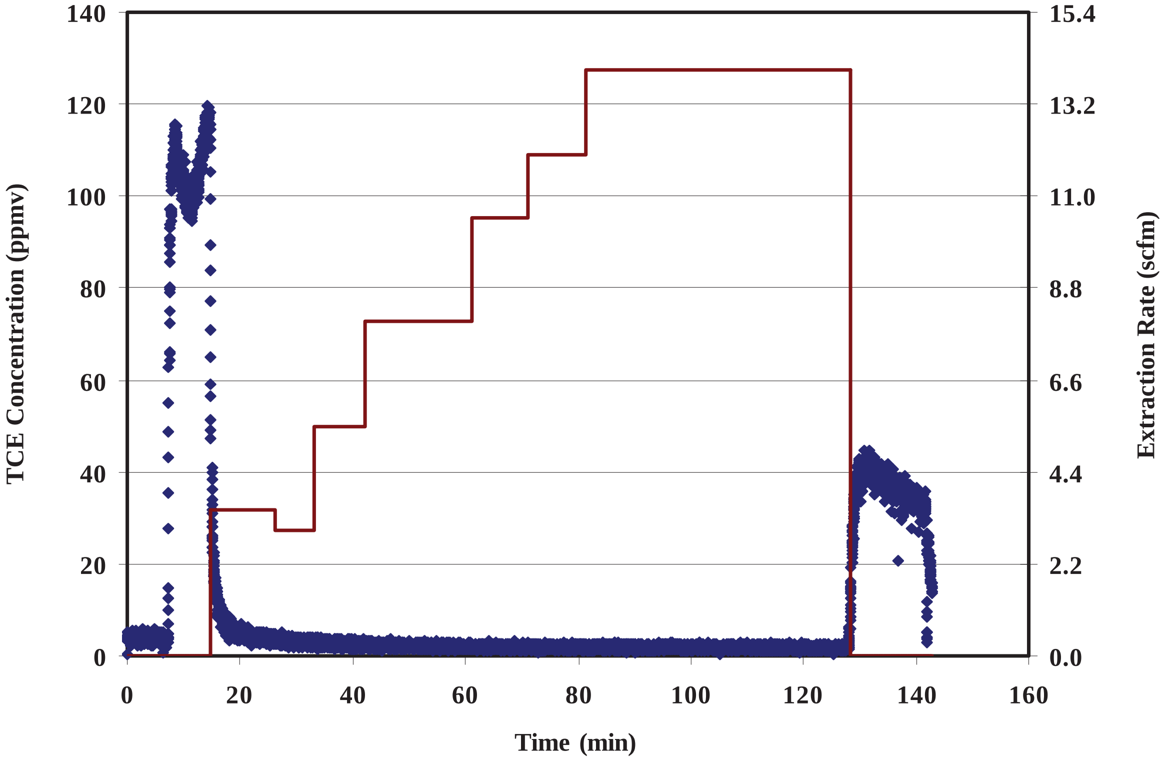
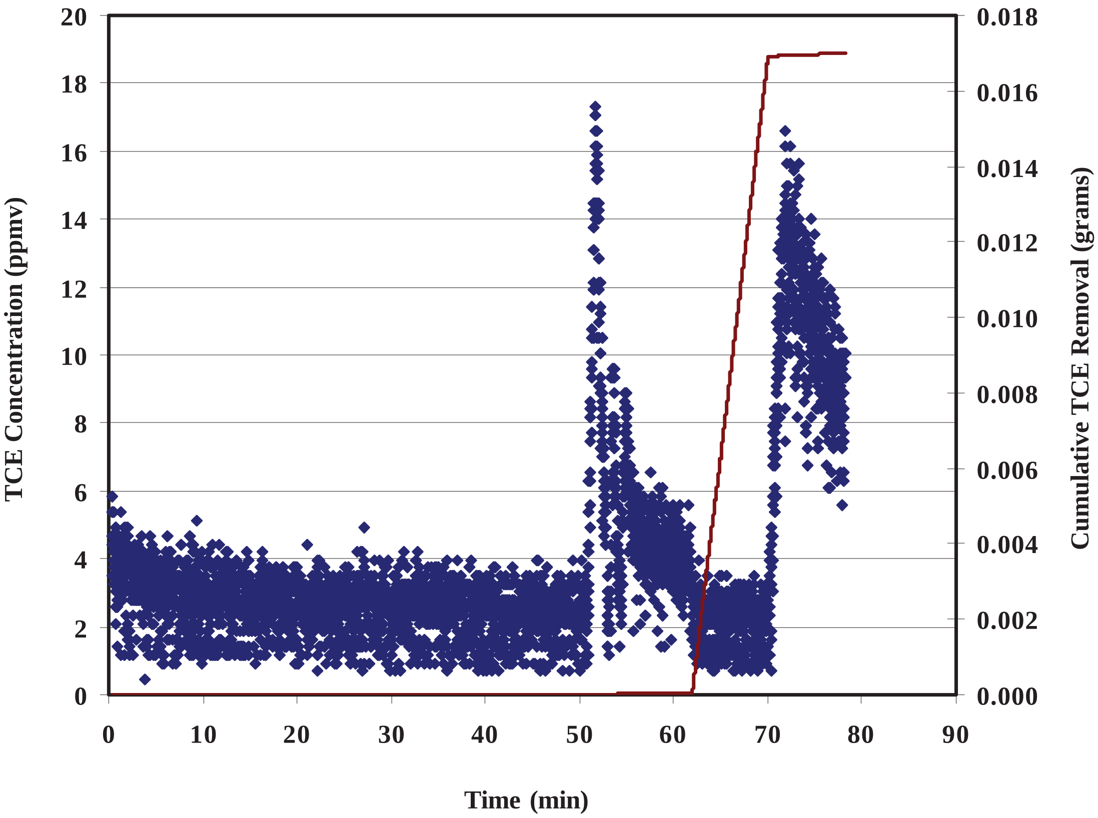


Figure 5-33. TCE vapor data obtained at U12-VP4 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).



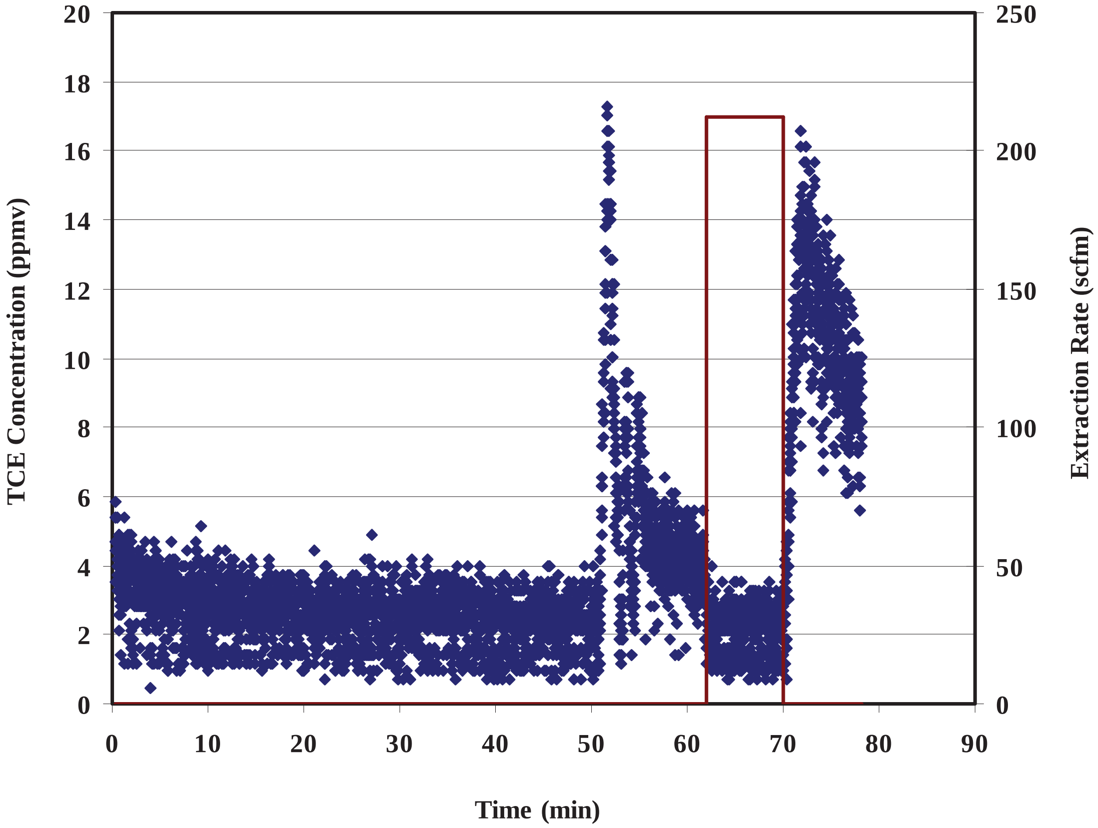


Figure 5-34. TCE vapor data obtained at U12-VP5 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).

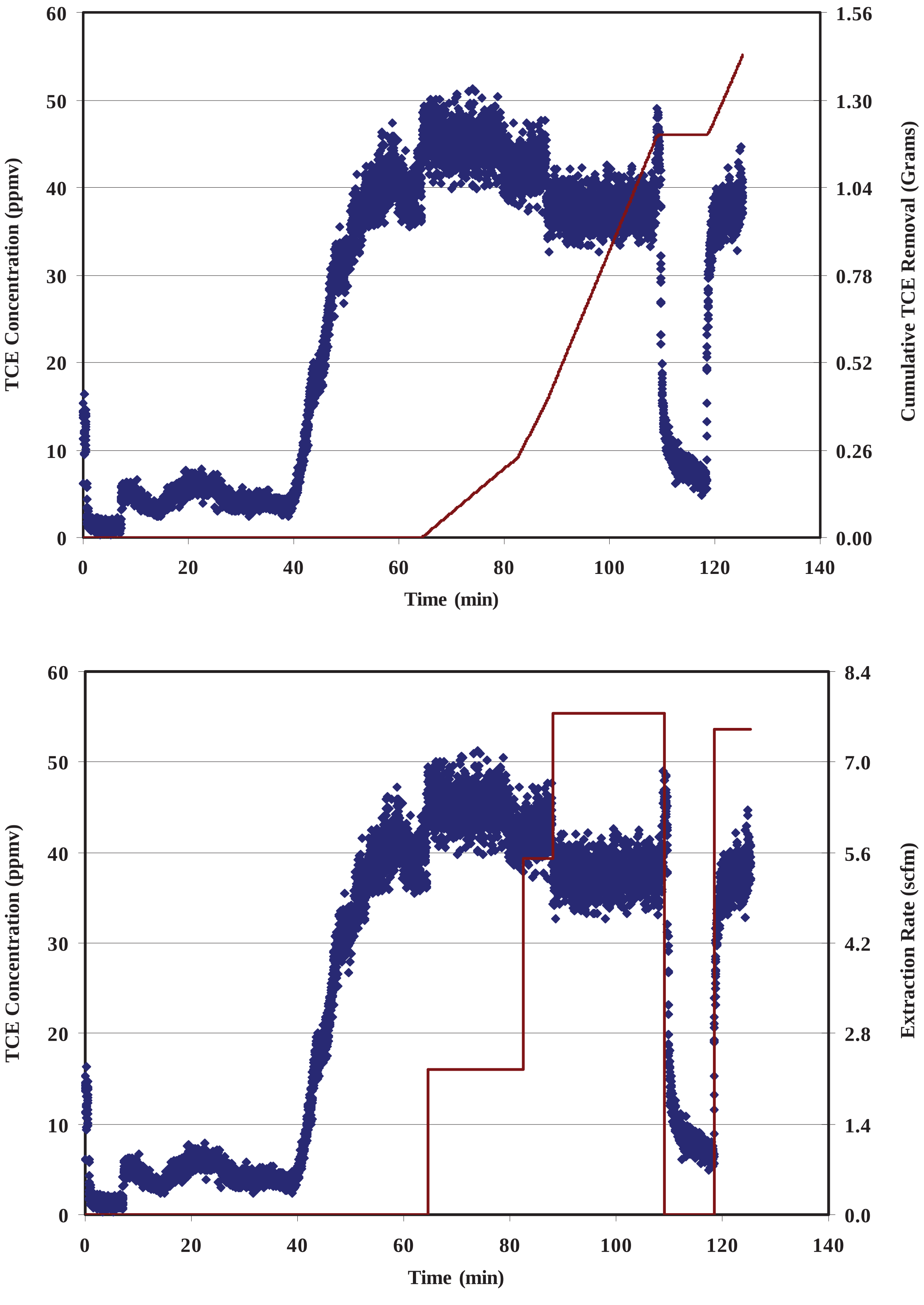


Figure 5-35. TCE vapor data obtained at U12-VP6 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).

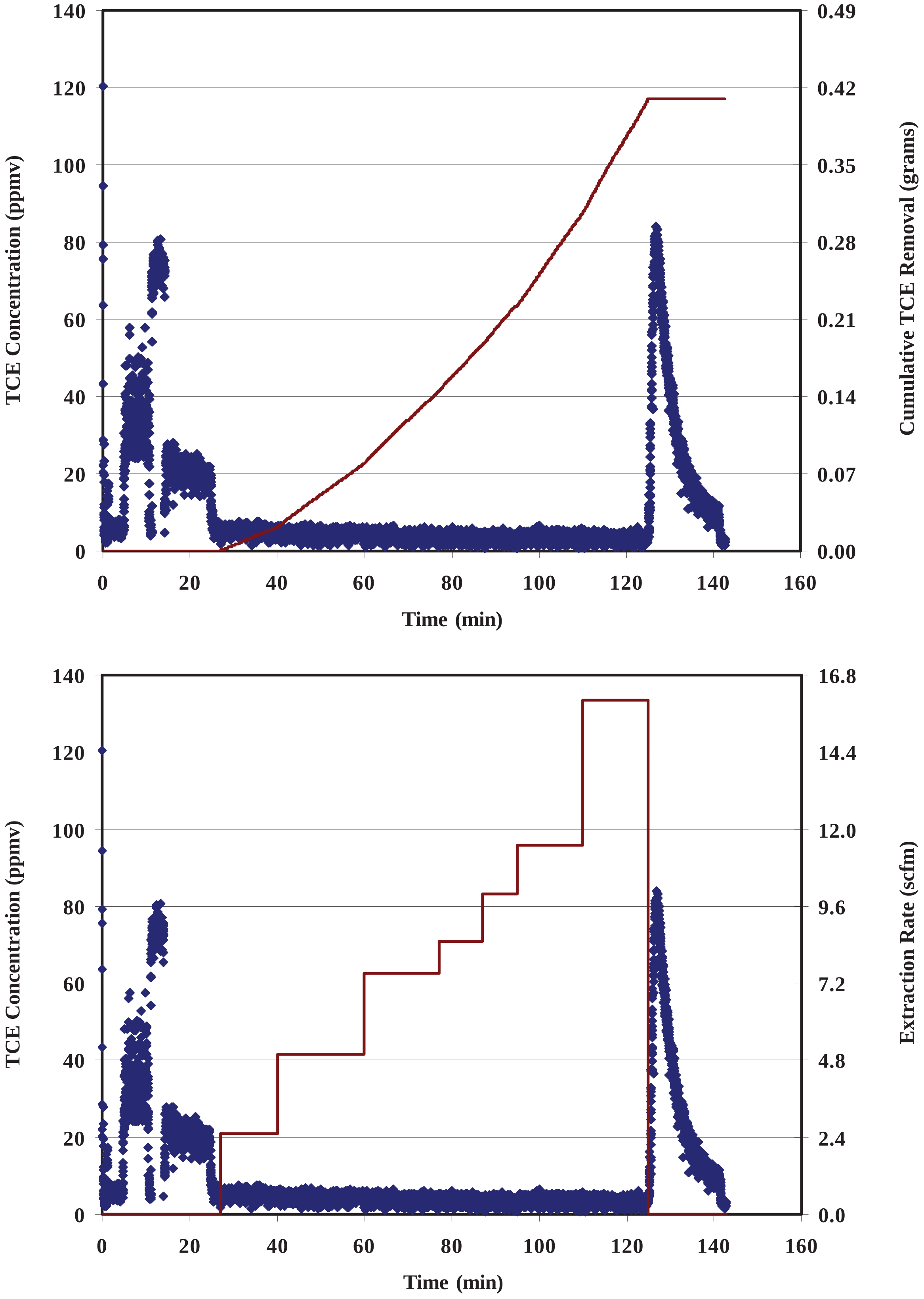


Figure 5-36. TCE vapor data obtained at U12-VP7 during OU 12 SVE demonstration (red line denotes cumulative TCE removal in grams [top graph] and extraction rate in scfm [bottom graph]).

streamtubes can result in the mixing of contaminated streamtubes with uncontaminated streamtubes. Under these conditions, concentrations of contaminants are diluted to values below those concentrations at, or in the immediate vicinity of, a source zone. As the source zone is progressively removed from the well, the well sees a smaller and smaller source as the angle subtended by the contaminated streamtube becomes smaller. Thus, the amount of streamtube dilution increases with the distance of the source zone from the extraction well. For soil vapor extraction, operating conditions significantly influence the zone of influence of the treatment system, and subsequently, the amount of streamtube dilution experienced by the flow field. The effects of streamtube dilution are compounded as the flow regime transitions from low-flow to high-flow conditions where mass transfer limitations become increasingly important and can limit the rate of mass removal thereby, reducing the TCE concentration in the extracted vapor.

The position of the screened intervals of the vapor extraction wells in relation to the modeled vadose zone soil architecture is shown in Figure 5-37. The screened interval of each well is shown in red on a west-to-east vertical cross section through the model at a northing corresponding to the northing of the well. The inferred soil types immediately adjacent to the screened interval of each well are summarized in Table 5-6. The spatial continuity of soil types between extraction wells, partially apparent on Figure 5-37, is illustrated in Figure 5-38, which shows a series of eight horizontal slices at five-foot increments through the soil architecture. The elevation of the slices shown in Figure 5-38 includes the screened interval of all six of the vapor extraction wells and ranges from 4,560 to 4,525 feet amsl. A red circle surrounding a blue dot indicates that a well is screened at the indicated elevation, whereas a solid blue dot indicates that a well is not screened at that elevation.

The modeling of TCE contamination in the soil illustrated that the highest levels of soil contamination are located at an elevation approximately between 4,555 and 4,560 feet amsl, and at an easting between 1,856,090 and 1,856,110 feet and a northing between 298,250 and 298,280 feet. The top of the screened interval of U12-VP1 is located within this region while the top of the screened interval of U12-VP2 is located on its outer perimeter. In addition, the upper nine feet of the screened interval in both wells are located in an extensive silty-sand region, similar to the highest soil contamination. The middle six feet of

Table 5-6. Percentage of Soil Type in Screened Interval of Vapor Extraction Wells

Boring	Screened Interval Length (ft)	Percentage of Soil Type in Screened Interval[1]			
		Sand	Silty-Sand	Sandy-Silt	Silt
U12-VP1	20.0	0	70	30	0
U12-VP2	20.0	0	70	30	0
U12-VP3	20.0	0	5	95	0
U12-VP4	19.4	0	45	55	0
U12-VP5	19.1	0	0	80	20
U12-VP6	14.9	0	30	45	25
U12-VP7	15.3	25	60	15	0

[1] Rounded to nearest 5 percent

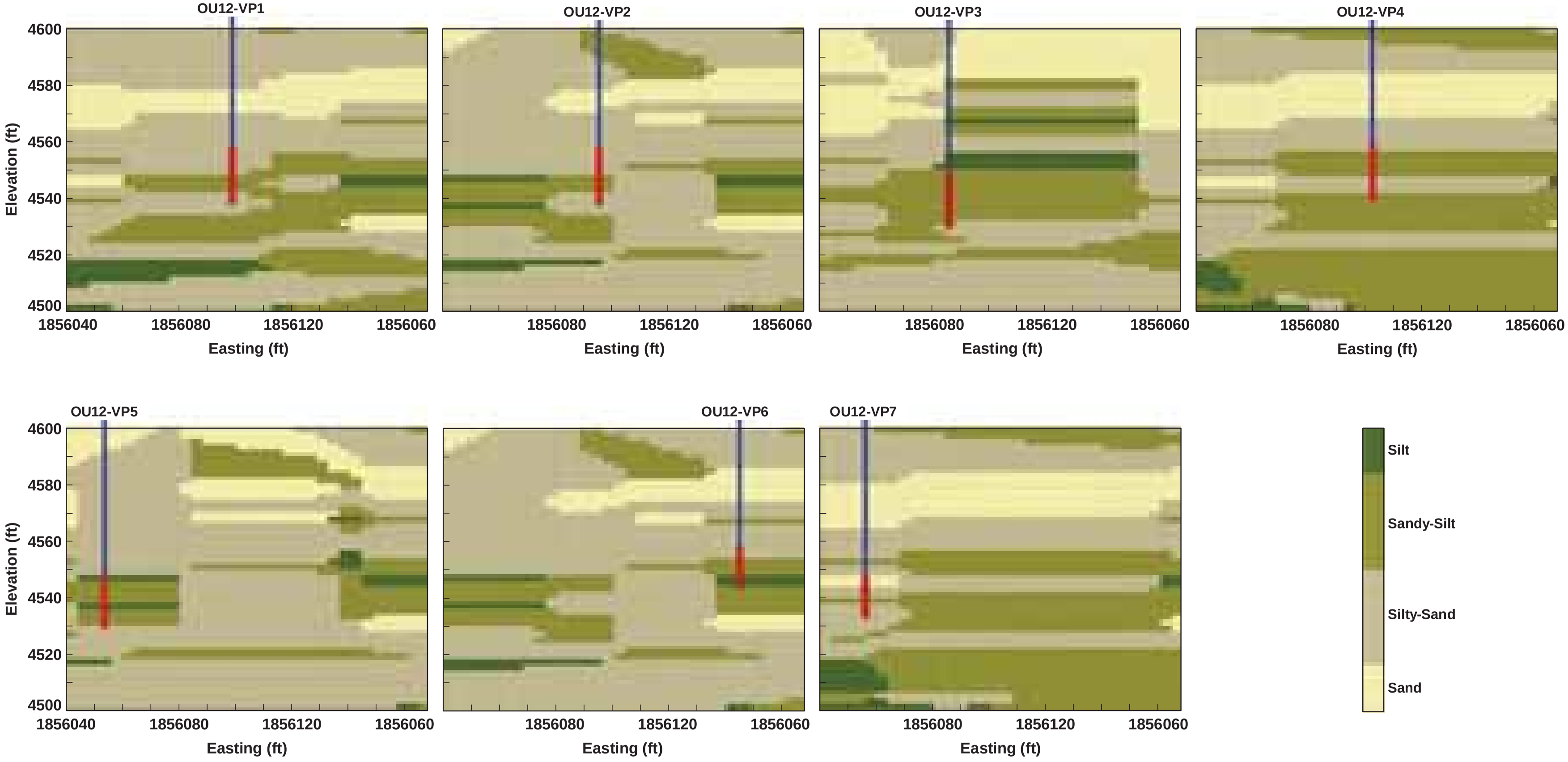


Figure 5-37. Screened intervals of the vapor extraction wells in relation to the modeled vadose zone soil architecture (screened interval of each well is shown in red).

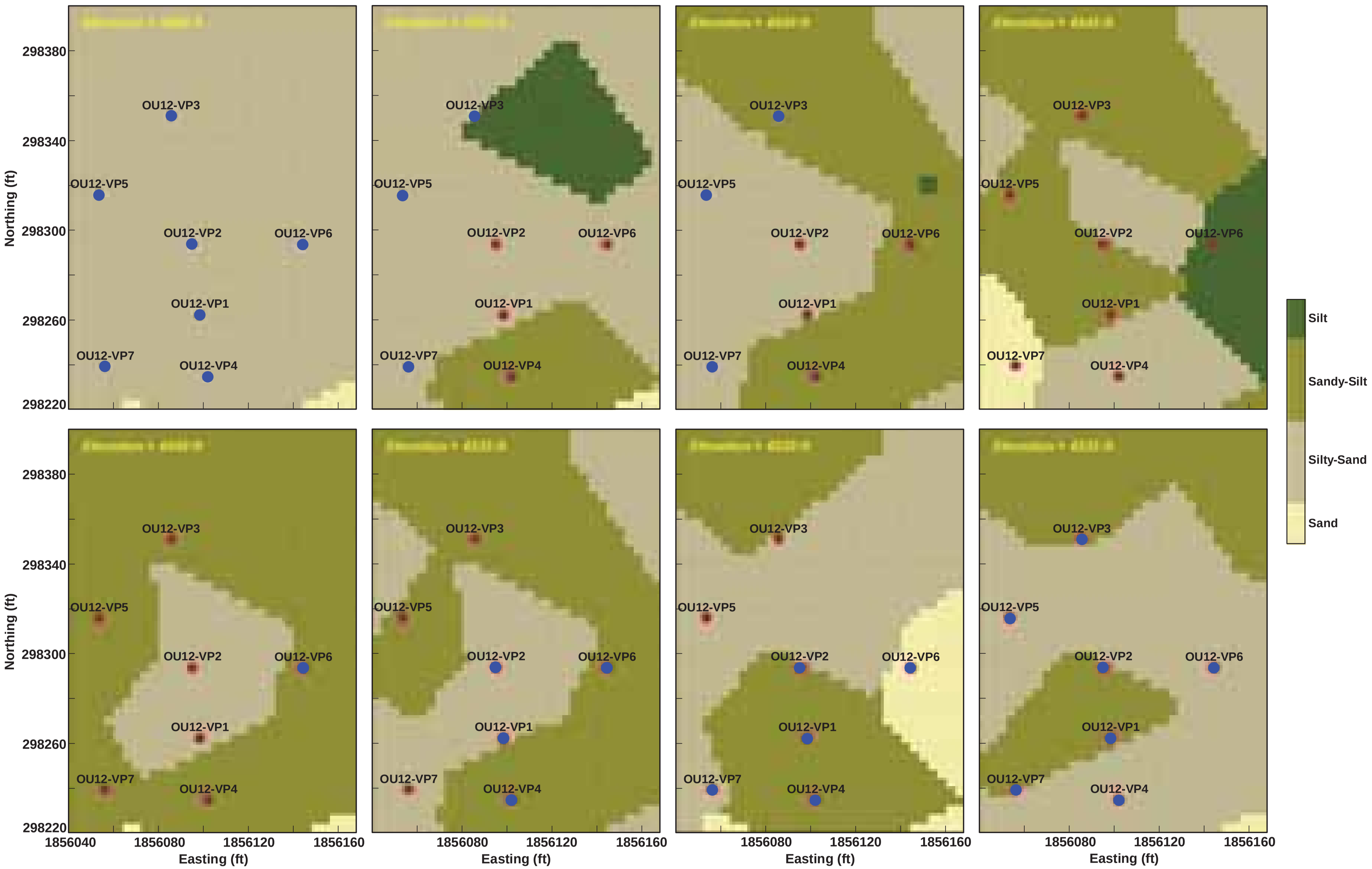


Figure 5-38. Horizontal slices at five-foot increments through the soil architecture showing screened intervals of vapor extraction wells (a red circle surrounding a blue dot indicates that a well is screened at the indicated elevation, whereas a solid blue dot indicates that a well is not screened at that elevation).

the screened interval in U12-VP1 and U12-VP2 is located in a sandy-silt zone, which likely has a lower permeability than the overlying silty-sand region. These observations are manifest in the vapor-phase TCE concentrations observed during vapor extraction operations from U12-VP1 and U12-VP2 (see Figures 5-30 and 5-31). The highest levels of TCE concentration in the extracted vapor were detected in U12-VP1 (approximately 1,000 ppmv) and U12-VP2 (approximately 400 ppmv). Because the measured concentration of TCE in the extracted soil vapor corresponds to an average vapor concentration for the entire length of the screened interval, it is impossible to delineate the relative contribution to the total measured contamination supplied by the various soil intervals spanned by the screen. However, due to the close proximity of U12-VP1 and U12-VP2 to high soil contamination and the local soil stratigraphy of their screened intervals, it is surmised that the upper few feet of the intervals for these wells yielded the bulk of the contaminated vapor.

In contrast, the screened interval of U12-VP5 is almost entirely within a lens of interbedded sandy-silt and silt, and the top of the screened interval is approximately ten feet below the region of highest soil contamination. In addition, the horizontal distance is relatively large between U12-VP5 and the region of highest soil contamination. These observations may explain the low concentration of TCE (approximately 16 ppmv maximum) measured in the extracted vapor from this well. However, the maximum measured concentration of TCE in vapor extracted from U12-VP3 was approximately 70 ppmv, nearly five times higher than in U12-VP5. Higher TCE concentrations were observed at U12-VP3 although its screened interval has characteristics much like the screened interval of U12-VP5, and U12-VP3 is more distant from higher soil contamination. This may reflect interbedding of thin, higher permeability soils above and near the top of the screened interval. As previously discussed in Section 5.1.2, such thin layers are beyond resolution of the soil architecture model.

The upper four feet of the screened interval of U12-VP6 are located in silty-sand, and the top of the interval is within elevations of the highest soil contamination. There is evidently a good pneumatic connection between U12-VP6 and the soil contamination as observed during vapor extraction operations. The highest TCE vapor concentrations at U12-VP6 generally corresponded with increased extraction rates. The top of the screened interval of U12-VP7 is approximately 10 feet below the highest soil contamination. Although the upper four feet of the screened interval are in sand, the sand is discontinuous, and the screened interval is isolated from the high soil contamination by an overlying thin layer of sandy-silt that appears to be spatially continuous (see Figures 5-37 and 5-38). These factors may explain the poor response observed from U12-VP7 during vapor extraction operations.

The generally poor pneumatic response of U12-VP4 is difficult to explain. The upper two feet of the screened interval are in a silty-sand that is apparently areally continuous, and there are no silty layers evident within the screened interval. The poor performance of this vapor extraction well may be due to soil characteristics beyond the resolution of the model, or possibly to construction problems.

5.2.3 Vapor Transport Modeling

The TCE time-series data collected during the OU 12 SVE demonstration were compared with simulated time-series data using a theoretical distribution of TCE mass in the zone of influence and a sequential forward numerical modeling scheme in an attempt to help delineate source-zone contamination in the vadose zone of the investigative area. A three-dimensional, finite-difference code for simulating isothermal vapor flow and transport of multicomponent mixtures called VENT3D [Benson, 1998] was used for the simulations. As discussed in Section 4.0 of this report, VENT3D solves the three-dimensional vapor phase advective and/or dispersive flux of multicomponent mixtures using an orthogonal grid. Any number of vapor extraction and injection wells can be simulated, and grid-variable initial permeability and contaminant distributions can be specified. The equilibrium four-phase distribution of each compound in the mixture is solved in VENT3D between time steps, facilitating the explicit solution of the time-variable retardation of the various compounds. During the OU 12 SVE simulations, a third-order, Courant-number-weighted (Total Variation Diminishing [TVD]) algorithm was used for increased accuracy.

The simulation grid used for the SVE modeling was 230 feet long (x-direction), 240 feet wide (y-direction), and 70 feet deep (z-direction). The grid block spacing was constant at 5 feet in all directions. The x-direction contained 46 grid-blocks, the y-direction contained 48 grid-blocks, and the z-direction contained 14 grid-blocks. The top and side layers of the simulation grid were assumed open to both air and chemical movement; the bottom layer was assumed closed (i.e., zero-flux boundary). The bulk density of the soil was assumed to be 1.9 kg/L with an average porosity of 30% and fractional organic carbon content of 0.001 mg/mg. The average water saturation was assumed to be 1% for the top 20 feet of the modeling domain (corresponding to the upper sandy gravel zone) and 10% for the bottom 50 feet (corresponding to the lower sandy-silt and silty-sand zones). The longitudinal dispersivity was assumed to be 100 cm with an average vertical permeability 10% the value of the horizontal permeability. The chemical properties of TCE used during the simulations included a molecular weight of 131.4 g/mol, solubility of 1,100 mg/L, and octanol/water partitioning coefficient of 242; boiling point and vapor pressure at 20 °C of 86.7 °C and 0.076 atm, respectively; liquid density of 1.46 kg/L; and free-air diffusion coefficient of 0.084 cm^2/sec.

The construction of detailed vapor transport models almost always requires the input of several parameters that have not been measured (e.g., dispersion coefficients or partitioning coefficients). In addition, the calibration process often requires adjustment of parameters to achieve a fit between actual and simulated data. That process is very time consuming and requires considerable judgment based on experience. Thus, since this sequential forward modeling exercise was conducted in an attempt to demonstrate the applicability of using vapor-phase contaminant concentrations to delineate a suspected source in the vadose zone, it was decided to use a simple two-layer permeability field for the simulations. The first permeability layer was comprised of the bottom 50 feet of the modeling domain (corresponding to the lower sandy-silt and silty-sand zone) with an assumed permeability ranging from 0.1 to 100 Darcy. The second permeability field was comprised of the upper 20 feet of the modeling domain (corresponding to the upper sandy gravel zone) with an assumed permeability of 5 to 10 times greater than the lower permeability layer. Final adjustment of the permeability value for each layer was made based on the vacuum distribution match between the model results and actual field measurements.

The six vapor extraction/monitoring wells were located in the modeling domain and screened within three grid-blocks in the z-direction for nominal 15-foot well screens and four grid-blocks for nominal 20-foot well screens. Multiple stress periods were simulated according to the vapor extraction operations conducted at each individual vapor extraction well. The first stress period consisted of 10, 20, or 30 years of no-flow at the extraction well to simulate the natural transport of TCE in the vapor phase via diffusion and corresponds to a source spill or creation date of 1992, 1982, or 1972, respectively. Following the diffusive transport period, simulations were conducted using the various flow regimes investigated at each individual extraction well (see Table 4-3) and using various source configurations (areal extent, depth, concentration, and location). In addition to the simulations conducted with an initial diffusive transport period, simulations also were conducted to assess the predicted TCE concentrations in the vapor phase for source zone architecture in the absence of a pre-diffusion stress period.

Due to the vast amount of information obtained from the VENT3D simulation code, several OU 12-specific programs were written to extract the required simulation data (e.g., TCE time-series vapor concentration, vacuum distribution, and TCE soil distribution) from the VENT3D output file.

5.2.3.1 *Vacuum Distribution*

As discussed above, a simple two-layer permeability field was used for the OU 12 SVE simulations. The first permeability layer was comprised of the bottom 50 feet of the modeling domain (corresponding to the lower sandy-silt and silty-sand zone) with an assumed permeability ranging from 0.1 to 100 Darcy. The second permeability field was comprised of the upper 20 feet of the modeling domain (corresponding to the upper sandy gravel zone) with an assumed permeability of 5 to 10 times greater than the lower permeability layer. The predicted vacuum distribution obtained for layer 6 of the modeling domain (corresponding to 40 to 45 feet bgs) was compared with actual field measurements to arrive at the final permeability field. Since the vapor extraction wells were generally screened from 35 to 55 feet bgs and from 40 to 60 feet bgs, the 40- to 45-foot interval was selected as representative of the screened interval of the six extraction/monitoring wells.

The best fit between the predicted vacuum distribution and the field measurements were obtained assuming a permeability of 10 Darcy for the bottom 50 feet of the modeling domain and 100 Darcy for the upper 20 feet of the domain. Figure 5-39 shows the predicted vacuum distribution at 40 to 45 feet bgs during vapor extraction from U12-VP2 for 6 hours at 12 scfm for a two-layer permeability field of 10 and 100 Darcy. A comparison of the predicted versus measured vacuum distribution at each monitoring well during vapor extraction at U12-VP2 is shown in Table 5-7. With the exception of monitoring wells U12-VP4 and U12-VP6, the predicted vacuum was in good agreement with the measured values. For U12-VP4 and U12-VP6, the predicted vacuum was an order of magnitude higher than actually observed during field operations.

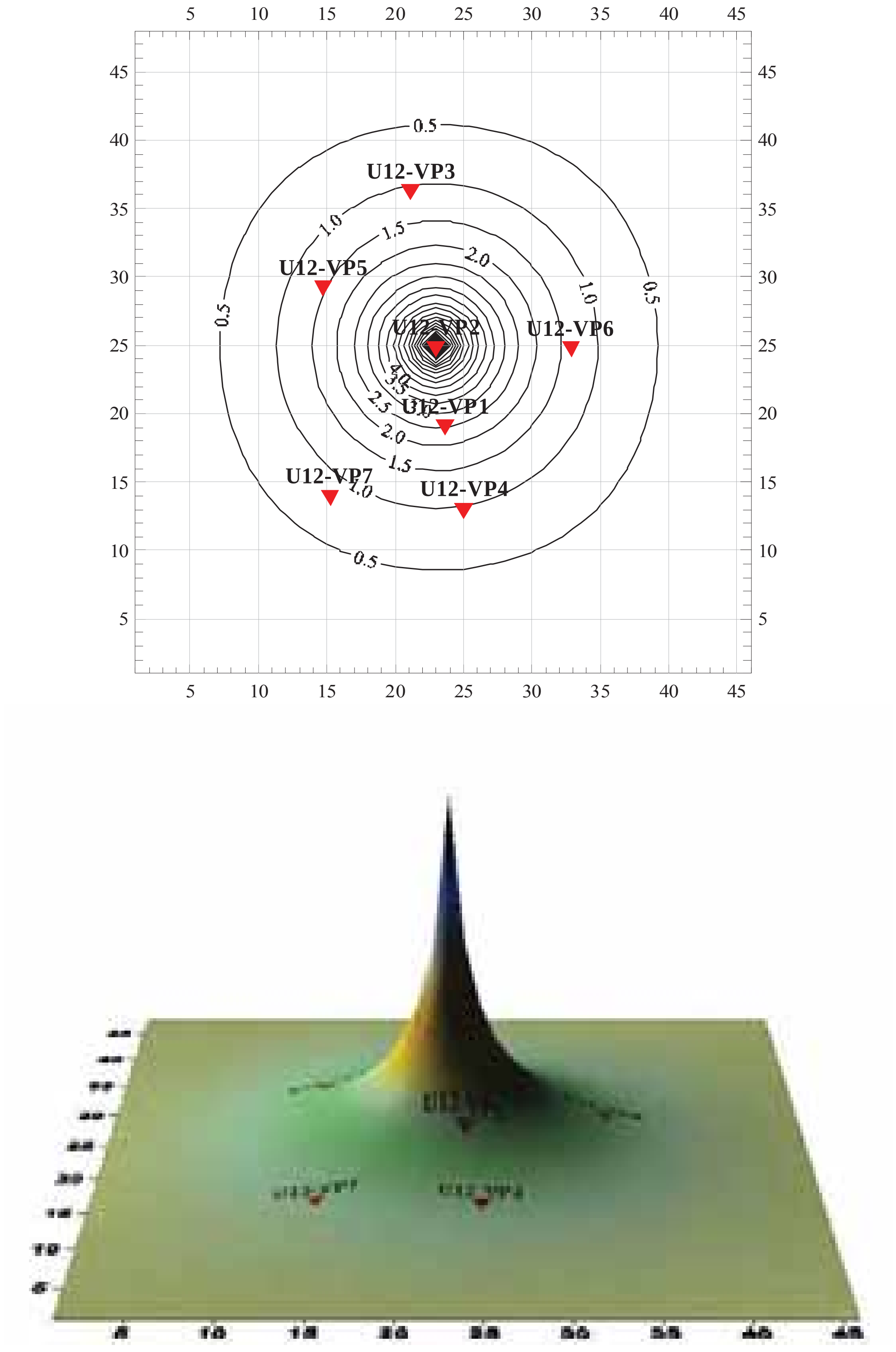


Figure 5-39. Vacuum distribution predicted at 40 to 45 feet bgs during vapor extraction from U12-VP2 for 6 hours at 12 scfm assuming a two-layer permeability field (10 and 100 Darcy).

Table 5-7. Comparison of Measured and Predicted Vacuum Distribution

Monitoring Well[1]	Distance from Extraction Well (ft)	Measured Vacuum (inches of water)	Predicted Vacuum[2] (inches of water)
U12-VP1	31.6	2.50	2.50
U12-VP3	58.0	1.40	1.10
U12-VP4	59.5	0.02	0.50
U12-VP5	46.8	2.40	1.50
U12-VP6	49.5	0.12	1.30
U12-VP7	66.8	0.90	0.80

[1] Vapor extraction conducted at U12-VP2.

[2] Predicted vacuum at 40 to 45 feet bgs during vapor extraction from U12-VP2 for 6 hours at 12 scfm for two-layer permeability field (10 and 100 Darcy) using VENT3D.

5.2.3.2 *Sequential Forward Modeling*

Predicted TCE concentration profiles in the vapor phase were generated for each extraction well using a sequential forward modeling scheme and various source configurations (areal extent, depth, concentration, and location). A summary of the modeling scenarios investigated is provided in Table 5-8 and the spatial location of each simulated source area in relation to the vapor extraction/monitoring wells is shown in Figures 5-40a through 5-40e. During the investigation, over 160 scenarios were numerically simulated. Due to the elevated concentrations of TCE observed in extraction wells U12-VP1 and U12-VP2, these wells were used for the initial comparison between the predicted TCE concentration profiles and the concentration profiles observed during vapor extraction operations at OU 12. This demonstration focused on the effect of single homogeneous source zones in relation to predicted TCE concentration profiles in the vapor phase; the effect of multiple and/or heterogenous sources were not investigated as part of this demonstration. A formal inversion scheme would be required to assess the effect of multiple, heterogeneous sources due to the vast number of permutations associated with more than one source zone.

A comparison between the predicted and the measured TCE concentration profiles in the vapor phase at extraction wells U12-VP1 and U12-VP2 for source area 1 is shown in Figure 5-41. Source area 1 is located approximately 43 feet north of U12-VP1 and 13 feet north of U12-VP2, and represents a simulated TCE source 20 feet by 10 feet in areal extent and 10 to 15 feet thick. An initial source concentration ranging from 100 to 10,000 mg/kg prior to a 30-year diffusion period was investigated. As the initial source concentration is increased from 100 mg/kg to 4,500 mg/kg, the predicted TCE concentration profile for U12-VP1 changes from a downward to an upward trend, characteristic of that observed during actual vapor extraction operations. Although the predicted concentration profile is similar to that observed in the field, the predicted TCE concentrations are approximately two times the measured values. Additionally, the predicted response at U12-VP2 is significantly different than the measured response.

Table 5-8. OU 12 SVE Sequential Forward Modeling Scenarios

File Name	Extraction Well	Source	Source Distance from Well	Source Location			Source Size (ft)	Source Concentration (mg/kg)	30-Year Diffusion	Permeability
				i-node	j-node	k-node				
U12-VP1/Source Area #1										
twolayer_vp1_1	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	5,000	Yes	Normal
twolayer_vp1_2	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	1,000	Yes	Normal
twolayer_vp1_3	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	100	Yes	Normal
twolayer_vp1_4	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	3,000	Yes	Normal
twolayer_vp1_5	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	4,000	Yes	Normal
twolayer_vp1_6	U12-VP1	SA1	43 ft N	23-26	28-29	7-9	20 x 10 x 15	4,500	Yes	Normal
twolayer_vp1_7	U12-VP1	SA1	43 ft N	23-26	28-29	8-9	20 x 10 x 10	5,000	Yes	Normal
twolayer_vp1_8	U12-VP1	SA1	43 ft N	23-26	28-29	8-9	20 x 10 x 10	10,000	Yes	Normal
U12-VP1/Source Area #2										
twolayer_vp1_1b	U12-VP1	SA2	8 ft NE	25-26	21-22	7-9	10 x 10 x 15	5,000	Yes	Normal
twolayer_vp1_2b	U12-VP1	SA2	8 ft NE	25-26	21-22	7-9	10 x 10 x 15	1,000	Yes	Normal
twolayer_vp1_3b	U12-VP1	SA2	8 ft NE	25-26	21-22	7-9	10 x 10 x 15	10,000	Yes	Normal
twolayer_vp1_4b	U12-VP1	SA2	8 ft NE	25-26	21-22	7-9	10 x 10 x 15	15,000	Yes	Normal
twolayer_vp1_5b	U12-VP1	SA2	8 ft NE	25-26	21-22	7-9	10 x 10 x 15	25,000	Yes	Normal
twolayer_vp1_6b	U12-VP1	SA2	8 ft NE	25-26	21-22	9	10 x 10 x 5	50	No	Normal
twolayer_vp1_7b	U12-VP1	SA2	8 ft NE	25-26	21-22	9	10 x 10 x 5	100	No	Normal
twolayer_vp1_8b	U12-VP1	SA2	8 ft NE	25-26	21-22	9	10 x 10 x 5	200	No	Normal
twolayer_vp1_9b	U12-VP1	SA2	8 ft NE	25-26	21-22	8-9	10 x 10 x 10	200	No	Normal
U12-VP1/Source Area #3										
twolayer_vp1_1c	U12-VP1	SA3	19 ft NW	19-20	21-22	7-9	10 x 10 x 15	5,000	Yes	Normal
twolayer_vp1_2c	U12-VP1	SA3	19 ft NW	19-20	21-22	7-9	10 x 10 x 15	1,000	Yes	Normal
twolayer_vp1_10c	U12-VP1	SA3	19 ft NW	19-20	21-22	7-9	10 x 10 x 15	10,000	Yes	Normal
twolayer_vp1_11c	U12-VP1	SA3	19 ft NW	19-20	21-22	7-9	10 x 10 x 15	8,000	Yes	Normal
U12-VP1/Source Area #4										
twolayer_vp1_1d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	5,000	Yes	Normal
twolayer_vp1_2d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	1,000	Yes	Normal
twolayer_vp1_10d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	10,000	Yes	Normal
twolayer_vp1_12d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	15,000	Yes	Normal
twolayer_vp1_13d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	15,000	Yes	0.5 x Perm
twolayer_vp1_14d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	15,000	Yes	0.1 x Perm
twolayer_vp1_15d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	10,000	Yes	0.1 x Perm
twolayer_vp1_16d	U12-VP1	SA4	23 ft E	29	20-21	7-9	5 x 10 x 15	10,000	Yes	0.5 x Perm
twolayer_vp1_20d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	15,000	Yes	Normal
twolayer_vp1_21d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	10,000	Yes	Normal
twolayer_vp1_22d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	20,000	Yes	Normal
twolayer_vp1_23d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	18,000	Yes	Normal
twolayer_vp1_24d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	16,000	Yes	Normal
twolayer_vp1_25d	U12-VP1	SA4	23 ft E	29	20-21	8-9	5 x 10 x 10	17,000	Yes	Normal
U12-VP1/Source Area #5										
twolayer_vp1_1e	U12-VP1	SA5	8 ft N	23-26	21-22	7-9	20 x 10 x 15	5,000	Yes	Normal
twolayer_vp1_2e	U12-VP1	SA5	8 ft N	23-26	21-22	7-9	20 x 10 x 15	1,000	Yes	Normal
U12-VP1/Source Area #6										
twolayer_vp1_1f	U12-VP1	SA6	0	24-28	18-24	8-9	25 x 35 x 10	5,000	Yes	Normal
twolayer_vp1_2f	U12-VP1	SA6	0	24-28	18-24	8-9	25 x 35 x 10	1,000	Yes	Normal
twolayer_vp1_21f	U12-VP1	SA6	0	24-28	18-24	8-9	25 x 35 x 10	100	No	Normal
twolayer_vp1_22f	U12-VP1	SA6	0	24-28	18-24	8-9	25 x 35 x 10	50	No	Normal
twolayer_vp1_20f	U12-VP1	SA6	0	24-28	18-24	8-9	25 x 35 x 10	200	No	Normal
U12-VP1/Source Area #7										
twolayer_vp1_1g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	5,000	Yes	Normal
twolayer_vp1_3g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	10,000	Yes	Normal
twolayer_vp1_4g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	15,000	Yes	Normal
twolayer_vp1_5g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	20,000	Yes	Normal
twolayer_vp1_6g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	18,000	Yes	Normal
twolayer_vp1_7g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	17,000	Yes	Normal
twolayer_vp1_8g	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	17,500	Yes	Normal
twolayer_vp1_8g_2	U12-VP1	SA7	26 ft NE	29	22	7-9	5 x 5 x 15	17,500	Yes	Normal
twolayer_vp1_9g	U12-VP1	SA7	26 ft NE	29	22	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp1_10g	U12-VP1	SA7	26 ft NE	29	22	9	5 x 5 x 5	25,000	Yes	Normal
twolayer_vp1_11g	U12-VP1	SA7	26 ft NE	29	22	9	5 x 5 x 5	25,000	Yes	10 x Perm
twolayer_vp1_12g	U12-VP1	SA7	26 ft NE	29	22	9	5 x 5 x 5	16,000	20 yrs	Normal
twolayer_vp1_13g	U12-VP1	SA7	26 ft NE	29	22	9	5 x 5 x 5	4,000	10 yrs	Normal
twolayer_vp1_14g	U12-VP1	SA7	26 ft NE	29	22	9	5 x 5 x 5	6,000	10 yrs	Normal
U12-VP1/Source Area #8										
twolayer_vp1_1h	U12-VP1	SA8	15 ft NE	27	21	8-9	5 x 5 x 10	22,000	Yes	Normal
twolayer_vp1_2h	U12-VP1	SA8	15 ft NE	27	21	8-9	5 x 5 x 10	20,000	Yes	Normal

Table 5-8. *continued*

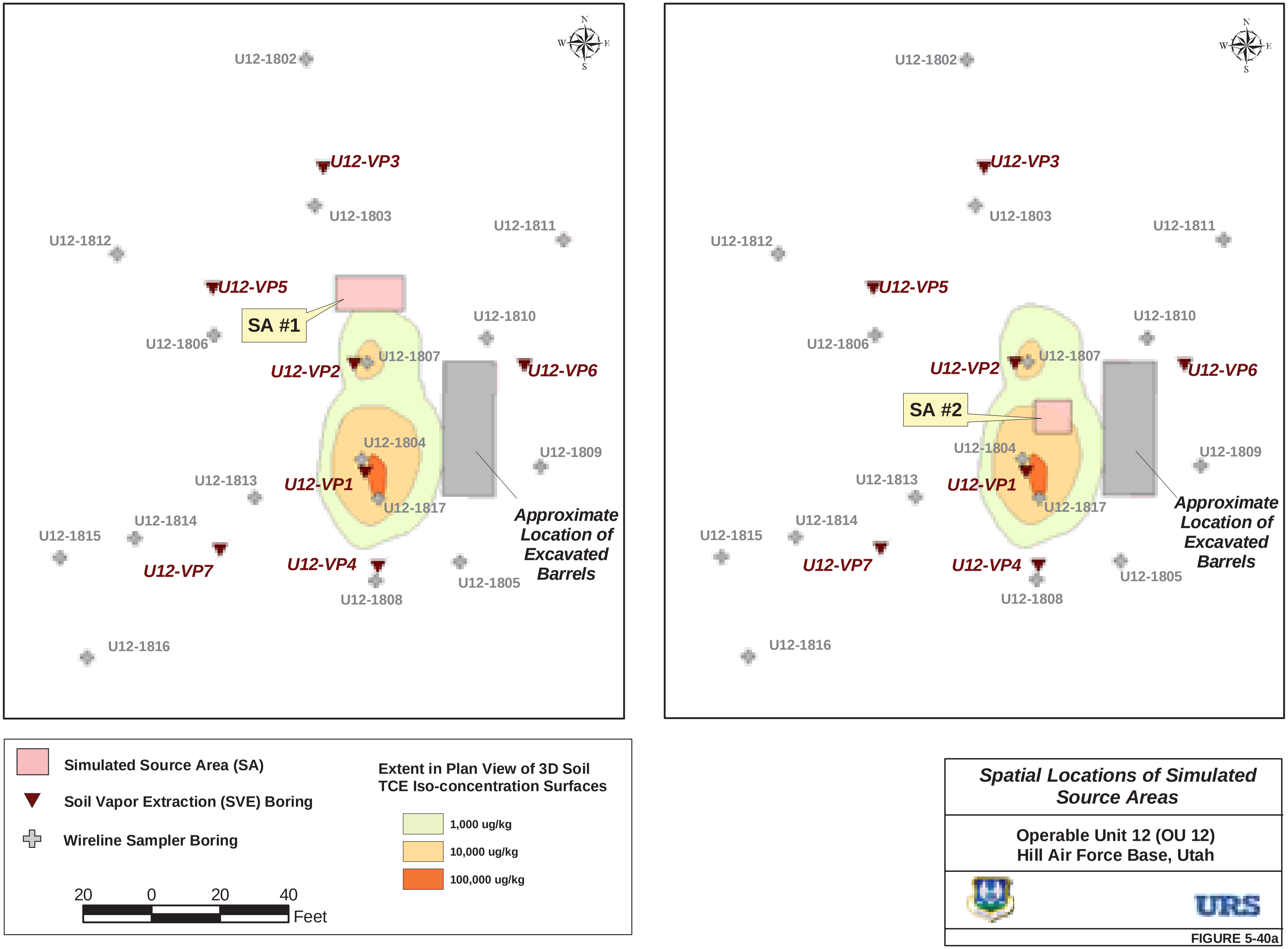
File Name	Extraction Well	Source	Source Distance from Well	Source Location			Source Size (ft)	Source Concentration (mg/kg)	30-Year Diffusion	Permeability
				i-node	j-node	k-node				
twolayer_vp1_3h	U12-VP1	SA8	15 ft NE	27	21	9	5 x 5 x 5	25,000	Yes	Normal
twolayer_vp1_4h	U12-VP1	SA8	15 ft NE	27	21	9	5 x 5 x 5	5,000	10 yrs	Normal
twolayer_vp1_5h	U12-VP1	SA8	15 ft NE	27	21	9	5 x 5 x 5	8,000	10 yrs	Normal
twolayer_vp1_6h	U12-VP1	SA8	15 ft NE	27	21	9	5 x 5 x 5	10,000	10 yrs	Normal
twolayer_vp1_7h	U12-VP1	SA8	15 ft NE	27	21	9	5 x 5 x 5	12,000	10 yrs	Normal
U12-VP1/Source Area #9										
twolayer_vp1_1i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	25,000	Yes	Normal
twolayer_vp1_2i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	25,000	15 yrs	Normal
twolayer_vp1_3i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	20,000	15 yrs	Normal
twolayer_vp1_4i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	15,000	15 yrs	Normal
twolayer_vp1_5i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	10,000	15 yrs	Normal
twolayer_vp1_6i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	5,000	15 yrs	Normal
twolayer_vp1_7i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	30,000	15 yrs	Normal
twolayer_vp1_8i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	40,000	15 yrs	Normal
twolayer_vp1_9i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	200	No	Normal
twolayer_vp1_10i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	400	No	Normal
twolayer_vp1_11i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	1,000	No	Normal
twolayer_vp1_12i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	2,000	No	Normal
twolayer_vp1_13i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	3,000	No	Normal
twolayer_vp1_14i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	5,000	No	Normal
twolayer_vp1_15i	U12-VP1	SA9	8 ft NE	25	21	9	5 x 5 x 5	10,000	No	Normal
twolayer_vp1_16i	U12-VP1	SA9	8 ft NE	25	21	8-9	5 x 5 x 10	400	No	Normal
twolayer_vp1_17i	U12-VP1	SA9	8 ft NE	25	21	8-9	5 x 5 x 10	200	No	Normal
twolayer_vp1_18i	U12-VP1	SA9	8 ft NE	25	21	8-9	5 x 5 x 10	600	No	Normal
U12-VP1/Source Area #10										
twolayer_vp1_1j	U12-VP1	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp1_1k	U12-VP1	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP2/Source Area #1										
twolayer_vp2_1	U12-VP2	SA1	13 ft N	23-26	28-29	7-9	20 x 10 x 15	5,000	Yes	Normal
twolayer_vp2_2	U12-VP2	SA1	13 ft N	23-26	28-29	7-9	20 x 10 x 15	1,000	Yes	Normal
twolayer_vp2_7	U12-VP2	SA1	13 ft N	23-26	28-29	8-9	20 x 10 x 10	5,000	Yes	Normal
U12-VP2/Source Area #2										
twolayer_vp2_1b	U12-VP2	SA2	15 ft SE	25-26	21-22	7-9	10 x 10 x 15	5,000	Yes	Normal
twolayer_vp2_2b	U12-VP2	SA2	15 ft SE	25-26	21-22	7-9	10 x 10 x 15	1,000	Yes	Normal
twolayer_vp2_3b	U12-VP2	SA2	15 ft SE	25-26	21-22	8-9	10 x 10 x 10	200	No	Normal
U12-VP2/Source Area #3										
twolayer_vp2_1c	U12-VP2	SA3	18 ft SW	19-20	21-22	7-9	10 x 10 x 15	5,000	Yes	Normal
twolayer_vp2_2c	U12-VP2	SA3	18 ft SW	19-20	21-22	7-9	10 x 10 x 15	1,000	Yes	Normal
U12-VP2/Source Area #4										
twolayer_vp2_1d	U12-VP2	SA4	33 ft SE	29	20-21	7-9	5 x 10 x 15	5,000	Yes	Normal
twolayer_vp2_2d	U12-VP2	SA4	33 ft SE	29	20-21	7-9	5 x 10 x 15	1,000	Yes	Normal
U12-VP2/Source Area #7										
twolayer_vp2_8g	U12-VP2	SA7	28 ft SE	29	22	7-9	5 x 5 x 15	17,500	Yes	Normal
twolayer_vp2_9g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	17,500	Yes	Normal
twolayer_vp2_10g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp2_11g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	19,000	Yes	Normal
twolayer_vp2_12g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	19,000	Yes	0.5 x Perm
twolayer_vp2_13g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	19,000	Yes	0.2 x Perm
twolayer_vp2_14g	U12-VP2	SA7	28 ft SE	29	22	7-9	5 x 5 x 15	25,000	Yes	Normal
twolayer_vp2_15g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	25,000	Yes	Normal
twolayer_vp2_16g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	22,000	Yes	Normal
twolayer_vp2_17g	U12-VP2	SA7	28 ft SE	29	22	8-9	5 x 5 x 10	21,000	Yes	Normal
twolayer_vp2_18g	U12-VP2	SA7	28 ft SE	29	22	7-9	5 x 5 x 15	18,000	Yes	Normal
twolayer_vp2_19g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	20,000	Yes	Normal
twolayer_vp2_20g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	22,000	Yes	Normal
twolayer_vp2_21g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	Normal
twolayer_vp2_22g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	0.5 x Perm
twolayer_vp2_23g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	2 x Perm
twolayer_vp2_24g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	5 x Perm
twolayer_vp2_25g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	10 x Perm
twolayer_vp2_26g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	25,000	20 yrs	Normal
twolayer_vp2_27g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	20,000	20 yrs	Normal
twolayer_vp2_28g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	15,000	20 yrs	Normal
twolayer_vp2_29g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	17,500	20 yrs	Normal
twolayer_vp2_30g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	16,000	20 yrs	Normal
twolayer_vp2_31g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	16,000	10 yrs	Normal

Table 5-8. *continued*

File Name	Extraction Well	Source	Source Distance from Well	Source Location			Source Size (ft)	Source Concentration (mg/kg)	30-Year Diffusion	Permeability
				i-node	j-node	k-node				
twolayer_vp2_32g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	12,000	10 yrs	Normal
twolayer_vp2_33g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	10,000	10 yrs	Normal
twolayer_vp2_34g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	8,000	10 yrs	Normal
twolayer_vp2_35g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	6,000	10 yrs	Normal
twolayer_vp2_36g	U12-VP2	SA7	28 ft SE	29	22	9	5 x 5 x 5	4,000	10 yrs	Normal
U12-VP2/Source Area #8										
twolayer_vp2_1h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	15,000	Yes	Normal
twolayer_vp2_2h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	10,000	Yes	Normal
twolayer_vp2_3h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp2_4h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	22,000	Yes	Normal
twolayer_vp2_5h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	23,000	Yes	Normal
twolayer_vp2_6h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	21,000	Yes	Normal
twolayer_vp2_7h	U12-VP2	SA8	25 ft SE	27	21	8-9	5 x 5 x 10	25,000	Yes	Normal
twolayer_vp2_8h	U12-VP2	SA8	25 ft SE	27	21	9	5 x 5 x 5	25,000	Yes	Normal
U12-VP2/Source Area #9										
twolayer_vp2_1i	U12-VP2	SA9	19 ft SE	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP2/Source Area #10										
twolayer_vp2_1j	U12-VP2	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp2_1k	U12-VP2	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP3/Source Area #7										
twolayer_vp3_1g	U12-VP3	SA7	77 ft SE	29	22	9	5 x 5 x 5	25,000	Yes	Normal
twolayer_vp3_2g	U12-VP3	SA7	77 ft SE	29	22	8-9	5 x 5 x 10	20,000	Yes	Normal
U12-VP3/Source Area #9										
twolayer_vp3_1i	U12-VP3	SA9	75 ft SE	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP3/Source Area #10										
twolayer_vp3_1j	U12-VP3	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp3_1k	U12-VP3	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP4/Source Area #7										
twolayer_vp4_1g	U12-VP4	SA7	46 ft NE	29	22	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp4_2g	U12-VP4	SA7	46 ft NE	29	22	7-9	5 x 5 x 15	17,500	Yes	Normal
twolayer_vp4_3g	U12-VP4	SA7	46 ft NE	29	22	7-9	5 x 5 x 15	15,000	Yes	Normal
twolayer_vp4_4g	U12-VP4	SA7	46 ft NE	29	22	7-9	5 x 5 x 15	12,000	Yes	Normal
twolayer_vp4_5g	U12-VP4	SA7	46 ft NE	29	22	7-9	5 x 5 x 15	10,000	Yes	Normal
twolayer_vp4_6g	U12-VP4	SA7	46 ft NE	29	22	9	5 x 5 x 5	25,000	Yes	Normal
U12-VP4/Source Area #9										
twolayer_vp4_1i	U12-VP4	SA9	38 ft N	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP4/Source Area #10										
twolayer_vp4_1j	U12-VP4	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp4_1k	U12-VP4	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP5/Source Area #9										
twolayer_vp5_1i	U12-VP5	SA9	61 ft SE	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP5/Source Area #10										
twolayer_vp5_1j	U12-VP5	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp5_1k	U12-VP5	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP6/Source Area #7										
twolayer_vp6_1g	U12-VP6	SA7	22 ft SW	29	22	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp6_2g	U12-VP6	SA7	22 ft SW	29	22	7-9	5 x 5 x 15	17,500	Yes	Normal
twolayer_vp6_3g	U12-VP6	SA7	22 ft SW	29	22	7-9	5 x 5 x 15	12,000	Yes	Normal
twolayer_vp6_4g	U12-VP6	SA7	22 ft SW	29	22	9	5 x 5 x 5	25,000	Yes	Normal
U12-VP6/Source Area #8										
twolayer_vp6_1h	U12-VP6	SA8	33 ft SW	27	21	8-9	5 x 5 x 10	20,000	Yes	Normal
twolayer_vp6_2h	U12-VP6	SA8	33 ft SW	27	21	7-9	5 x 5 x 15	17,500	Yes	Normal
U12-VP6/Source Area #9										
twolayer_vp6_1i	U12-VP6	SA9	41 ft SW	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP6/Source Area #10										
twolayer_vp6_1j	U12-VP6	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp6_2k	U12-VP6	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal
U12-VP7/Source Area #9										
twolayer_vp7_1i	U12-VP7	SA9	58 ft NE	25	21	8-9	5 x 5 x 10	400	No	Normal
U12-VP7/Source Area #10										
twolayer_vp7_1j	U12-VP7	SA10	0	EVS	EVS	EVS	EVS	EVS Max	No	Normal
twolayer_vp7_2k	U12-VP7	SA10	0	EVS	EVS	EVS	EVS	EVS Ave	No	Normal

Notes

Normal permeability is 10 Darcy for the bottom 50 feet and 100 Darcy for the upper 20 feet of the modeling domain.

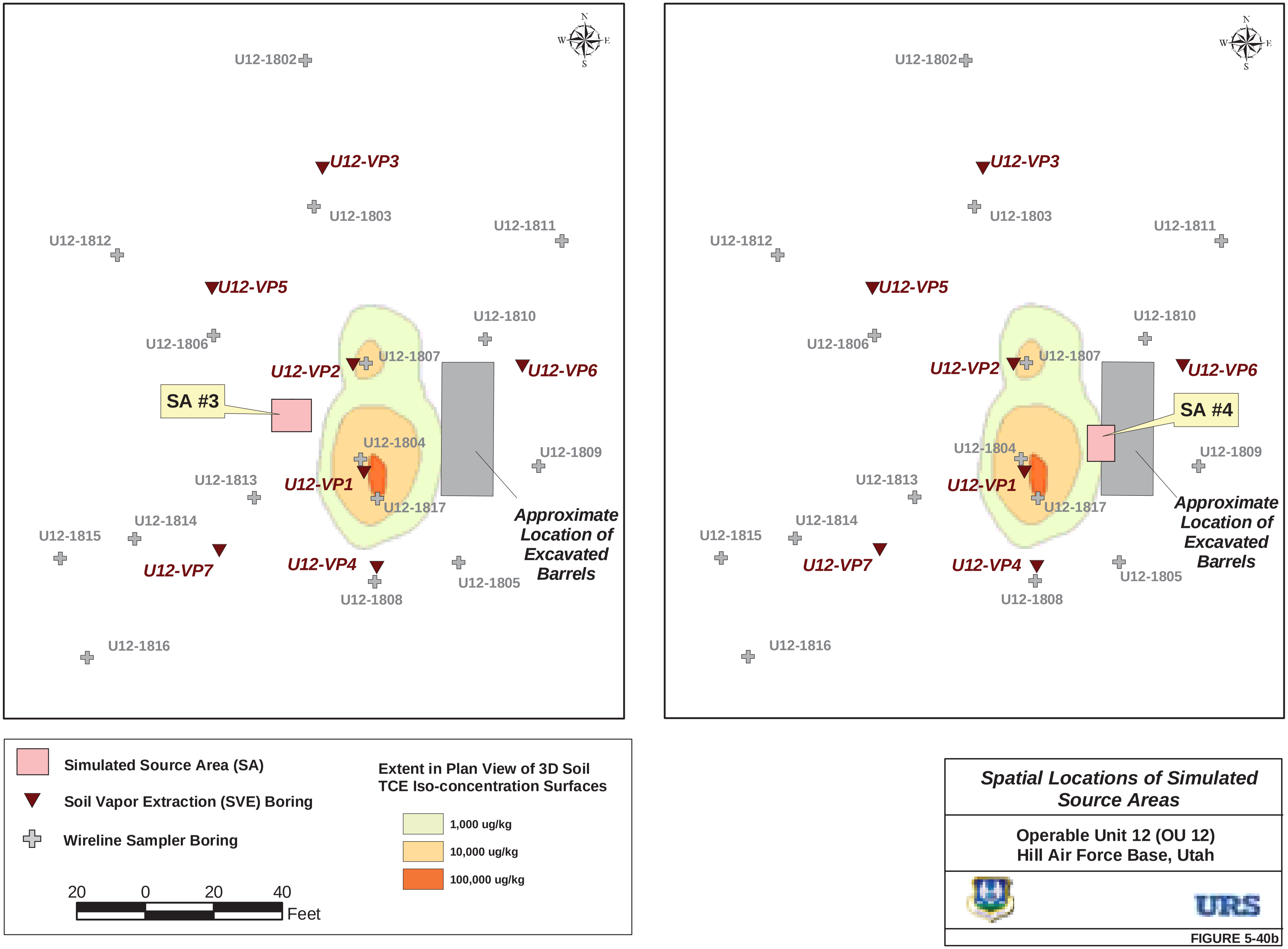


Spatial Locations of Simulated Source Areas

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-40a

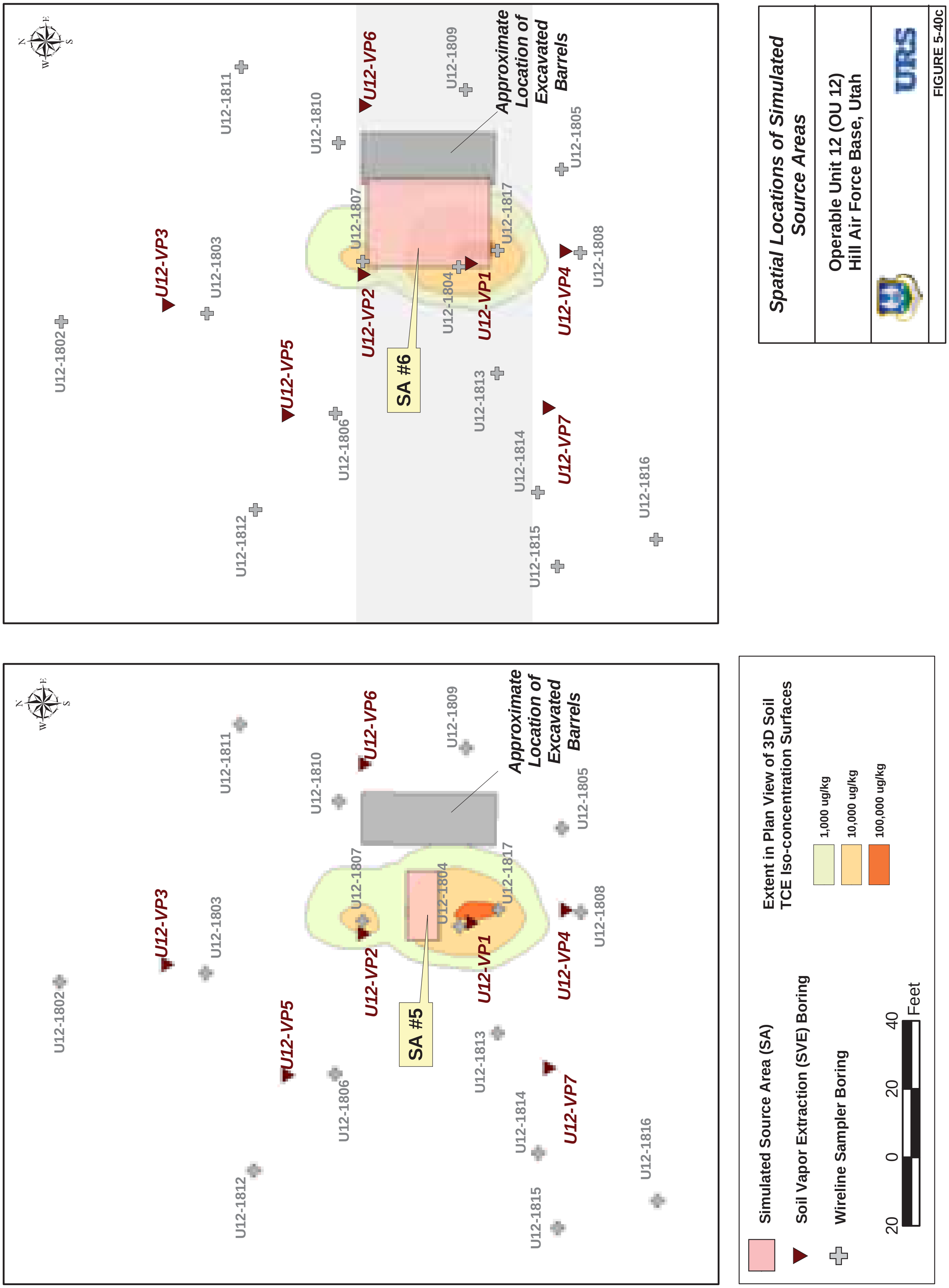


Spatial Locations of Simulated Source Areas

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-40b

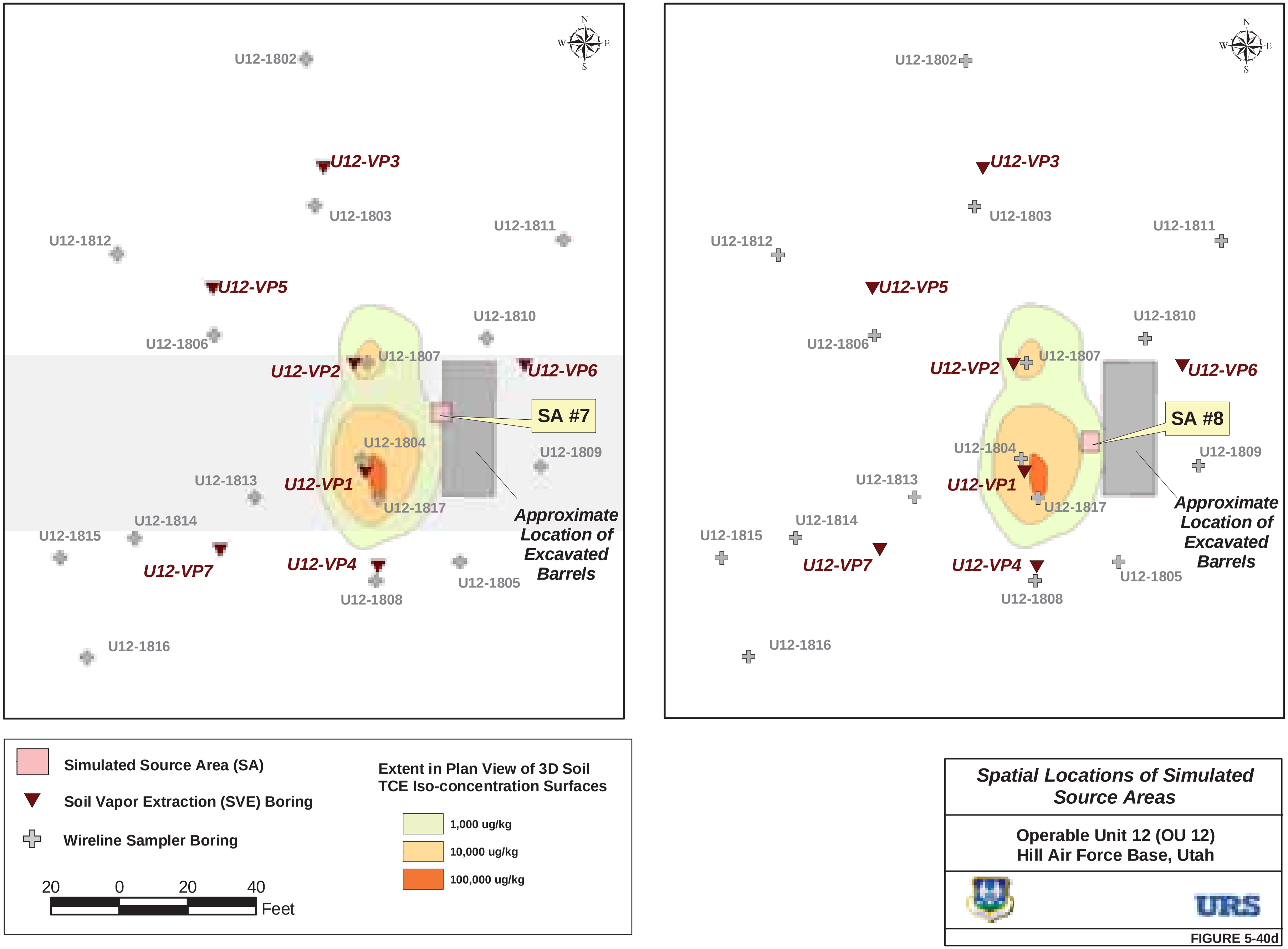


Spatial Locations of Simulated Source Areas

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-40c

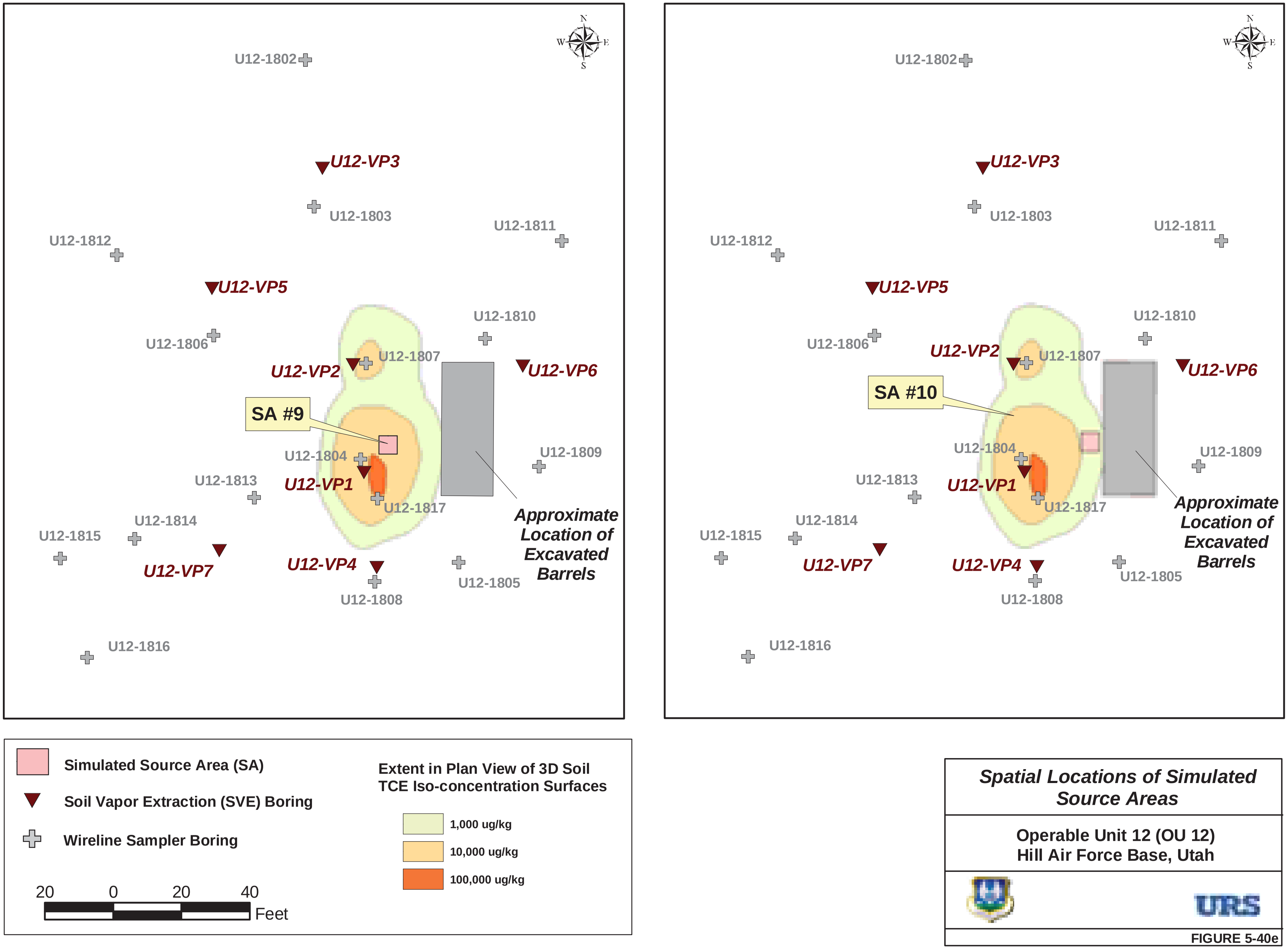


Spatial Locations of Simulated Source Areas

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-40d



Spatial Locations of Simulated Source Areas

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

URS

FIGURE 5-40e

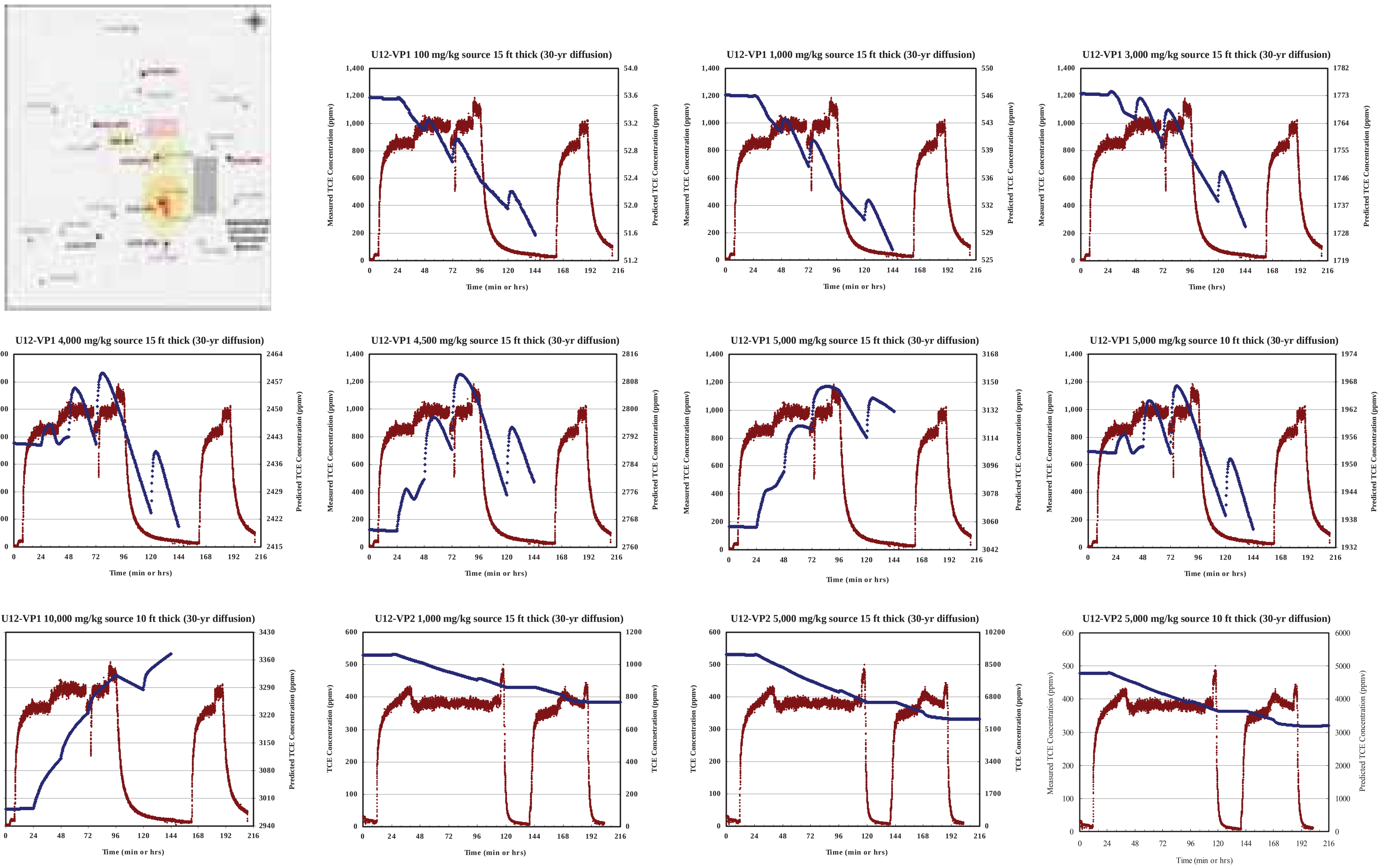


Figure 5-41. Predicted versus measured TCE concentrations at U12-VP1 and U12-VP2 for source area #1 (predicted concentration shown in blue and measured concentration shown in red).

Figure 5-42 shows a comparison between the predicted and the measured TCE concentration profiles in the vapor phase at extraction wells U12-VP1 and U12-VP2 for source area 2. Source area 2 is located approximately 8 feet northeast of U12-VP1 and 15 feet southeast of U12-VP2, and represents a simulated TCE source 10 feet by 10 feet in areal extent and 5 to 15 feet thick. An initial source concentration ranging from 1,000 to 25,000 mg/kg prior to a 30-year diffusion period and from 50 to 200 mg/kg without diffusion was investigated. Without a pre-extraction diffusion period, the predicted concentration profiles show a sharp increase in TCE concentration with increased time typically associated with advective-dominated contaminant transport of a source located distant from the extraction well. This sharp increase in TCE concentration also was observed in the measured concentrations during the SVE demonstration at OU 12. Assuming a 10-foot thick source zone containing 200 mg/kg TCE, the predicted TCE concentrations for extraction wells U12-VP1 and U12-VP2 are in range of the measured values. However, the exponential decline observed during the blower shutdown periods is not apparent in the predicted concentration profiles.

A comparison between the predicted and the measured TCE concentration profiles in the vapor phase at extraction well U12-VP1 for source area 6 is shown in Figure 5-43. Extraction well U12-VP1 is located within source area 6, which consists of a simulated TCE source 25 feet by 35 feet in areal extent and 10 feet thick. An initial source concentration ranging from 1,000 to 5,000 mg/kg prior to a 30-year diffusion period and from 50 to 200 mg/kg without diffusion was investigated. The predicted TCE concentration profiles do not match the actual profiles obtained during the SVE demonstration and appear to resemble a localized, diminishing source or a diffusion-dominated flow regime

Figure 5-44 shows a comparison between the predicted and the measured TCE concentration profiles in the vapor phase at extraction wells U12-VP1, U12-VP2, U12-VP3, U12-VP4, and U12-VP6 for source area 7. Source area 7 is located approximately 26 feet northeast of U12-VP1 and 28 feet southeast of U12-VP2, and represents a simulated TCE source 5 feet by 5 feet in areal extent and 5 to 15 feet thick. An initial source concentration ranging from 4,000 to 25,000 mg/kg prior to a 10-, 20-, or 30-year diffusion period was investigated. The best match between the predicted and the measured TCE concentrations was obtained assuming a 5-foot thick source located at a depth of 25 to 30 feet bgs. The predicted concentration profiles for U12-VP2 are in relatively good agreement with the observed profiles; however, the predicted concentrations are slightly elevated for the 20- and 30- year diffusion scenario and low for the 10-year diffusion scenario. For wells U12-VP1 and U12-VP3, only the 30-year diffusion scenario resulted in a reasonable prediction, whereas the results for wells U12-VP4 and U12-VP6 were poor for all scenarios investigated.

The predicted TCE soil concentration after each of the diffusion periods (10, 20, or 30 years) and prior to vapor extraction operations is shown in Figure 5-45 for source area 7 assuming a 5-foot thick source located at a depth of 25 to 30 feet bgs. The concentration contours shown in Figure 5-45 represent the soil concentration in the depth interval of the original source (i.e., 25 to 30 feet bgs). As is evident, a significant fraction of the original simulated source has been lost due to the natural diffusive transport of the TCE. The results of vapor extraction conducted for 1 day at U12-VP2 as predicted for source area 7 are shown in Figure 5-46 for the soil and Figure 5-47 for the soil gas. Although the short duration of

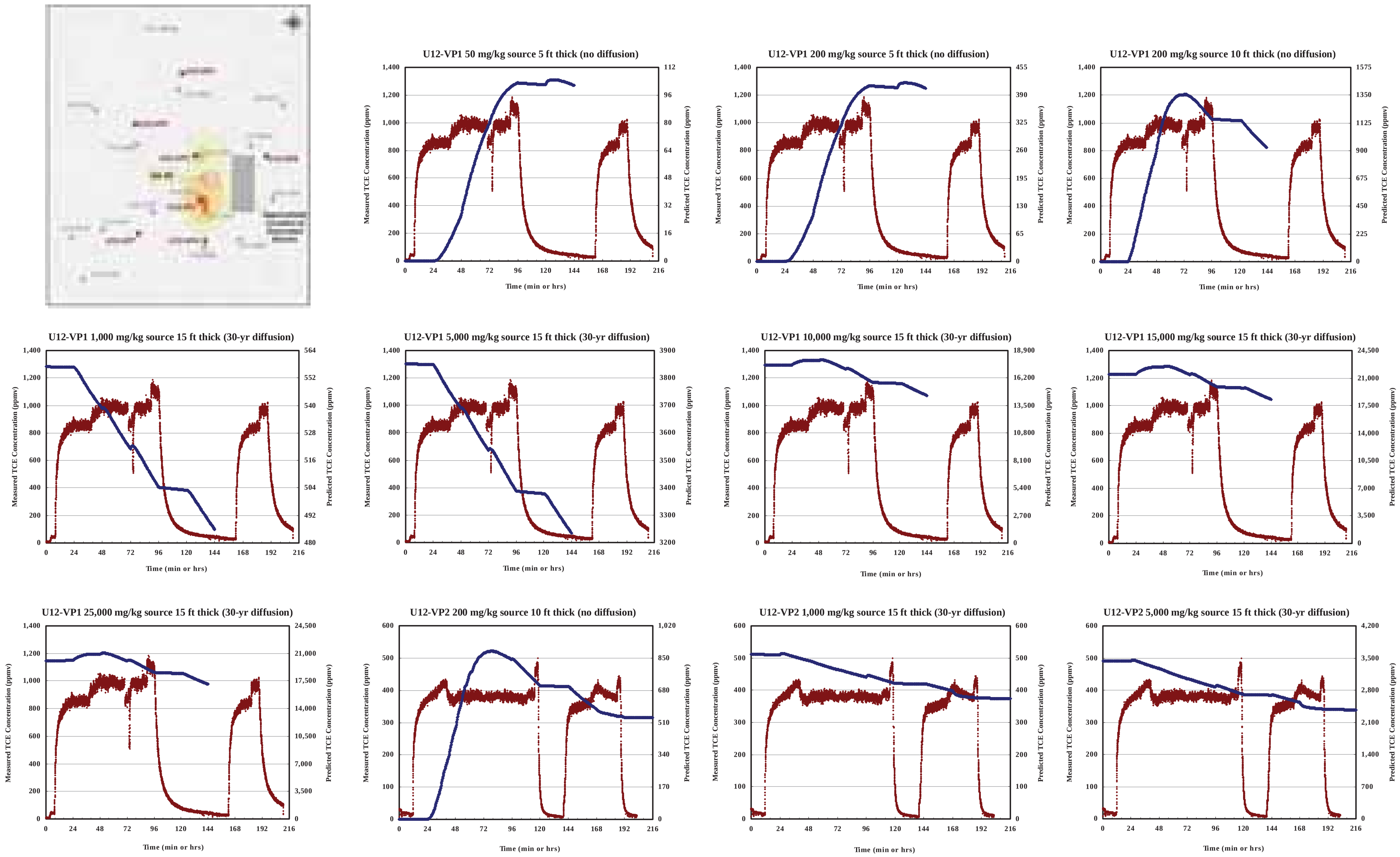


Figure 5-42. Predicted versus measured TCE concentrations at U12-VP1 and U12-VP2 for source area #2 (predicted concentration shown in blue and measured concentration shown in red).

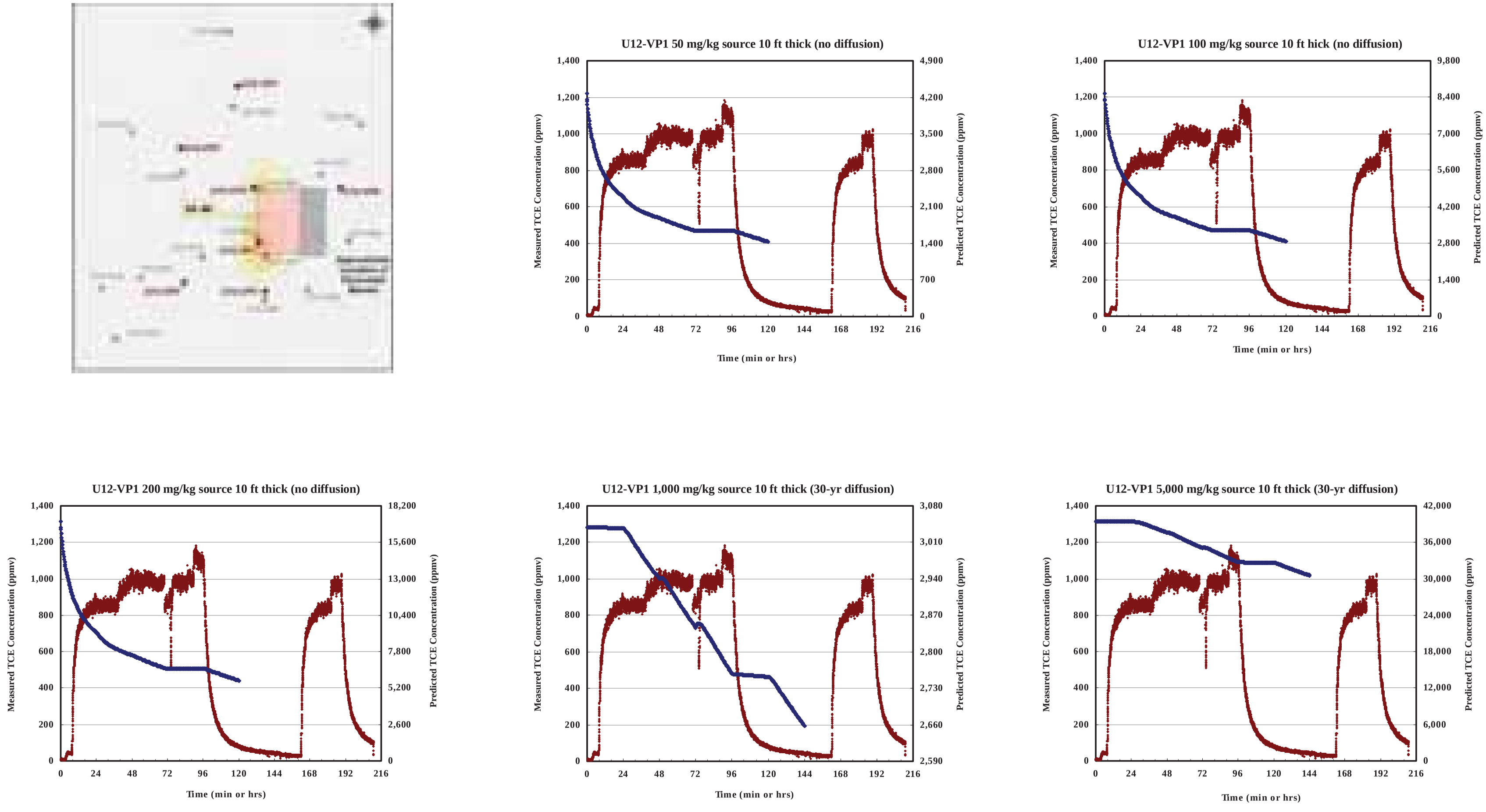
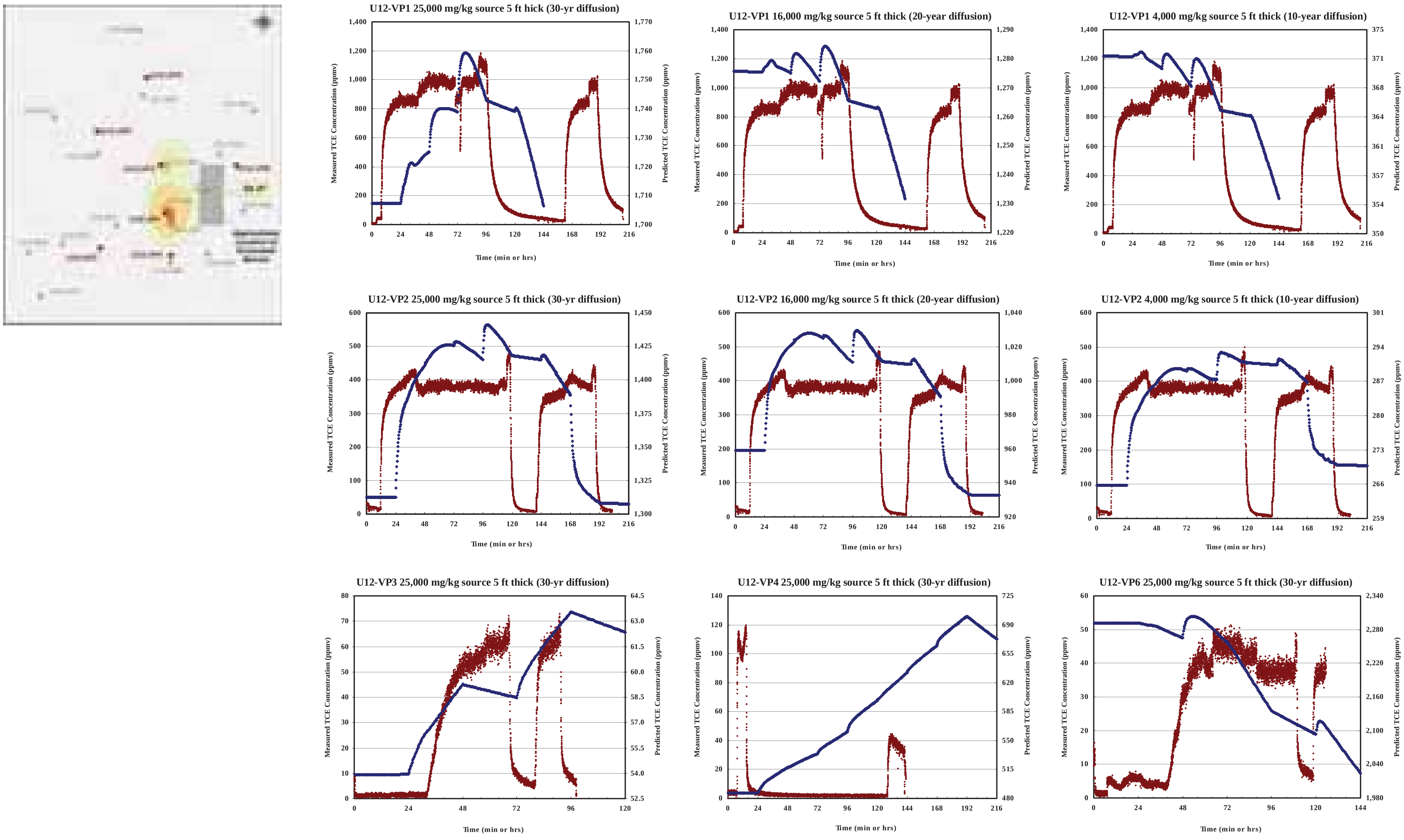


Figure 5-43. Predicted versus measured TCE concentrations at U12-VP1 for source area #6 (predicted concentration shown in blue and measured concentration shown in red).



U12-VP1 25,000 mg/kg source 5 ft hick (30-yr diffusion)

U12-VP1 16,000 mg/kg source 5 ft thick (20-year diffusion)

U12-VP1 4,000 mg/kg source 5 ft thick (10-year diffusion)

U12-VP2 25,000 mg/kg source 5 ft thick (30-yr diffusion)

U12-VP2 16,000 mg/kg source 5 ft thick (20-year diffusion)

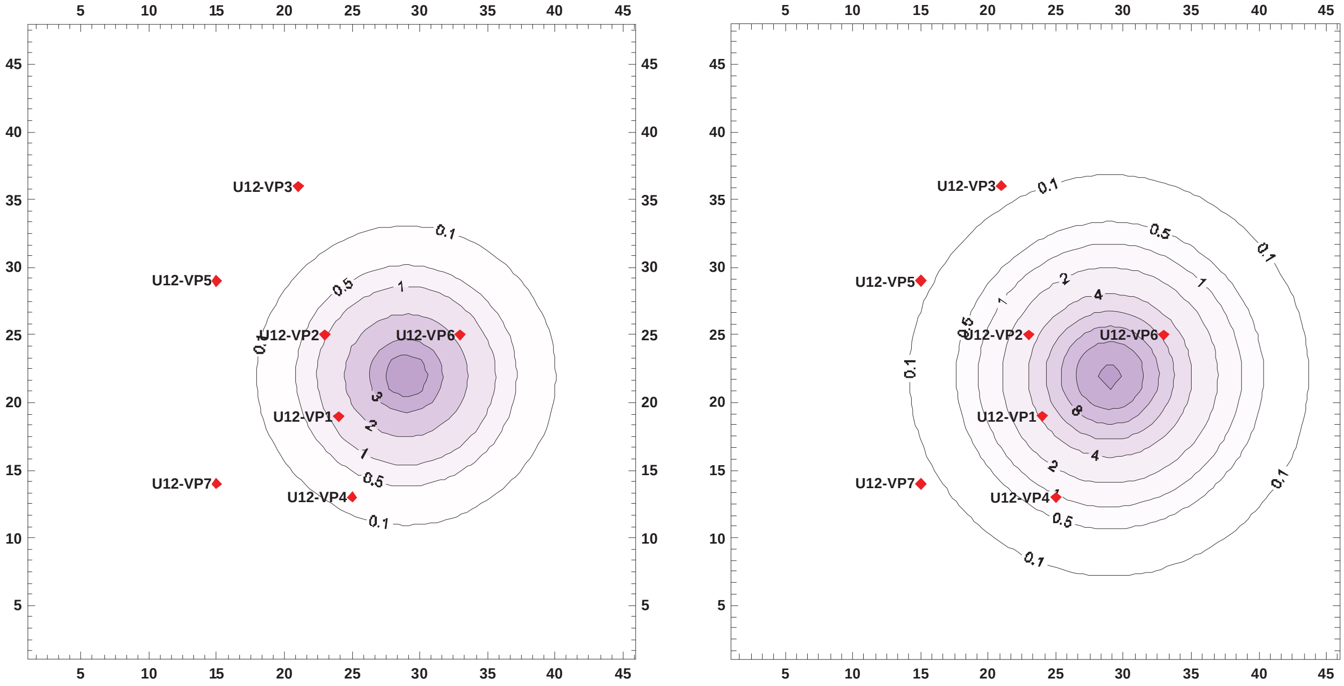
U12-VP2 4,000 mg/kg source 5 ft thick (10-year diffusion)

U12-VP3 25,000 mg/kg source 5 ft thick (30-yr diffusion)

U12-VP4 25,000 mg/kg source 5 ft thick (30-yr diffusion)

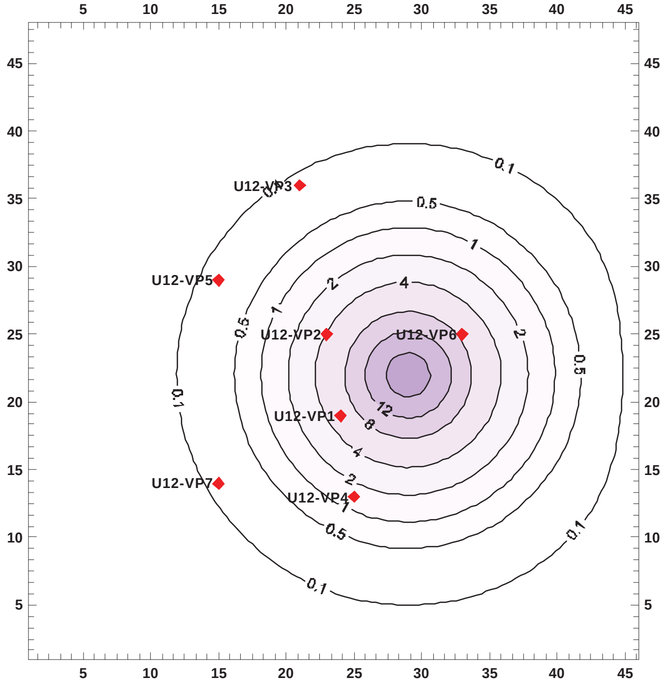
U12-VP6 25,000 mg/kg source 5 ft thick (30-yr diffusion)

Figure 5-44. Predicted versus measured TCE concentrations at U12-VP1, U12-VP2, U12-VP3, U12-VP4, and U12-VP6 for source area #7 (predicted concentration shown in blue and measured concentration shown in red).



4,000 mg/kg initial source and 10-year diffusion

16,000 mg/kg initial source and 20-year diffusion



25,000 mg/kg initial source and 30-year diffusion

Figure 5-45. Predicted TCE soil concentration (mg/kg) at 25 to 30 feet bgs after diffusion period and prior to vapor extraction operations in source area 7.

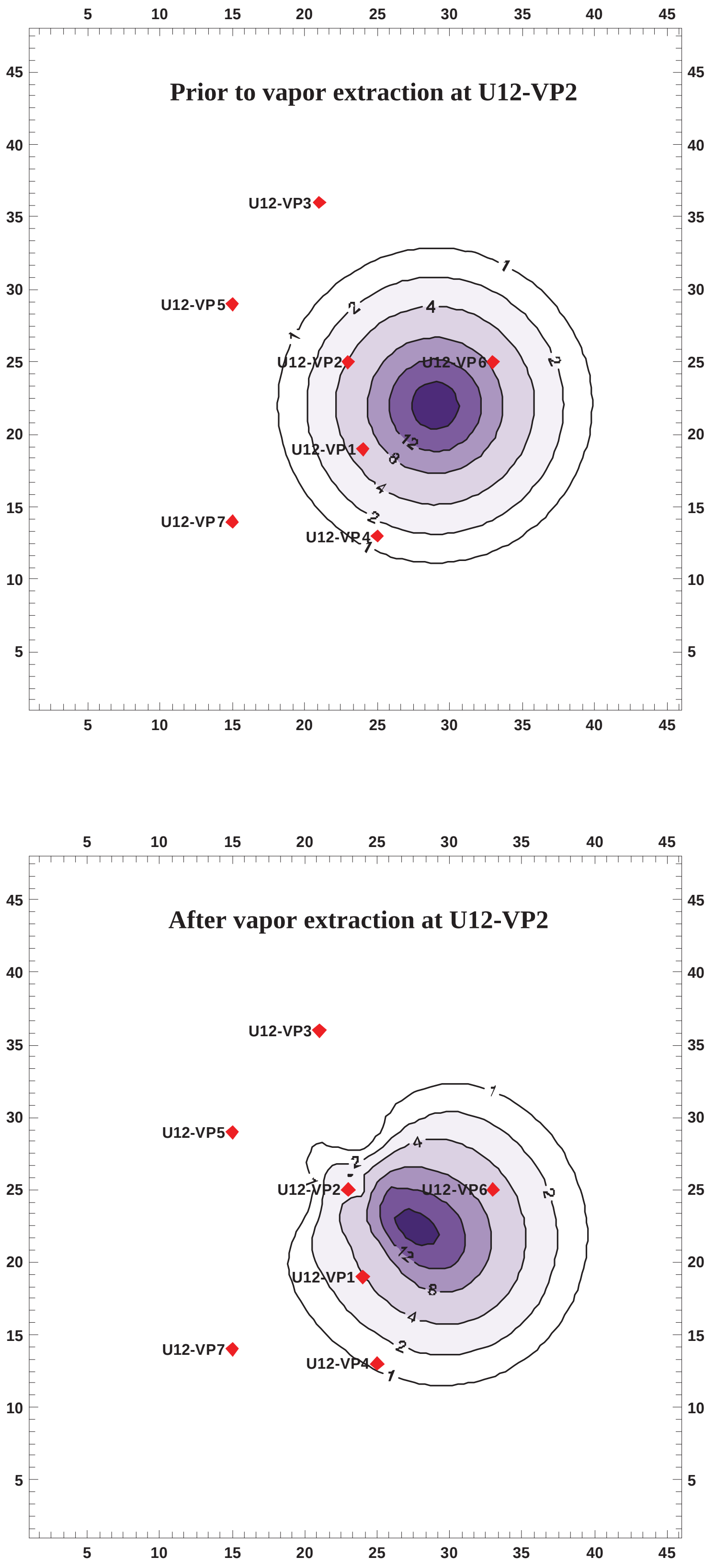


Figure 5-46. Predicted TCE soil concentration (mg/kg) at 25 to 30 feet bgs prior to and after soil vapor extraction operation at U12-VP2 for source area 7 and 25,000 mg/kg original source.

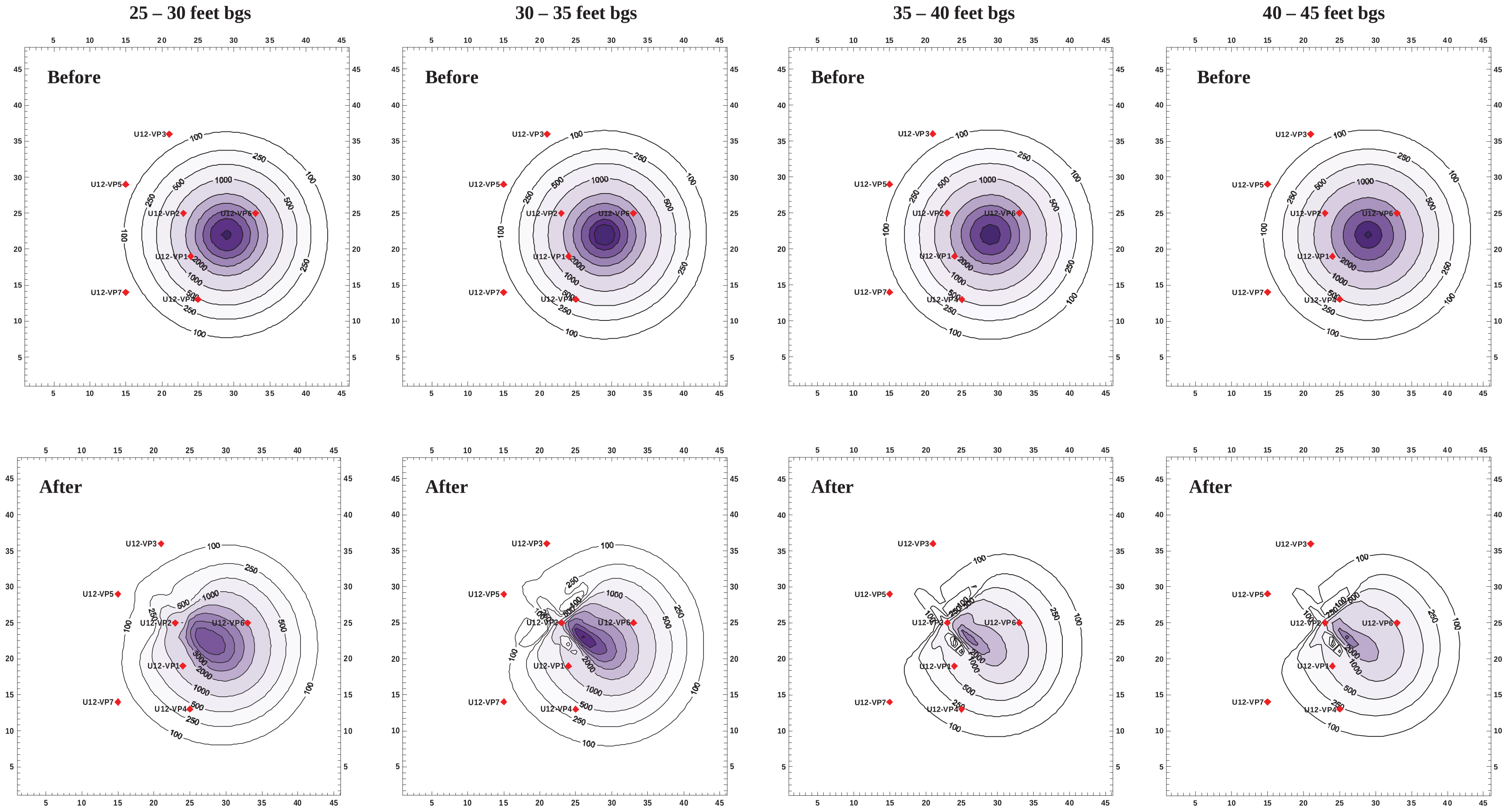


Figure 5-47. Predicted TCE soil gas concentration (ppmv) prior to and following soil vapor extraction from U12-VP2 for source area 7 and 25,000 mg/kg original concentration with a 30-year diffusion period.

vapor extraction does not significant reduce the predicted soil concentration, the concentration contours are considerable perturbed (see Figure 5-46). Similar results are observed for the predicted concentration of TCE in the soil gas, especially for depths below 30 feet bgs (see Figure 5-47). This perturbation in the natural distribution of TCE in both the soil and the soil gas may have influenced the observed TCE concentration profiles during the step tests conducted at OU 12 near the end of the demonstration, following several days of vapor extraction from the relatively small investigative area.

A comparison between the predicted and the measured TCE concentration profiles in the vapor phase at extraction well U12-VP1 for source area 9 is shown in Figure 5-48. Source area 9 is located approximately 8 feet northeast of U12-VP1, and represents a simulated TCE source 5 feet by 5 feet in areal extent and 5 to 10 feet thick. An initial source concentration ranging from 5,000 to 40,000 mg/kg prior to a 15-year or 30-year diffusion period and from 200 to 10,00 mg/kg without diffusion was investigated. Without a pre-extraction diffusion period, the predicted concentration profiles show a sharp increase in TCE concentration with increased time. This sharp increase in TCE concentration also was observed in the measured concentrations during the SVE demonstration at OU 12. Assuming a 5-foot thick source zone located at 25 to 30 feet bgs, the predicted TCE concentration profile in the vapor at U12-VP1 becomes independent of soil concentration above 1,000 mg/kg and never rises above approximately 450 ppmv in the vapor phase during the simulated test period. In addition, the concentration profiles appear relatively linear without the characteristic exponential decline observed in the measured concentration profiles during the blower shutdown periods. The TCE concentration profiles predicted for the 15-year and 30-year diffusive period scenario do not match the actual profiles obtained during the SVE demonstration and appear to resemble a localized, diminishing source or a diffusion-dominated flow regime. Assuming a 10-foot thick source zone containing 400 mg/kg and no pre-extraction diffusion, the predicted TCE vapor concentrations at U12-VP1 are in very good agreement with the measured values; however, during periods of blower shutdown, the predicted concentration profiles become relatively flat and do not exhibit the characteristic exponential decline. As extraction operations are continued following the blower shutdown period, the predicted vapor-phase concentrations sharply decline, apparently from streamtube dilution. This effect was not observed during actual vapor extraction operations at U12-VP1.

Although the exponential decline in the concentration of TCE in the vapor phase during blower shutdown periods was not predicted for a 10-foot thick source containing 400 mg/kg TCE in source area 9, the predicted concentrations were in good agreement with the measured values for U12-VP1. Thus, a comparison between the predicted concentrations of TCE in the vapor phase with the actual measured values was conducted for all seven extraction wells for this source zone configuration and is shown in Figure 5-49. Although the predicted vapor-phase concentrations and the general concentration profiles are in relatively good agreement for U12-VP1, U12-VP2, U12-VP4, U12-VP5, and U12-VP7, there are significant differences between the predicted and measured profiles for U12-VP3 and U12-VP6. For instance, the measured concentration of TCE in the vapor phase at U12-VP3 increased from a few parts-per-million by volume to approximately 65 ppmv with increased vapor extraction rates before sharply decreasing during blower shutdown. However, the concentration of TCE in the vapor phase is predicted to be near zero with no observed increase or decrease for all simulated rates of vapor extraction.

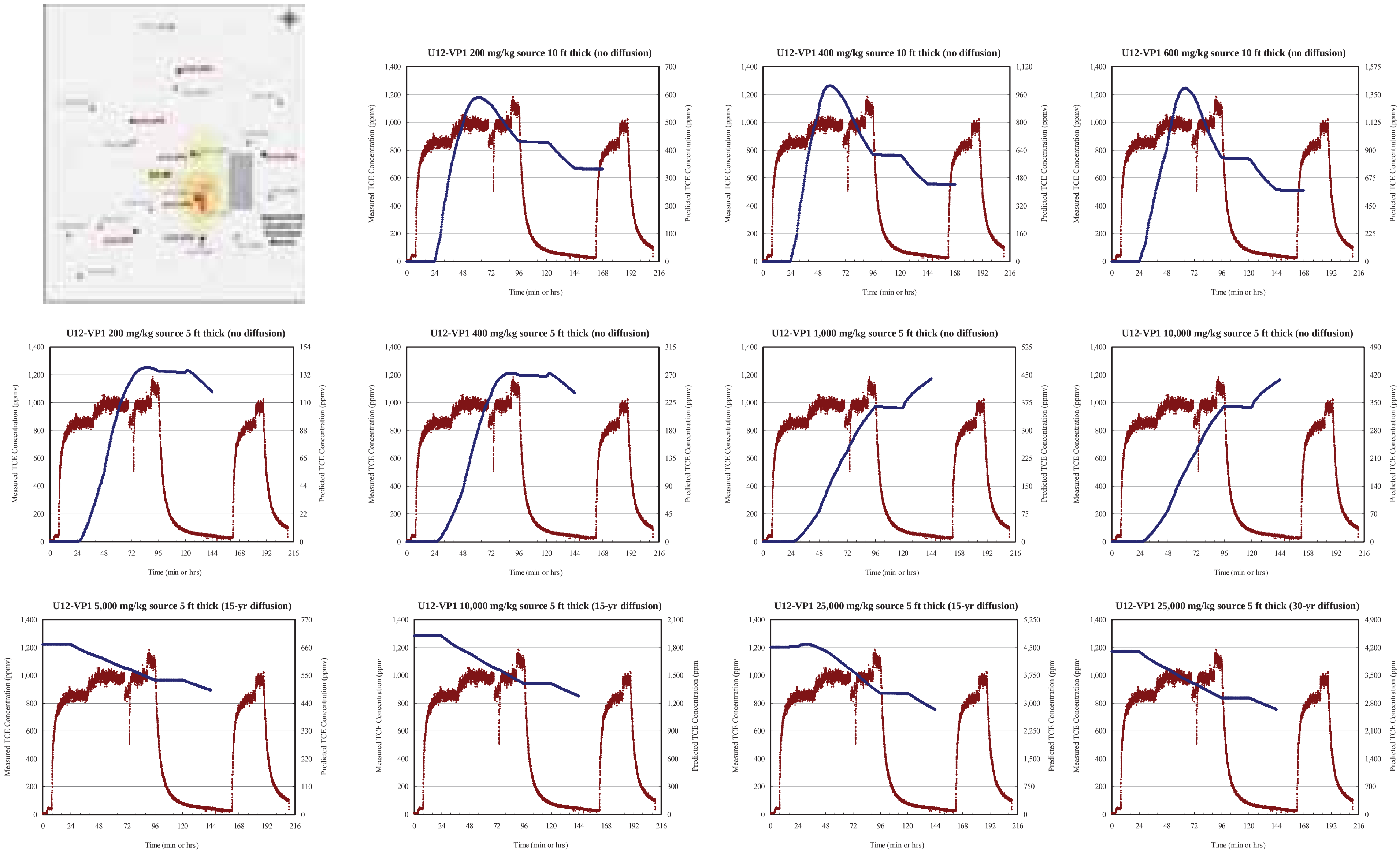


Figure 5-48. Predicted versus measured TCE concentrations at U12-VP1 for source area #9 (predicted concentration shown in blue and measured concentration shown in red).

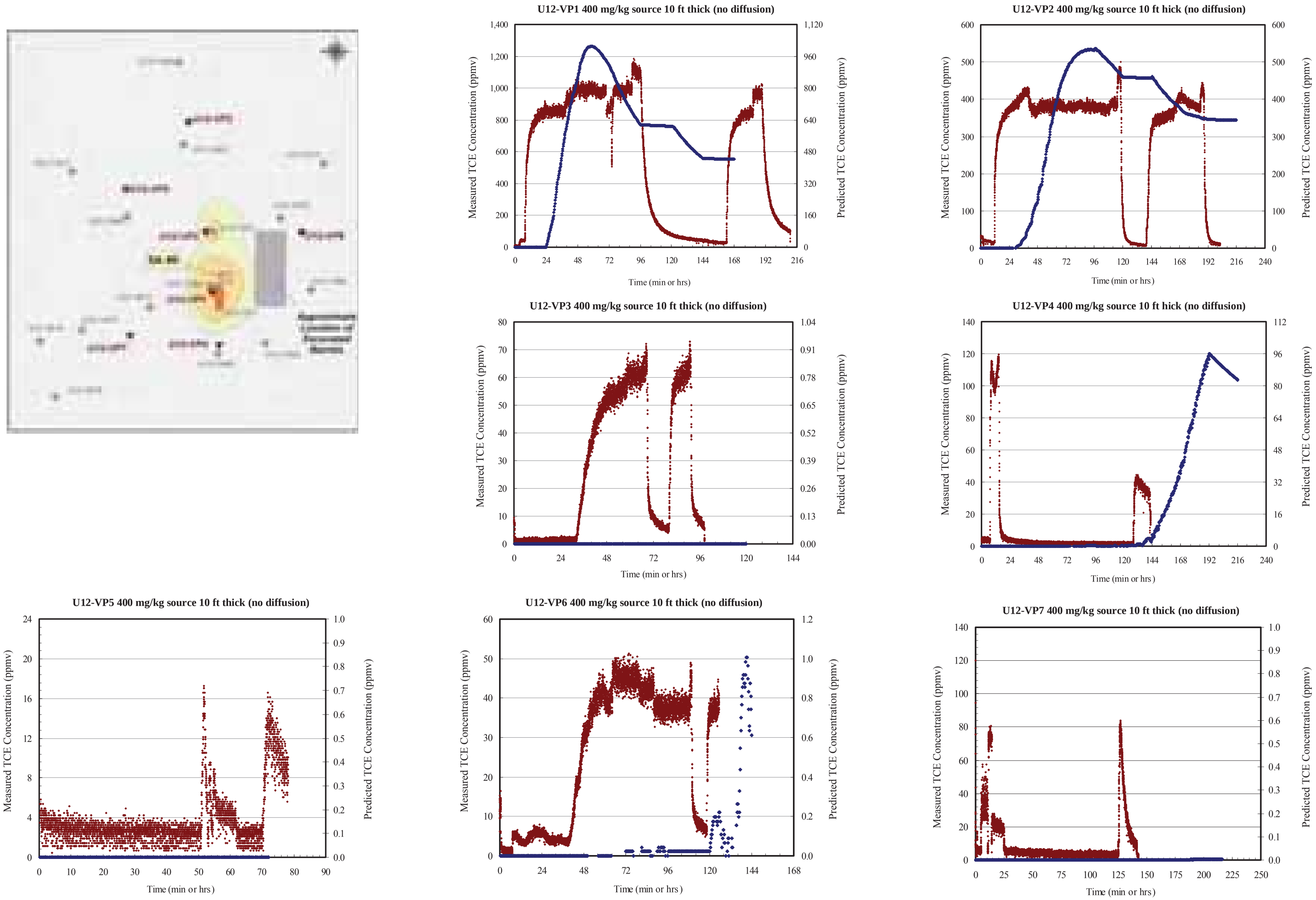


Figure 5-49. Predicted versus measured TCE concentrations at vapor extraction wells for 400 mg/kg TCE in source area #9 (predicted concentration shown in blue and measured concentration shown in red).

A comparison between the predicted and the measured TCE concentration profile in the vapor phase was conducted using the three-dimensional distribution of TCE in the subsurface at OU 12 developed using the EVS-Pro software system (CTECH, 2002) and based on the data collected during the Wireline CPT soil sampling investigation. Since the EVS modeling domain used to develop the distribution of TCE in soil is different than the VENT3D modeling domain, an orthogonal (x,y) grid was created in EVS that was coincident with the grid in VENT3D. Once the orthogonal grid was created, two EVS models were built. The first model consisted of 14 layers with each layer five feet thick and was identical to the VENT3D grid. The ASCII output from EVS was then reformatted for use in VENT3D. The average value was used for each layer because the original EVS model was based on vertical layers of two feet in thickness and not five feet as was used in the VENT3D model for the soil vapor simulations. Using a vertical grid spacing of five feet in EVS rather than two feet results in additional vertical averaging. Thus, the maximum TCE concentration in VENT3D (38.9 mg/kg) is much lower than the maximum TCE concentration in the original EVS soil model (100 mg/kg).

To address the issue of vertical averaging, a second EVS soil model was created and consisted of 70 layers with each layer one foot thick. To generate the TCE concentration at each node (x,y,z) of the VENT3D model, the output from the 70 layer EVS model was segregated into 14 layer-groups of five layers each with each group spanning five feet The maximum TCE concentration at the specified x and y coordinate within each group for each layer was used as the TCE concentration for each VENT3D node. For example, for layer 2 in VENT3D, the maximum at each x and y coordinate was selected from EVS layer-group 2, which consisted of EVS layers six through ten. Thus, the maximum TCE concentration in VENT3D is consistent with the original EVS model.

The EVS transformed TCE source configuration is referred to as source area 10 for the VENT3D simulations. The distribution of TCE in the soil for the bottom 12 layers (i.e., 10 to 70 feet bgs) of the EVS average layer model and the EVS maximum layer model is shown in Figures 5-50 and 5-51, respectively. As is apparent from the figures, the vertical averaging required to transform the 2-foot layers from EVS into 5-foot layers for use in VENT3D resulted in lower overall TCE soil concentrations as well as a smaller distribution of TCE within the modeling domain as that generated with the EVS maximum layer model transformation.

A comparison between the predicted and the measured TCE concentration profiles in the vapor phase at all seven extraction wells for source area 10 is shown in Figures 5-52 and 5-53. The main difference in the predicted TCE vapor concentrations between the EVS average layer model (Figure 5-52) and the EVS maximum layer model (Figure 5-53) occurs for extraction wells U12-VP1, U12-VP2, and U12-VP4. The predicted vapor concentrations at these particular extraction wells are significantly higher for the EVS maximum layer model due to the higher soil concentrations and the close proximity of these wells to the suspected source. However, most notable is that for both concentration scenarios (EVS average layer and EVS maximum layer), the predicted response is significantly different than the actual measured response at all seven extraction wells.

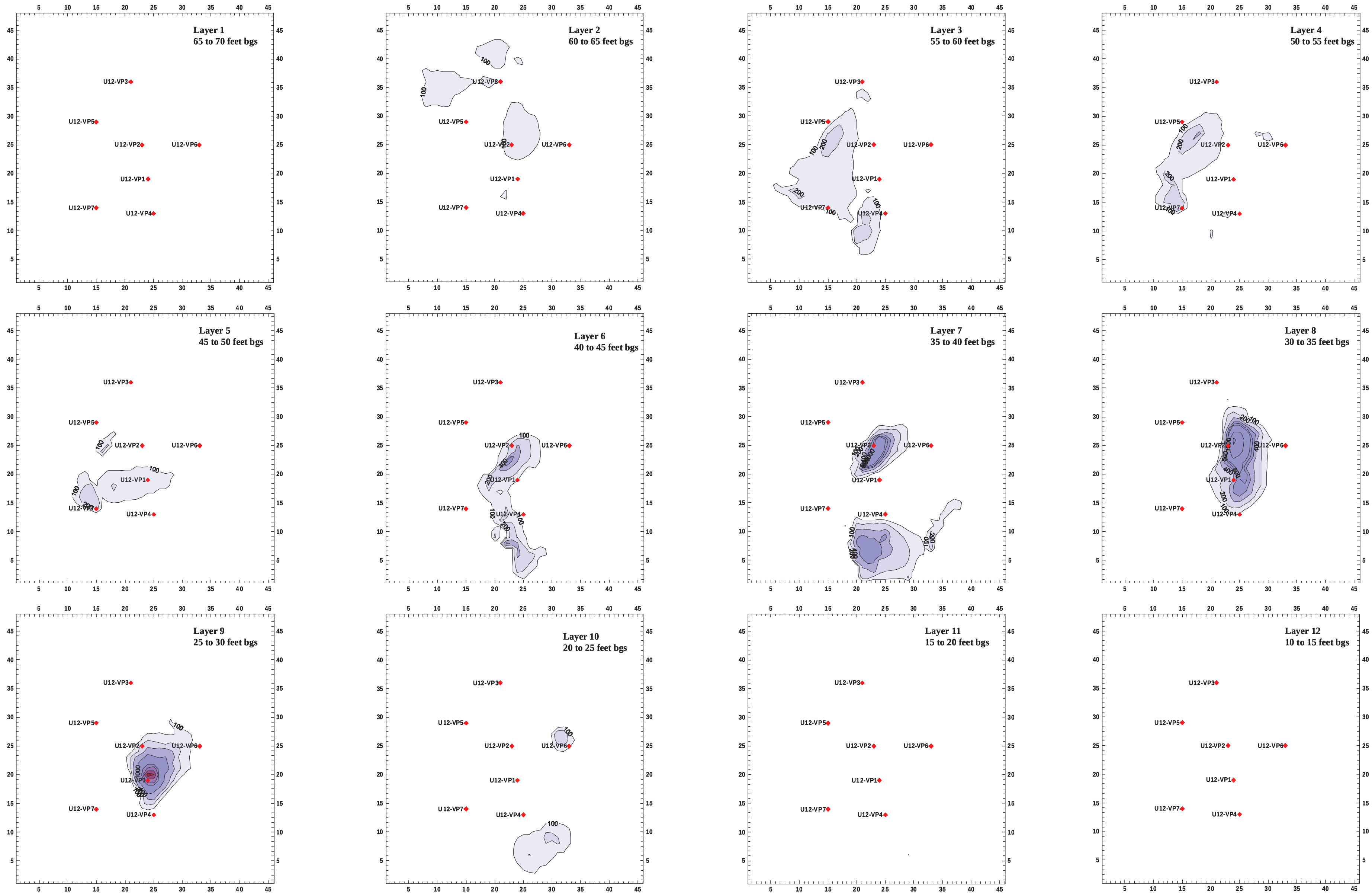


Figure 5-50. Contours of TCE soil concentrations (µg/kg) for source area 10 using the EVS average layer model.

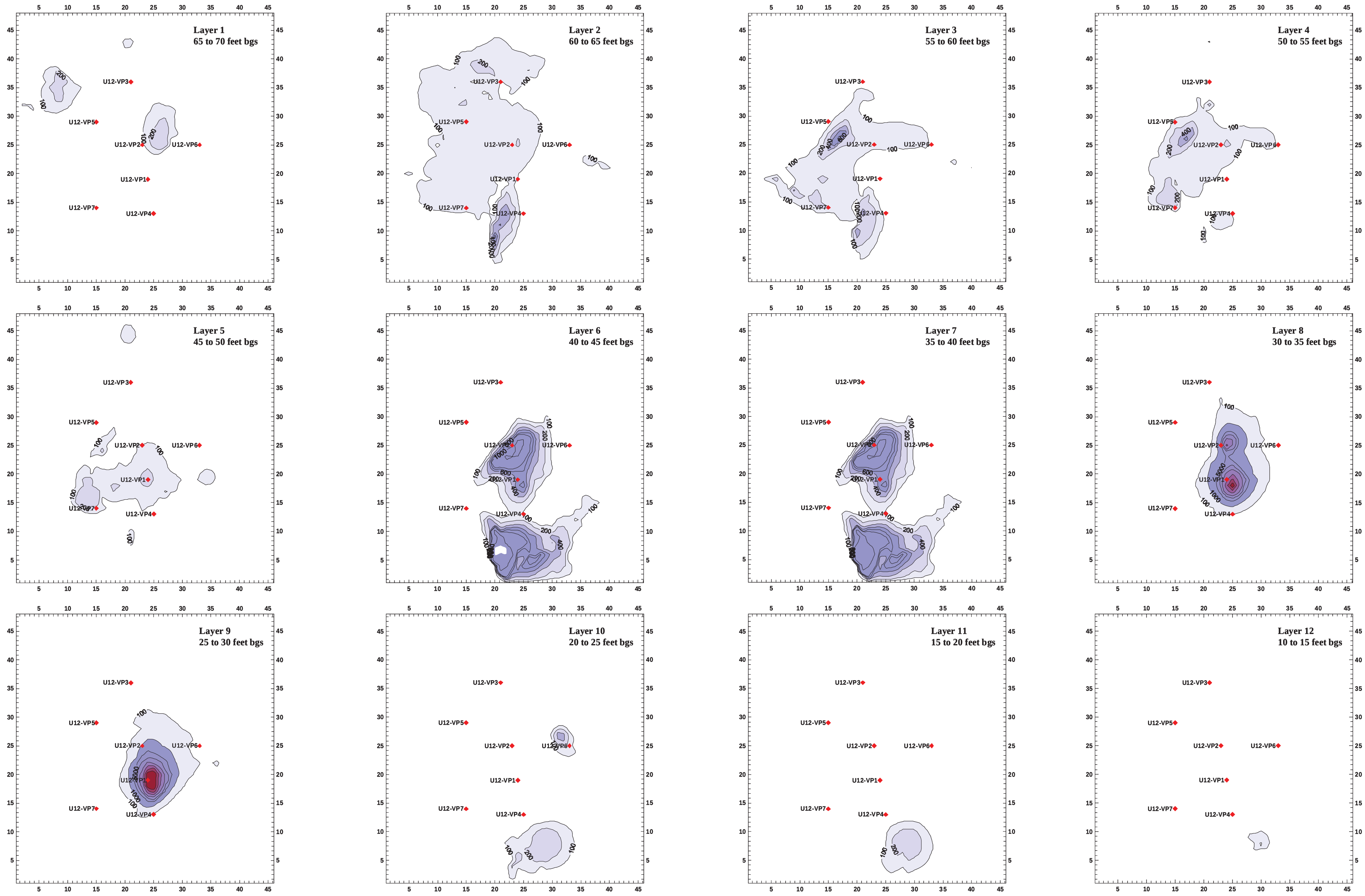


Figure 5-51. Contours of TCE soil concentrations (μg/kg) for source area 10 using the EVS maximum layer model.

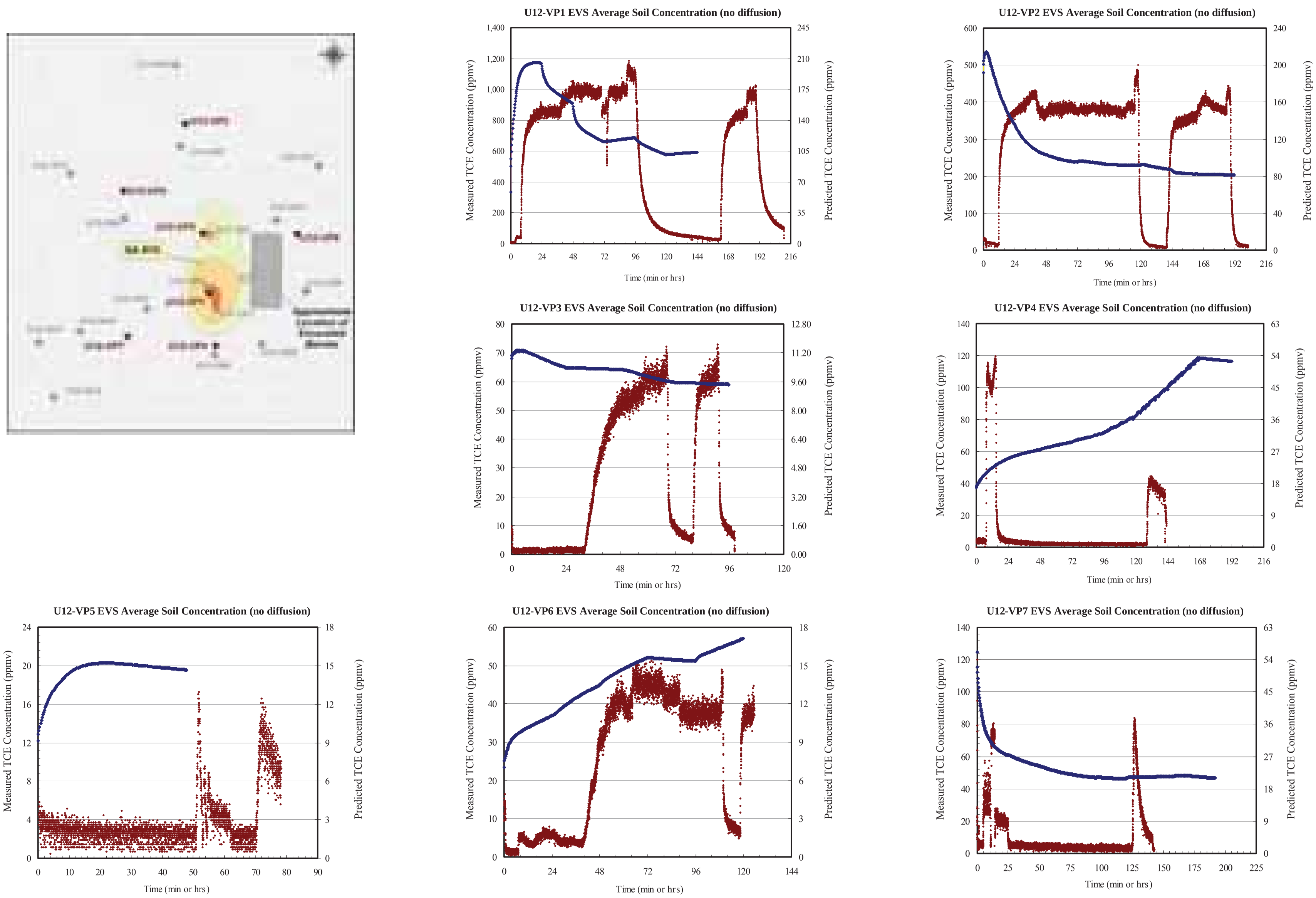


Figure 5-52. Predicted versus measured TCE concentrations at vapor extraction wells for EVS average soil concentrations in source area #10 (predicted concentration shown in blue and measured concentration shown in red).

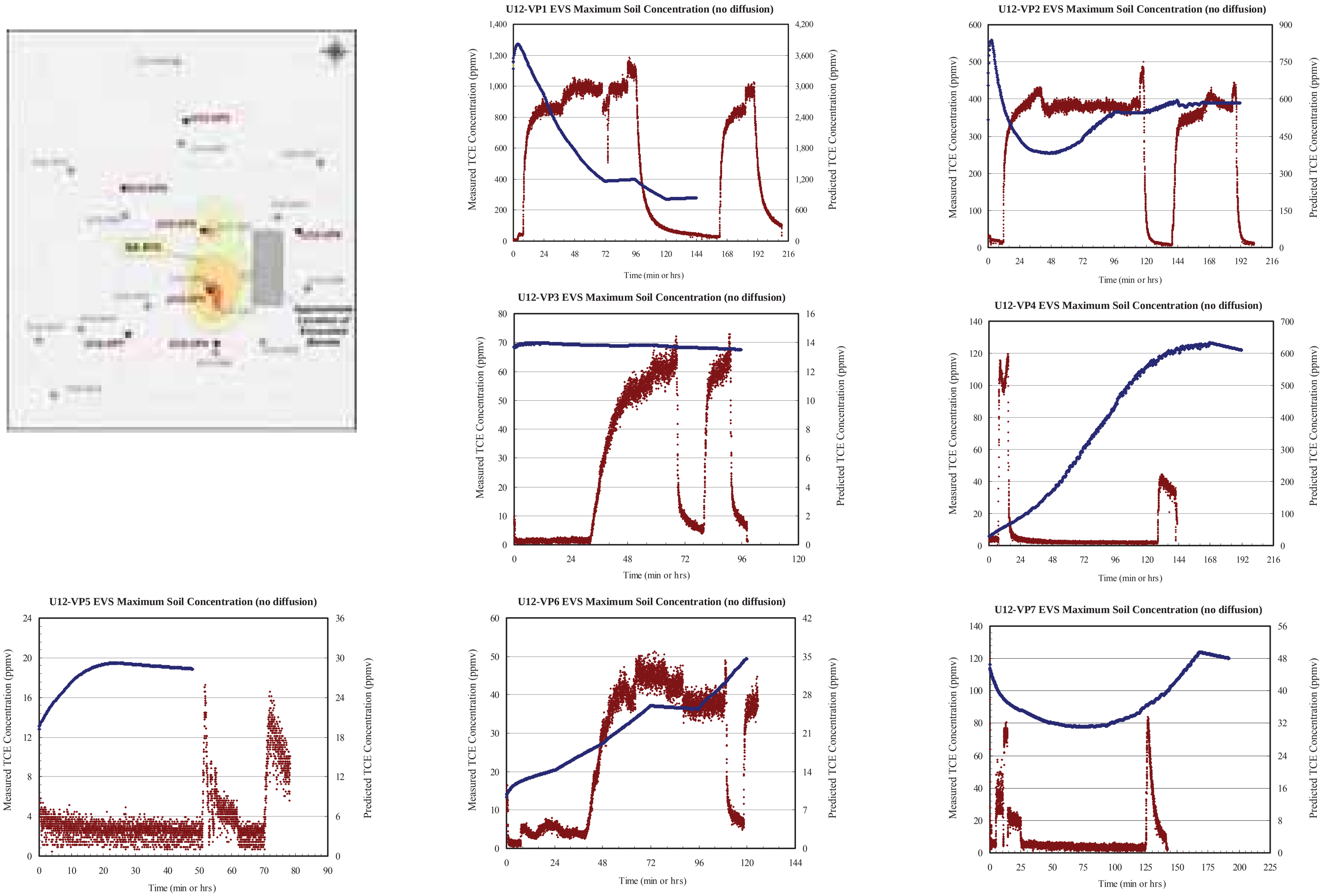
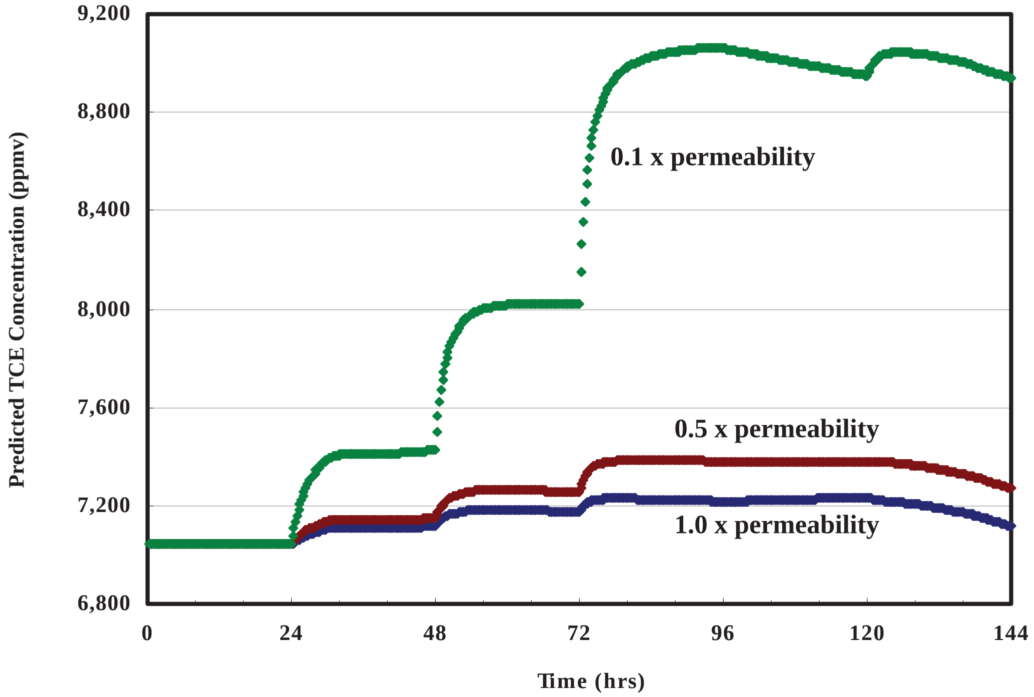


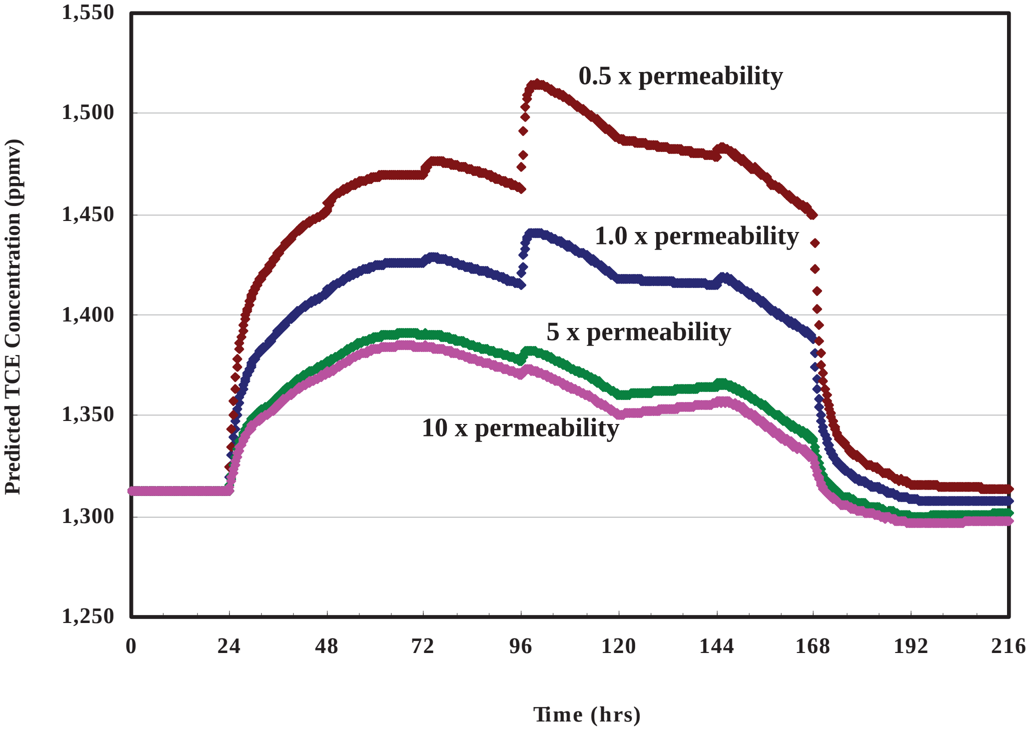
Figure 5-53. Predicted versus measured TCE concentrations at vapor extraction wells for EVS maximum soil concentrations in source area #10 (predicted concentration shown in blue and measured concentration shown in red).

The effects of changing the permeability field on the predicted TCE concentration profile for the vapor phase is shown in Figure 5-54 for U12-VP1 and source area 1, and U12-VP2 and source area 7. As the permeability is decreased, the response to increased blower pressure (vacuum) is accentuated.

Based on the preliminary results of the sequential forward modeling, there does not appear to be a separate immiscible TCE phase present in the investigative area at OU 12. The major contamination appears to be associated with a sorbed fraction and probably a separate LNAPL phase identified during the Wireline CPT soil investigation. It is surmised that the major source of TCE contamination is located in the upper portion of the vadose zone (20 to 35 feet bgs) offset to the east between U12-VP1 and U12-VP2. This is supported by the results of the TCE soil model developed during the soil investigation.



U12-PV1 and Source Area 1 (15,000 mg/kg original concentration)



U12-PV2 and Source Area 7 (25,000 mg/kg original concentration)

Figure 5-54. Permeability effects on the predicted TCE vapor-phase concentration profile.

6.0 COST ANALYSIS

Two innovative investigative techniques were employed in the *OU 12 Source Zone Delineation Demonstration*. The first was the concurrent use of the Wireline CPT soil sampler to rapidly obtain closely spaced (in depth) soil samples from the vadose zone, an on-site DSITMS to obtain immediate analyses of the samples, and three-dimensional modeling of the analytical data to guide placement of subsequent sampling locations. The second was the characterization of the vadose zone using TCE concentration profiles in the vapor phase obtained through the combined application of SVE and DSITMS. In both cases, the rapid availability of analytical results provided by the DSITMS enabled an adaptive (in-the-field adjustments) sampling program that would not have been possible using an off-site laboratory as is customary with a conventional investigation approach. The real-time update of the conceptual site model (CSM) and the use of an adaptive sampling program also reduced the total amount of time required to characterize the area of investigation as compared with time delays normally associated with off-site sample analyses and subsequent data evaluation.

This section provides a cost comparison between conventional and adaptive methods that could be used to investigate a suspected vadose zone source. Four hypothetical investigative methods are compared, two conventional and two adaptive. The two conventional methods of investigation differ by the technique used to advance the boring and collect soil samples and consist of hollow stem auger (HSA) and direct push technology (DPT). The two adaptive methods of investigation are based on the results of this demonstration and consist of (1) a Wireline CPT soil sampler/DSITMS (WS/DSITMS) soil investigation and (2) an SVE/DSITMS investigation.

The comparison between the different methods is based on a suspected source investigation located in the vadose zone of a hypothetical site similar in characteristics to that of OU 12. It is assumed that the upgradient spatial extent and magnitude of a groundwater plume contaminated by dissolved TCE has been previously identified, constraining the general location of the suspected source(s) to within the vadose zone. It is also assumed that the groundwater investigation has provided data regarding the soil stratigraphy in the investigative region. Thus, the objective of each hypothetical investigative method is to characterize the nature and extent of DNAPL contamination in the vadose zone.

Costs associated with field activities for each of the investigative methods are based on the actual field time required to complete the *OU 12 Source Zone Delineation Demonstration*. Other costs were developed using recent subcontractor bids and invoices (drilling and off-site analytical costs) and average rate categories for project personnel (field geologist, field engineer, senior hydrogeologist, and senior engineer). Several tasks, such as project planning, data evaluation and reporting, and preparation of a remedial investigation (RI) report are common to all investigations. In most cases, the costs associated with each of these tasks are very similar, if not identical, regardless of the investigation method. The key differences in cost between the adaptive and conventional investigative methods are due to whether an on-site or off-site laboratory is used, and whether one or two phases of field investigation are necessary to adequate characterize the source. Project management costs were estimated assuming 10% of the primary costs for each investigation.

6.1 Conventional Sampling and Analysis

Two conventional methods of investigation that differ by the technique used to advance the boring and collect soil samples were considered - HSA and DPT. A summary of the major tasks associated with each of these methods of investigation and the estimated cost for each task is summarized in Table 6.1 for HSA and in Table 6.2 for DPT.

For the conventional investigation, it is assumed that soil samples are collected and submitted to an off-site laboratory for volatile organic compound (VOC) analysis. It also is assumed that two distinct phases of field investigation are necessary during a conventional investigation. The second phase of investigation is required to address data gaps remaining after the evaluation of the analytical data generated during the first phase of the investigation. Thus, it is assumed that two separate soil sampling events and subsequent data evaluation periods are required for both hypothetical conventional methods of investigation. Assumptions common to both the HSA and the DPT investigations include:

Phase I Investigation

- The advancement of 17 borings each to 60 feet bgs for a total of 1,020 linear feet.
- The collection of 20 soil samples from each boring, starting at 20 feet bgs with a nominal spacing of 2 feet.
- The collection of quality control (QC) samples at the rate of 10% of the primary samples, for a total of 374 samples (340 primary samples and 34 QC samples).
- Two sample shipments per day for 9 days for a total of 18 shipments for next day delivery.
- Sample analyses at an off-site laboratory for VOCs according to USEPA SW846 Method 8260.

Phase II Investigation

- The advancement of six borings each to 60 feet bgs for a total of 360 linear feet.
- The collection of twenty soil samples from each boring, starting at 20 feet bgs with a nominal spacing of 2 feet.
- The collection of quality control (QC) samples at the rate of 10% of the primary samples, for a total of 132 samples (120 primary samples and 12 QC samples).
- Two sample shipments per day for 3 days for a total of 6 shipments for next day delivery.
- Sample analyses at an off-site laboratory for VOCs according to SW846 Method 8260.

A nominal soil sample spacing of two feet in the vertical extent was assumed to more closely match the nominal sample spacing of one foot achieved during the wireline soil sampling demonstration summarized in this report. Although soil samples could be collected on one-foot intervals using either HSA or DPT to provide a direct comparison with the sample spacing of a wireline investigation, a sample frequency of one foot is typically not used during conventional investigations due to the associated analytical costs. For instance, the total analytical cost estimated for both phases of the hypothetical conventional investigation would increase from approximately $68,000 to $136,000 if the sampling frequency was increased from one- to two-foot intervals.

Table 6-1. Estimated Cost for OU 12 Vadose Zone Investigation Using HSA

Task	Duration (days)	Quantity	Unit	Unit Cost	Total Cost	Assumptions
Project Plans						
Draft Work Plan	40	1	ls	$20,000	$20,000	Assume standard cost and preparation time for project plans (WP, HASP, and SAP).
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Work Plan	21	1	ls	$5,000	$5,000	Assume standard time and cost to respond to comments and modify project plans.
				Subtotal	**$25,000**	
Phase I Investigation						
Coordination and Planning	5	40	hr	$65	$2,600	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Sample Collection	9					
- mobilization/demobilization	---	1	ls	$1,000	$1,000	Mobilization/demobilization cost based on recent quote.
- drilling	---	1020	lf	$19	$19,380	Drill 17 locations to 60 ft bgs (1,020 linear ft) with sample collection every 2 ft starting at 20 ft bgs for a total of 20 samples per location.
- deconning	---	18	hr	$85	$1,530	Assume 9 days drilling with 2 hr/day deconning.
- field geologist	---	108	hr	$65	$7,020	Assume 9 days x 12 hr/day = 108 hrs for field geologist to log cores and collect samples.
- borehole abandonment	---	1020	lf	$5	$5,100	Borehole abandonment based on recent quote.
- sample shipment	---	18	ea	$75	$1,350	Assume overnight shipping includes 2 shipments/day x 9 days = 18 shipments.
Off-Site Laboratory Analysis	15	374	ea	$135	$50,490	Assume 10% QC samples; 20 samples/loc x 17 loc x 1.1 = 374 samples.
				Subtotal	**$88,470**	
Data Evaluation and Reporting						
Update CSM	14	80	hr	$90	$7,200	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
Draft Tech Memo/Sampling Plan	21	60	hr	$90	$5,400	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Tech Memo/Sampling Plan	14	24	hr	$90	$2,160	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
				Subtotal	**$14,760**	
Phase II Investigation (Data Gap Collection)						
Coordination and Planning	5	24	hr	$65	$1,560	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Sample Collection	3					
- mobilization/demobilization	---	1	ls	$1,000	$1,000	Mobilization/demobilization cost based on recent quote.
- drilling	---	360	lf	$19	$6,840	Drill 6 locations to 60 ft bgs (360 linear ft) with sample collection every 2 ft starting at 20 ft bgs for a total of 20 samples per location.
- deconning	---	6	hr	$85	$510	Assume 3 days drilling with 2 hr/day deconning.
- field geologist	---	36	hr	$65	$2,340	Assume 3 days x 12 hr/day = 36 hrs for field geologist to log cores and collect samples.
- borehole abandonment	---	360	lf	$5	$1,800	Borehole abandonment based on recent quote.
- sample shipment	---	6	ea	$75	$450	Assume 2 shipments/day x 3 days = 6 shipments.
Off-Site Laboratory Analysis	15	132	ea	$135	$17,820	10% QC samples; 20 samples/loc x 6 loc x 1.1 = 132 samples.
				Subtotal	**$32,320**	
Remedial Investion (RI) Report						
Update CSM	10	48	hr	$90	$4,320	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
Draft RI Report	30	120	hr	$90	$10,800	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final RI Report	21	40	hr	$90	$3,600	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
ERPIMS Data Package	---	48	hr	$70	$3,360	Laboratory includes ERPIMS-formatted electronic data package.
				Subtotal	**$22,080**	
IDW Disposal (Soil)						
Roll-off and Hazardous Waste Tranportation	---	1	ls	$1,500	$1,500	
Hazardous Waste Disposal (Incineration)	---	34,155	lb	$0.29	$9,905	Assume 1,485 lb TCE-contaminated soil per location using 8.25-inch diameter auger, upper 20 feet uncontaminated, and bulk soil density of 100 lb/cubic foot; 23 total locations.
RCRA State Tipping Fee	---	17	ton	$28	$476	
				Subtotal	**$11,881**	
Travel		18	hr	$65	$1,170	Assume 1.5 hr/day x 18 days (9 days for phase I and 3 days for phase II) local travel for geologist.
Subtotal	313	---	---	---	$195,681	
Project Management	---	---	---	---	$19,568	Assume 10% of project subtotal cost for project management.
Total					**$215,249**	

Table 6-2. Estimated Cost for OU 12 Vadose Zone Investigation Using DPT

Task	Duration (days)	Quantity	Unit	Unit Cost	Total Cost	Assumptions
Project Plans						
Draft Work Plan	40	1	ls	$20,000	$20,000	Assume standard cost and preparation time for project plans (WP, HASP, and SAP).
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Work Plan	21	1	ls	$5,000	$5,000	Assume standard time and cost to respond to comments and modify project plans.
				Subtotal	**$25,000**	
Phase I Investigation						
Coordination and Planning	5	40	hr	$65	$2,600	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Sample Collection	9					
- mobilization/demobilization	---	1.5	hr	$110	$165	Assume local mobilization/demobilization cost.
- DPT rig with operator	---	108	hr	$140	$15,120	Drill 17 locations to 60 ft bgs with sample collection every 2 ft starting at 20 ft bgs for a total of 20 samples per location. Assume 2 locations per day = 9 days x 12 hr/day = 108 hrs.
- drillers assistant	---	108	hr	$45	$4,860	
- field geologist	---	108	hr	$65	$7,020	Assume 9 days x 12 hr/day = 108 hrs for field geologist to log cores and collect samples.
- bentonite grout	---	34	bag	$25	$850	Assume 2 bags of bentonite grout per location; 17 total locations.
- sample shipment	---	18	ea	$75	$1,350	Assume overnight shipping includes 2 shipments/day x 9 days = 18 shipments.
Off-Site Laboratory Analysis	15	374	ea	$135	$50,490	Assume 10% QC samples; 20 samples/loc x 17 loc x 1.1 = 374 samples.
				Subtotal	**$82,455**	
Data Evaluation and Reporting						
Update CSM	14	80	hr	$90	$7,200	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
Draft Tech Memo/Sampling Plan	21	60	hr	$90	$5,400	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Tech Memo/Sampling Plan	14	24	hr	$90	$2,160	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
				Subtotal	**$14,760**	
Phase II Investigation (Data Gap Collection)						
Coordination and Planning	5	24	hr	$65	$1,560	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Sample Collection	3					
- mobilization/demobilization	---	1.5	hr	$110	$165	Assume local mobilization/demobilization cost.
- DPT rig with operator	---	36	hr	$140	$5,040	Drill 6 locations to 60 ft bgs with sample collection every 2 ft starting at 20 ft bgs for a total of 20 samples per location. Assume 2 locations per day =3 days x 12 hr/day = 36 hrs.
- drillers assistant	---	36	hr	$45	$1,620	
- field geologist	---	36	hr	$65	$2,340	Assume 3 days x 12 hr/day = 36 hrs for field geologist to log cores and collect samples.
- bentonite grout	---	12	bag	$25	$300	Assume 2 bags of bentonite grout per location; 6 total locations.
- sample shipment	---	6	ea	$75	$450	Assume 2 shipments/day x 3 days = 6 shipments.
Off-Site Laboratory Analysis	15	132	ea	$135	$17,820	10% QC samples; 20 samples/loc x 6 loc x 1.1 = 132 samples.
				Subtotal	**$29,295**	
Remedial Investion (RI) Report						
Update CSM	10	48	hr	$90	$4,320	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
Draft RI Report	30	120	hr	$90	$10,800	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final RI Report	21	40	hr	$90	$3,600	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
ERPIMS Data Package	---	48	hr	$70	$3,360	Laboratory includes ERPIMS-formatted electronic data package.
				Subtotal	**$22,080**	
IDW Disposal (Soil)						
Drum and Hazardous Waste Tranportation	---	1	ls	$500	$500	Assume three 55-gallon drums of TCE-contaminated soil generated during sampling.
Hazardous Waste Disposal (Incineration)	---	2000	lb	$0.29	$580	Assume 87 lb TCE-contaminated soil per location using 2-inch diameter DPT rod, 40 ft total depth per location, and bulk soil density of 100 lb/cubic foot; 23 total locations
RCRA State Tipping Fee	---	1	ton	$28	$28	
				Subtotal	**$1,108**	
Travel		18	hr	$65	$1,170	Assume 1.5 hr/day x 18 days (9 days for phase I and 3 days for phase II) local travel for geologist.
Subtotal	313	---	---	---	$175,868	
Project Management	---	---	---	---	$17,587	Assume 10% of project subtotal cost for project management.
Total					**$193,455**	

For the conventional investigation, it is assumed that soil samples are analyzed by an off-site analytical laboratory for the full suite of VOC analytes according to USEPA SW846 Method 8260. This is in contrast to the adaptive investigations that employ an on-site laboratory using DSITMS to analyze the soil samples for an abbreviated analyte list (TCE, PCE, DCE, and vinyl chloride) according to USEPA SW846 Method 8265. The costs associated with project planning, data evaluation and reporting, and the preparation of a RI report are assumed identical for both the HAS and DPT investigations.

6.1.1 Hollow Stem Auger (HSA)

The total estimated cost of a hypothetical HSA investigation is $215,250 (see Table 6-1) representing the highest cost of the four hypothetical investigations considered as part of this analysis. By comparison, the estimated costs associated with the other investigative methods are $193,460 ($21,790,or 10% less) for DPT, $149,620 ($65,630, or 30% less) for WS/DSITMS; and $125,100 ($90,150, or 42% less) for SVE/DSITMS.

Two primary reasons account for the elevated cost associated with the HSA investigation: (1) direct drilling costs and (3) the investigative-derived waste (IDW) disposal charges. Direct drilling costs include the expense of mobilization and demobilization, actual drilling costs, the cost to decontaminate equipment during and after drilling operations, and borehole abandonment. The total direct drilling costs for both phases of the HSA investigation are $37,160. This is compared to $28,120 in direct drilling for the DPT investigation, a difference of $9,040 or 24% less (decontamination is not shown as a separate line item but is included in the hourly equipment and field crew rate for the DPT investigation). The cost of IDW disposal for the HSA investigation is $11,880 and is estimated assuming an 8.25-inch auger and 40 feet of contaminated soil (upper 20 feet of vadose zone is assumed uncontaminated) in each of 23 borings. If a 6-inch auger is used, the IDW disposal cost is reduced by approximately $5,500. In either case, IDW disposal cost is considerably more than the estimate $1,100 incurred during the DPT investigation. The difference in the IDW disposal cost is due to the larger diameter boring and subsequent increase in the volume of contaminated waste generated with the HSA investigation.

Although the HSA investigation is estimated to be the most expensive, it does have some advantages over other investigative techniques. One advantage associated with HSA is the ability to construct a well in a boring following soil sampling. The decision to construct a well may be based on field observations, or may part included in the original investigation plan. With any of the other investigative techniques considered as part of this cost analysis, the decision to construct a well would incur additional drilling costs. In addition, HSA is more robust than DPT in terms of penetration into the vadose zone. Although HSA may encounter difficulty penetrating gravels and cobbles, it is likely to be more successful in these soils than DPT. Finally, HSA allows for the continuous logging of soil cores during a soil sampling investigation whereas continuous logging cannot adequately be performed using WS/DSITMS.

6.1.2 Direct Push Technology (DPT)

The total estimated cost of the hypothetical DPT investigation is $193,460, approximately 10% less than the estimated cost of a HSA investigation. The difference in cost between the DPT and the HSA investigative techniques was presented in the previous section, and is primary associated with a reduction in the direct drilling costs and IDW disposal charges.

6.2 Adaptive Sampling and Analysis

The details of the WS/DSITMS and SVE/DSITMS investigative techniques were presented in Sections 3.0 and 4.0, respectively, of this report. The distinguishing feature of these adaptive techniques is that new sampling locations are selected in the field, based on the real-time evaluation of the analytical data from previous locations. This is possible because of the rapid availability of soil contamination due to the on-site DSITMS and real-time update of the CSM. Although the on-site DSITMS enables data evaluation to be conducted in tandem with the fieldwork, its daily cost of $3,500 means that downtime in the field, for any reason, carries a heavy expense burden. For example, the cost of the DSITMS is incurred regardless of reduced sample collection frequency associated with drill-rig mechanical problems or penetration refusal. For this cost analysis, contingency and/or downtime are not included in the final cost estimates.

Unlike the two conventional investigative techniques previously discussed, which differ primarily by the method used to penetrate the vadose zone, the two adaptive techniques are fundamentally different. The WS/DSITMS investigation relies on closely spaced (vertically) soil samples, on-site analytical results, and rapid evaluation of the results through the use of three-dimensional computer modeling. The SVE/DSITMS investigation uses VOC time-series data in the extracted vapor at various well locations screened across differing intervals in the vadose zone to identify region(s) of contamination to be further characterized under a limited soil sampling program. This approach differs from that used during the *OU 12 Source Zone Delineation Demonstration* in that the sequential forward modeling used to further characterize the suspected source has been replaced with a small-scale soil sampling program utilizing DPT with DSITMS. A summary of the major tasks associated with each of these methods of investigation and the estimated cost for each task is summarized in Table 6.3 for WS/DSITMS and in Table 6.4 for SVE/DSITMS.

6.2.1 Wireline Sampler/DSITMS (WS/DSITMS)

The estimated total cost of the WS/DSITMS investigation is $149,620 (see Table 6-3), approximately $65,630 (30%) less than the cost of the HSA investigation and $43,840 (23%) less than the DPT investigation. However, the WS/DSITMS is approximately $24,500 more than the SVE investigation.

The reduced cost of the adaptive investigative techniques in comparison with the two conventional investigation techniques is due primarily to a single phase of field investigation; the second phase has been eliminated because data gaps are identified simultaneously with the fieldwork conducted during the initial phase. Because each new sampling location is selected based on all of the currently available data

Table 6-3. Estimated Cost for OU 12 Vadose Zone Investigation Using Wireline/DSITMS

Task	Duration (days)	Quantity	Unit	Unit Cost	Total Cost	Assumptions
Project Plans						
Draft Work Plan	40	1	ls	$20,000	$20,000	Assume standard cost and preparation time for project plans (WP, HASP, and SAP).
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Work Plan	21	1	ls	$5,000	$5,000	Assume standard time and cost to respond to comments and modify project plans.
				Subtotal	**$25,000**	
Phase I Investigation						
Coordination and Planning	5	40	hr	$65	$2,600	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Sample Collection	9					
- mobilization/demobilization	---	1	ls	$1,000	$1,000	Assume mobilization/demobilization cost from outside local area.
- CPT rig with wireline tool assembly	---	9	day	$3,500	$31,500	Drill 17 locations to 60 ft bgs with sample collection every 1 ft starting at 20 ft bgs for a total of 600 samples. Assume 2 locations per day = 9 days x 12 hr/day = 108 hrs.
- field engineer	---	108	hr	$85	$9,180	
- field geologist	---	108	hr	$65	$7,020	Assume 9 days x 12 hr/day = 108 hrs for field geologist to log cores and collect samples.
On-Site Laboratory Analysis	---	9	day	$3,500	$31,500	Analyses for TCE, PCE, DCE, and vinyl chloride; assumes no off-site confirmation analyses.
Continous CSM Update	---	68	hr	$115	$7,820	Includes 32 hrs initial model setup and an average of 4 hrs/day for 9 days to update the model.
				Subtotal	**$90,620**	
Remedial Investion (RI) Report						
Final Update of CSM	10	12	hr	$90	$1,080	Assumes model was continuously updated during field investigation task.
Draft RI Report	30	120	hr	$90	$10,800	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final RI Report	21	40	hr	$90	$3,600	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
ERPIMS Data Package	---	48	hr	$70	$3,360	No ERPIMS-formatted electronic data package from field lab but abbreviated analyte list.
				Subtotal	**$18,840**	
IDW Disposal (Soil)						
Drum and Hazardous Waste Tranportation	---	1	ls	$250	$250	Assume 30 gallons of TCE-contaminated soil generated during sampling.
Hazardous Waste Disposal (Incineration)	---	370	lb	$0.29	$107	Assume 370 lb TCE-contaminated soil per location using 1-inch diameter DPT rod, 40 ft total depth per location, and bulk soil density of 100 lb/cubic foot; 17 total locations
RCRA State Tipping Fee	---	1	ton	$28	$28	
				Subtotal	**$385**	
Travel		18	hr	$65	$1,170	Assume 1.5 hr/day x 18 days (9 days for phase I and 3 days for phase II) local travel for geologist.
Subtotal	196	---	---	---	$136,015	
Project Management	---	---	---	---	$13,602	Assume 10% of project subtotal cost for project management.
Total					**$149,617**	

Table 6-4. Estimated Cost for OU 12 Vadose Zone Investigation Using SVE/DSITMS

Task	Duration (days)	Quantity	Unit	Unit Cost	Total Cost	Assumptions
Project Plans						
Draft Work Plan	40	1	ls	$20,000	$20,000	Assume standard cost and preparation time for project plans (WP, HASP, and SAP).
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final Work Plan	21	1	ls	$5,000	$5,000	Assume standard time and cost to respond to comments and modify project plans.
				Subtotal	**$25,000**	
SVE Investigation						
Coordination and Planning	5	40	hr	$65	$2,600	Includes subcontractor coordinate, site preparation, utilities clearance, cleanup, and IDW disposal.
Vapor Probe Well Installation	1					
- mobilization/demobilization	---	1.5	hr	$110	$165	Assume local mobilization/demobilization cost.
- DPT rig with operator	---	10	hr	$140	$1,400	Assume seven 0.75-inch diameter vapor extraction wells installed from approx. 30 to 50 ft bgs.
- field geologist	---	10	hr	$65	$650	Assume 10 hrs for field geologist oversight.
- materials	---	7	ea	$250	$1,750	Assume $250 per well based on actual costs.
SVE Process System Setup	4					
- field engineer	---	40	hr	$85	$3,400	Assume 10 hrs per day for 4 days to construct skid-mounted SVE process system.
- field geologist	---	40	hr	$65	$2,600	Assume 10 hrs per day for 4 days to construct skid-mounted SVE process system.
- materials	---	1	ls	$1,000	$1,000	Includes 0.75-inch PVC piping, rotometers, and vacuum guages.
SVE Operations	5					
- field engineer	---	60	hr	$85	$5,100	Assumes 12 hrs per day for 5 days to conducted step tests at 7 locations.
- field geologist	---	60	hr	$65	$3,900	Assumes 12 hrs per day for 5 days to conducted step tests at 7 locations.
- field generator and diesel	---	5	day	$125	$625	Includes generator and diesel cost to operator blower 12 hrs per day for 5 days.
- on-site laboratory analysis	---	5	day	$3,500	$17,500	Analyses for TCE, PCE, DCE, and vinyl chloride; assumes no off-site confirmation analyses.
- data evaluation	---	24	hr	$115	$2,760	Assumes 24 hrs for engineer to evaluate SVE data and make recommendations for soil sampling.
				Subtotal	**$43,450**	
Limited Soil Investigation						
Coordination and Planning	---	8	hr	$65	$520	Assumes addition 8 hrs of labor for coordination to transition from SVE to soil sampling.
Sample Collection	3					
- mobilization/demobilization	---	1.5	hr	$110	$165	Assume local mobilization/demobilization cost.
- DPT rig with operator	---	36	hr	$140	$5,040	Drill 6 locations to 60 ft bgs with sample collection every 2 ft starting at 20 ft bgs for a total of 20 samples per location. Assume 2 locations per day = 3 days x 12 hr/day = 36 hrs.
- drillers assistant	---	36	hr	$45	$1,620	
- field geologist	---	36	hr	$65	$2,340	Assume 3 days x 12 hr/day = 36 hrs for field geologist to log cores and collect samples.
- bentonite grout	---	12	bag	$25	$300	Assume 2 bags of bentonite grout per location; 6 total locations.
- on-site laboratory analysis	---	3	day	$3,500	$10,500	Analyses for TCE, PCE, DCE, and vinyl chloride; assumes no off-site confirmation analyses.
				Subtotal	**$20,485**	
Remedial Investion (RI) Report						
Update of CSM	10	48	hr	$90	$4,320	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
Draft RI Report	30	120	hr	$90	$10,800	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
USAF Review	30	---	---	---	---	Assume standard 30-day review cycle.
Final RI Report	21	40	hr	$90	$3,600	Assume an average rate of $65/hr for geologist and $115/hr for hydrogeologist/engineer.
ERPIMS Data Package	---	48	hr	$70	$3,360	No ERPIMS-formatted electronic data package from field lab but abbreviated analyte list.
				Subtotal	**$22,080**	
IDW Disposal (Soil)						
Drum and Hazardous Waste Tranportation	---	1	ls	$250	$250	Assume 40 gallons of TCE-contaminated soil generated during sampling.
Hazardous Waste Disposal (Incineration)	---	525	lb	$0.29	$152	Assume 525 lb TCE-contaminated soil per location using 2-inch diameter DPT rod, 40 ft total depth per location, and bulk soil density of 100 lb/cubic foot; 6 total locations
RCRA State Tipping Fee	---	1	ton	$28	$28	
				Subtotal	**$430**	
Travel		35	hr	$65	$2,275	Assume 1.5 hr/day for 13 days for field geologist and 10 days for field engineer.
Subtotal	200	---	---	---	$113,720	
Project Management	---	---	---	---	$11,372	Assume 10% of project subtotal cost for project management.
Total					**$125,092**	

and the three-dimensional numerical modeling of soil contamination generated during the investigation, data gaps are identified prior to demobilizing from the site. Based on the experience from the *OU 12 Source Zone Delineation Demonstration,* it is feasible to update/refine the soil contamination model with the analytical data obtained from the most recent boring prior to mobilizing the CPT rig to the next sampling location. In addition, the WS/DSITMS investigation eliminates the data evaluation and reporting task typically required during a conventional investigation.

The total cost for a single phase of fieldwork and sample analyses in the WS/DSITMS investigation is $90,620, compared with $120,790 and $111,750 for two phases in the HSA investigation and DPT investigation, respectively. An additional cost of $14,760 is incurred during the conventional investigative approaches for data evaluation and reporting following the first phase of fieldwork. The data evaluation and reporting task is required to identify data gaps associated with the initial phase of sampling and develop a sampling and analysis plan to fill those gaps in order to adequate characterize the suspected source zone. By eliminating the need for a second phase of field investigation, the overall timeframe for making subsequent decisions is reduced. This results in a shorter timeframe by which to make investigative and/or remediation decisions and ultimately can reduce the lifecycle costs associate with a site.

Although the WS/DSITMS investigation does not require a separate data evaluation and reporting task between field sampling events, it does require the development of a site model to guide sample collection. For the WS/DSITMS investigation, it is assumed that $3,680 (32 hours of a senior hydrogeologist/engineer) is required to refine the site model from the work plan prior to the start of fieldwork. During field activities, it is assume that an additional $4,140 (4 hours per day for 9 days of a senior hydrogeologist/engineer) is required to continuously update/refine the site model with the most recently collected site data. Because the site model is built and continuously updated in the field, less time is required during the RI reporting stage to generate the final version of the CSM, thus reducing the overall cost of the RI report. In addition to a reduction in cost, one of the main advantages of the WS/DSITMS investigative approach is data density and the consequent improvement in the model of VOC contamination in the vadose zone. The nominal vertical spacing between soil samples is 1 foot for the WS/DSITMS investigation, compared to 2 feet for the conventional investigative techniques. Ultimately, the higher data density achieved in the WS/DSITMS investigation results in a very detailed model of vadose zone contamination. Decreasing the spacing to 1 foot during the conventional investigations doubles the analytical expense, significantly increasing total project costs.

In spite of its advantages, the WS/DSITMS investigation has some limitations. Flexibility in selecting a soil sample is lost, because a sample can only be collected from either end of the 1-inch diameter and 1-foot long stainless steel sampling tube. A related drawback is the inability to continuously log soil stratigraphy. At best, a one-foot composite soil type can be identified, based on the material removed from the sampling tube when it is cleaned. Moreover, none of the traditional CPT logging data is collected with the Wireline CPT sampler, precluding the inference of soil stratigraphy from CPT logs. The method is also constrained by the ability of the CPT rig to push, making the method difficult to apply in gravelly and cobbly soils, and also limiting the method to relatively shallow (<75 feet) depths. Finally, although a key premise of the investigation is that it is limited to the vadose zone, it is important to note that the Wireline CPT sampler cannot obtain samples from the saturated zone. Thus, an alternative method is required to investigate potential source(s) below the groundwater elevation.

6.2.2 Soil Vapor Extraction/DSITMS (SVE)

The total estimated cost of a hypothetical SVE/DSITMS investigation is $125,100 (see Table 6-4) representing the lowest cost of the four hypothetical investigations considered as part of this analysis. The cost of the SVE/DSITMS is $90,160 (42%) less than the HSA investigation, $68,360 (35%) less than the DPT investigation, and $24,520 (16%) less than the WS/DSITMS investigation.

The SVE investigation is qualitatively different than other hypothetical investigations because the initial phase of investigation involves the analysis of soil vapor extracted from a suite of 7 borings located within the suspected area of soil contamination. The borings may or may not be screened across different depth intervals. This comparison assumes that the 7 vapor extraction wells are installed from approximately 30 to 50 feet bgs. The on-site DSITMS provides soil vapor concentration data at very short time increments during step tests conducted at each vapor extraction well (see Section 4 of this report). In-the-field evaluation of the VOC concentration time-series data in the vapor phase narrows the size of the suspected source area, and a limited-scope soil investigation consisting of 6 DPT borings is conducted to refine the characterization. The borings are advanced to 60 feet bgs with sampling beginning at 20 feet bgs with a nominal 2-foot vertical spacing between samples. Soil samples are analyzed using the on-site DSITMS.

For this cost analysis, it is also assumed that a blower for SVE is available and does not need to be purchased. If it is necessary to purchase a blower, the cost of the SVE investigation would increase by approximately $5,000. In addition, it is assumed that the VOC time-series data is used to identify soil boring locations and that multiphase, multicomponent numerically modeling of the vapor phase is not required. Although extensive numerical simulation of the SVE step tests were performed as part of the *OU 12 Source Zone Delineation Demonstration* to evaluate the concentration time series data, the results appeared to have limited value in the refinement of the source location. Thus, the hypothetical SVE/DSITMS investigation does not include numerical modeling of the vapor phase but recommends a limited-scope (6 borings) soil investigation for further refinement of the source zone. If two additional borings are required to adequately refine the source zone, the additional expense is approximately $5,000.

The cost advantage of the SVE investigation compared to the other hypothetical investigation techniques is mainly associated with the reduced cost of field operations. The combined cost of the SVE step tests and the subsequent limited-scope DPT soil investigation is $63,940, including the cost of the on-site DSITMS. This is $56,860 (47%) less than fieldwork and laboratory expenses for the HSA investigation, $47,820 (43%) less than for the DPT investigation, and $26,690 (29%) less than for the WS/DSITMS investigation.

6.3 Summary

A cost comparison summary for each of the hypothetical investigative approaches is shown in Table 6-5. The two conventional investigative approaches are the most expensive, primarily because both include two phases of field activity separated by a data evaluation and reporting task. The HSA investigation incurs a very high cost associated with the disposal of IDW because of the comparatively larger diameter auger used to advance the boring for sample collection. However, HSA may be the most versatile of the investigative methods considered in this analysis due to its ability to penetrate through gravels and cobbles and the ability to complete a well following soil sampling activities.

Adaptive investigations reduce investigative costs and eliminate the need for multiple phases of fieldwork separated by weeks of sample analyses time. This is achieved through the use of on-site analytical capabilities and data evaluation being conducted concurrent with data acquisition. New sampling locations are selected adaptively based on the evaluation of all previously acquired analytical data.

The WS/DSITMS investigation is the most costly of the adaptive investigative techniques, but also results in the most detailed model of soil contamination in the vadose zone. The advantages of SVE/DSITMS as a characterization tool are the relative ease and low-cost of implementation, the large volume of the unsaturated zone affected, and the extensive amount of data collected as compared to soil borings. Each step test investigates a large volume of the unsaturated zone and can provide pneumatic data pertaining to the vadose zone, including radius of influence and bulk *in situ* air permeability for each vent well. An ancillary benefit associated with a SVE/DSITMS investigation is the potential to substantially remediate a source zone while characterizing it.

Table 6-5. Summary of Estimated Costs for Hypothetical Vadose Zone Investigations

Task	HSA	DPT	Wireline	SVE
Project Plans	$25,000	$25,000	$25,000	$25,000
Phase I Investigation	$88,470	$82,455	$90,620	$63,935
Data Evaluation and Reporting	$14,760	$14,760	NA	NA
Phase II Investigation (Data Gap Collection)	$32,320	$29,295	NA	NA
Remedial Investion (RI) Report	$22,080	$22,080	$18,840	$22,080
IDW Disposal (Soil)	$11,881	$1,108	$385	$430
Travel	$1,170	$1,170	$1,170	$2,275
Subtotal	$195,681	$175,868	$136,015	$113,720
Project Management	$19,568	$17,587	$13,602	$11,372
Total	**$215,249**	**$193,455**	**$149,617**	**$125,092**

Notes:
SVE phase I investigation consists of SVE at 7 vapor extraction wells followed by a limited DPT soil sampling program.
NA = not aplicable.

7.0 CONCLUSIONS AND RECOMMENDATIONS

A *Source Zone Delineation Demonstration* was conducted in the suspected source area at OU 12 to investigate VOC contamination in the vadose zone using rapid decision-making based on real-time data collected in the field. Conclusions and recommendations presented in this section are based on the results of the demonstration provided in Section 5.0 of this report.

7.1 Demonstration Results

The *Source Zone Delineation Demonstration* consisted of two technology demonstrations – (1) wireline cone penetrometer system for multiple tool usage and (2) soil vapor extraction for vadose zone characterization. Sampling and analysis were conducted in the field using DSITMS due to the rapid soil sampling capability of the wireline tool and to obtain adequate characterization of vapor-phase contaminant concentration profiles as a function of time across a varied flow regime. The results of each demonstration, including the capabilities of the DSITMS field analytics are discussed below.

7.1.1 Wireline CPT Soil Sampling

The Wireline CPT demonstration was conducted within the vadose zone and capillary fringe underlying the general area defined as the suspected source zone at OU 12. During the first four days of soil sampling using the Wireline CPT sampler, approximately 205 soil samples were collected from vertical traces at 5 discrete locations (approximately 50 samples per day). During the last five days of field operations, approximately 395 soil samples were collected from vertical traces at 11 discrete locations (approximately 80 samples per day). In total, 599 soil samples were collected from vertical traces at 16 discrete locations during the nine working days of the Wireline CPT demonstration. The increase in sample collection (approximately 38%) that occurred during the last five days of field operations was associated with several aspects of the demonstration, including the arrival of additional soil samplers for the Wireline CPT tool and an experienced Wireline CPT operator. Additionally, the decision not to collect samples from the upper gravelly sand zone that extended from approximately 18 to 22 feet bgs decreased the amount of soil that was lost from the Wireline soil sampler within the CPT rod. This resulted in a dramatic reduction in the accumulation of soil/grit in the interior of the locking and retrieval mechanism of the Wireline tool assembly.

The Wireline CPT tool was successful in collecting a large number of soil samples from the vadose zone in a short investigative timeframe. However, several aspects of the Wireline CPT tool must be carefully considered prior to using this technology for future investigative activities, including:

- Poor sample recovery resulted in the accumulation of dirt/grit in the locking and retrieval mechanism of the Wireline tool. Subsequently, a significant amount of time was spent trying to lock and unlock the Wireline tool, and on several occasions the Wireline CPT rod had to be retracted in order to clean the interior of the locking and retrieval mechanism. It is recommended that deployment of a sample catcher on the end of the Wireline CPT soil sampler be investigated to increase sample collection efficiency.

- The Wireline CPT tool is not effective at collecting soil samples below the capillary fringe, within the saturated zone. This limits the capability of the Wireline CPT tool to investigations conducted within the vadose zone and the upper portion of the capillary fringe underlying the vadose zone.
- The Wireline CPT soil sampler utilizes 1-foot long and 1-inch diameter hollow rods to obtain a soil core from which sample collection is facilitated from the ends of the rods. Since the soil cores cannot be extruded from the rods for inspection, accurate geologic logging of the cores is essentially impossible. Additionally, none of the traditional CPT sensor data are available in conjunction with the Wireline CPT soil sampler. Thus, the collection of stratigraphic information during sample collection is not possible when using the Wireline CPT soil sampler.
- Sample collection using the Wireline CPT soil sampler must occur from the ends of the 1-inch diameter rods and thus, soil samples cannot be collected from geologic contacts where NAPL would be expected to occur.
- Implementation of the technology requires an experienced Wireline CPT operator in order to conduct an investigation effectively. Without an experienced operator, sample collection frequency is significantly reduced and may result in appreciable downtime.

7.1.2 SVE for Characterization

The SVE demonstration conducted in the suspected source zone at OU 12 focused on step tests for estimating TCE distribution within the vadose zone of the investigative area using a multiphase, multicomponent numerical model. The TCE time-series data collected during the OU 12 SVE demonstration were compared with simulated time-series data using a theoretical distribution of TCE mass in the zone of influence and a sequential forward numerical modeling scheme in an attempt to help delineate source-zone contamination in the vadose zone of the investigative area. Although the step tests were optimized to assess contaminant distribution within the vadose zone of the investigative area, the data also provide an indication of the pneumatic response of the subsurface at OU 12 during vapor extraction operations. Based on a maximum radial extent of induced subsurface vacuum of 0.01 inch of water, the zone of pneumatic influence observed during the OU 12 SVE demonstration ranged from approximately 50 to 80 feet in the southern section of the investigative area to over 100 feet in the northern section. The average zone of pneumatic influence within the investigative area was approximately 85 feet. The average *in situ* air permeabilities observed during vapor extraction operations is typical of the fine-grained material in the vadose zone at OU 12 and ranged from 5 to 20 Darcy with a geometric mean of approximately 10 Darcy.

Over 160 theoretical source configurations were simulated numerically during the demonstration. The best correlation between the predicted and measured TCE vapor-phase concentration profile was obtained using a theoretical TCE source located approximately 8 feet northwest of U12-VP1 and 19 feet southeast of U12-VP2. This source was assumed to be 5 feet by 5 feet in areal extent, 10 feet thick, and containing 400 mg/kg TCE. For this source configuration, the predicted vapor-phase concentrations and the general concentration profiles were in relatively good agreement for five of the seven extraction wells but significant differences were observed for two wells distant from the assumed source location. In addition, the predicted TCE concentration profiles for U12-VP1 and U12-VP2 did not exhibit the characteristic exponential decline that was observed in the measured concentrations during periods of blower shutdown.

Although the measured TCE vapor-phase concentration profiles were successful in identifying the general source location, it is not apparent that the sequential forward modeling scheme was effective in refining that location. Thus, it appears that SVE can be effective in identifying a source area that can then be subjected to a small-scale confirmation soil-sampling program for additional refinement. The use of a sequential forward modeling scheme for additional refinement of the source location does not appear cost effective. It should be noted that this demonstration focused on the effect of single homogeneous source zones in relation to predicted TCE concentration profiles in the vapor phase using a manual sequential forward modeling scheme. The use of a formal inversion scheme using a large number of permutations would enable multiple, heterogeneous source configurations to be investigated and may result in a higher probability of convergence. However, the cost associated with developing a robust multiphase, multicomponent numerical model for inversion would have to be evaluated in relation to the increased probability of refining the areal extent of the source and thus, eliminating the need for confirmation soil sampling.

7.1.3 DSITMS Field Analytics

Approximately 600 primary soil samples were analyzed for TCE, PCE, DCE, and vinyl chloride in nine working days during the Wireline CPT soil investigation. A large number of QA sample analyses also were conducted during this time, including 74 continuing calibration standards, 78 blank samples, 35 matrix spikes, and 43 performance evaluation check samples (total of 230 QA samples). During the SVE demonstration, over 66,000 data were collected using the DSITMS equipped with an air module interface for real-time analysis of TCE in the extracted vapor. The total analytical cost for the soil analyses was \$58 per sample while the cost for the vapor analysis was \$0.26 per sample. The low cost per sample is due to the exceptionally large amount of samples analyzed.

The DSITMS field analytics resulted in an uncommonly dense spatial and temporal distribution of soil and vapor data, respectively. This enabled the use of an adaptive sampling program based on real-time or near real-time visualization and interpretation of the most current data gathered during the field activities. The adaptive sampling program resulted in the nearly complete characterization of the extent of TCE soil contamination in the vadose zone of the investigative area at OU 12 in approximately 10 days of field operations.

7.2 OU 12 Vadose Zone Contaminant Distribution

Inference of the magnitude and spatial extent of TCE contamination in the vadose zone at OU 12 was accomplished using three-dimensional modeling of TCE concentration measured in the soil samples retrieved with the Wireline CPT sampler. An isometric view of the 100 µg/kg iso-concentration surface from the final three-dimensional model of TCE contamination in soil is shown in Figure 7-1. The view is from the southwest corner of the model domain, looking to the northeast. The spheres on each of the borings represent soil sample locations, color-coded according to the measured concentration of TCE. The highest concentrations of TCE were observed in samples collected from U2-1804 at a depth of 27 feet (154,000 µg/kg) and 29 feet (73,000 µg/kg) bgs; from U2-1807 at 33 feet bgs (144,000 µg/kg); and from U2-1817 at 29 feet bgs (131,900 µg/kg). In contrast, surrounding borings yielded no soil samples

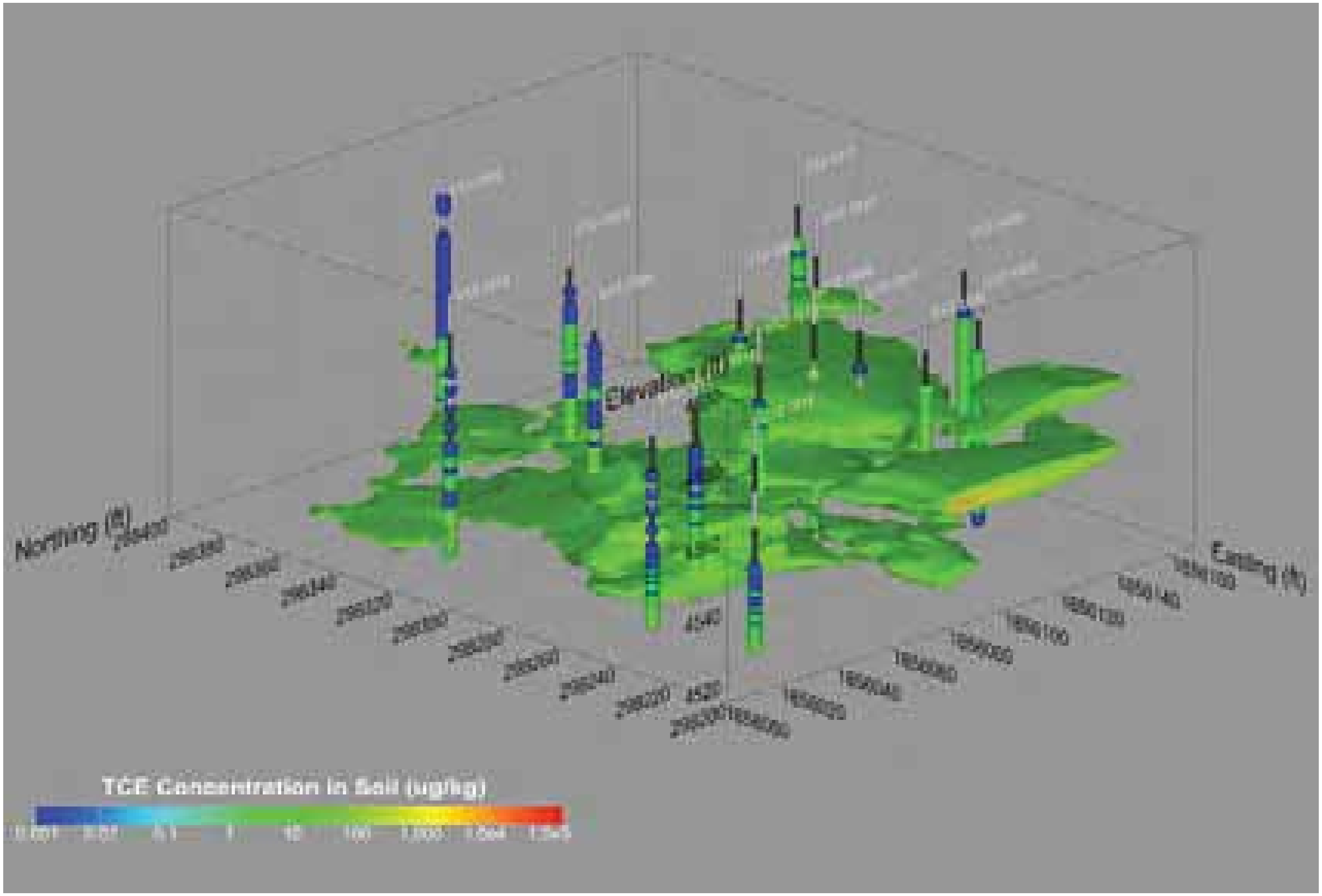


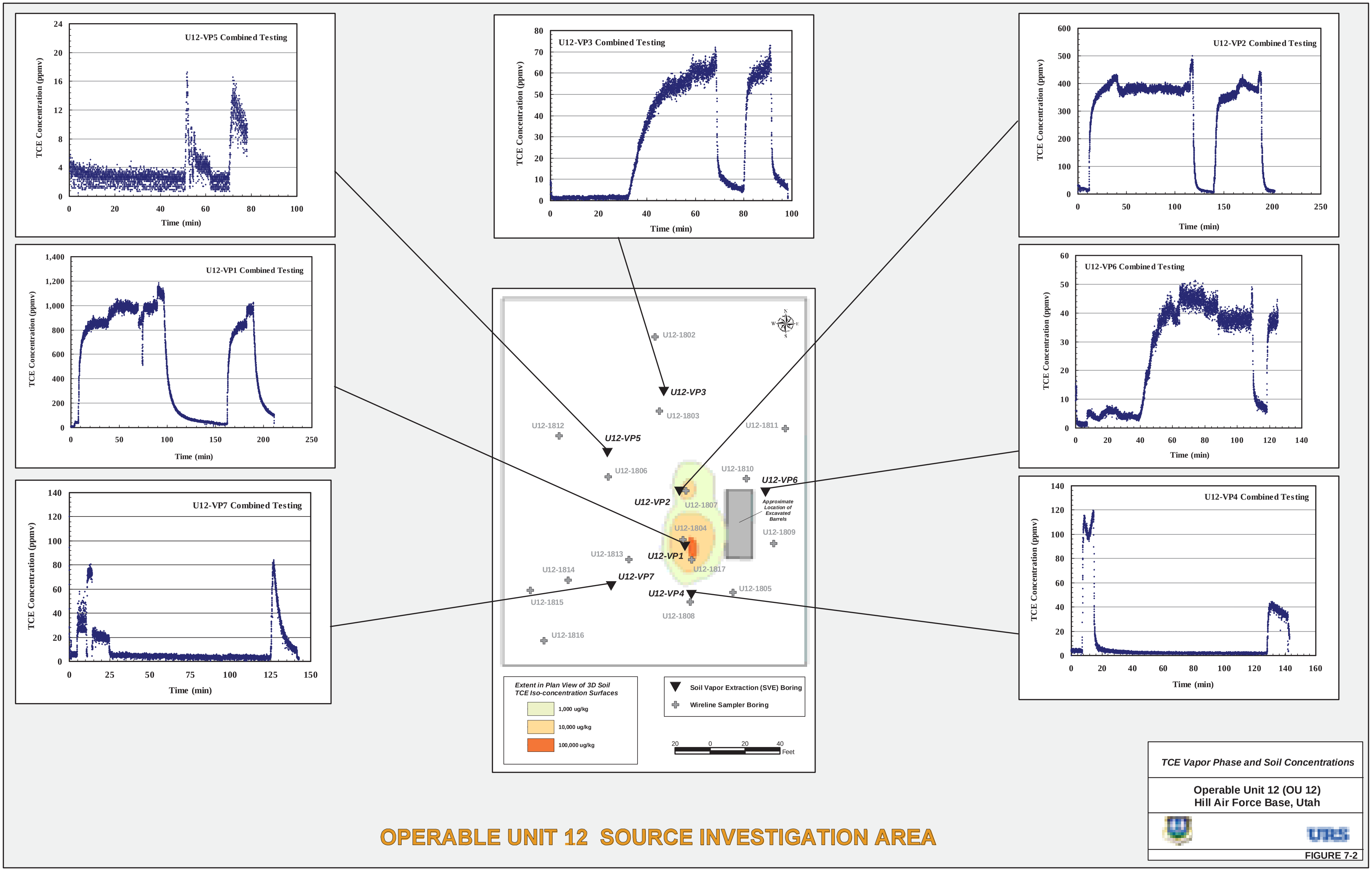
Figure 7-1. Iso-concentration surface of the 100 µg/kg TCE contamination in soil constructed using 599 wireline soil samples from 16 borings.

with a measured TCE concentration greater than 10,000 μg/kg. During the analysis of samples collected from U12-1807, four samples (30 to 33 feet bgs) were observed to contain LNAPL. In addition, two samples (27 to 29 feet bgs) from U12-1804 were observed to contain LNAPL.

Based on the results of the TCE soil model, contamination in the vadose zone at OU 12 has a distinctly layered character. Individual layers are elliptical in plan-view, approximately 5 to 10 feet thick, several hundreds of square feet in areal extent, and are present over most of the entire thickness of the vadose zone within the modeled region. The layers of TCE contamination tend to reside in silty-sand soils, joined vertically by narrow and tortuous throat-like connections evocative of migration pathways. This spatial pattern of TCE contamination in soil suggests that water, percolating downward under the force of gravity and carrying with it dissolved TCE, spreads laterally when it encounters capillary barriers. Pathways through the barriers are ultimately found, providing the contaminated water with a new avenue for downward percolation.

The vapor-phase concentration of TCE observed during SVE operations at OU 12 closely correlate with the spatial distribution of the TCE soil contamination as shown in Figure 7-2. The highest TCE vapor concentration was observed at U12-VP1 located approximately 20 feet west of the southern end of the drum excavation area. The maximum concentration of TCE in the extracted vapor from this location was approximately 1,150 ppmv. The next highest concentration of TCE was observed at U12-VP2, located approximately 35 feet north of U12-VP1 and 20 feet west of the north end of the drum excavation area. The maximum concentration of TCE in the extracted vapor at U12-VP2 during testing was approximately 500 ppmv. The concentration of TCE in the extracted vapor from the other five wells was less than approximately 100 ppmv during vapor extraction operations.

Although a final source configuration was not obtained with the sequential forward modeling scheme, the SVE modeling did suggest that the highest levels of soil contamination are located near the top of the screened intervals of U12-VP1 and U12-VP2. Based on the results of the model, it is inferred that the major source of TCE contamination is located in the upper portion of the vadose zone (20 to 35 feet bgs) offset slightly to the east of U12-VP1 and moderately more distant from U12-VP2. There does not appear to be an appreciable DNAPL phase present in the investigative area of the vadose zone at OU 12. This is illustrated in Figure 7-3 where the NAPL dilution factor is shown as a function of TCE sample concentration for various conditions considered representative of the OU 12 vadose zone. The dilution factor (as defined in Jackson and Mariner, 1995) represents a measure of how much more concentrated the contaminant mass must be before a NAPL would be predicted to exist in the sample. Calculations were performed assuming 30% porosity and for moisture contents ranging from 5 to 20% and a fractional organic carbon (f_{oc}) value of 0.001 mg/mg and 0.002 mg/mg. Under these conditions, the NAPL saturation limit ranges from approximately 300 mg/kg to 450 mg/kg TCE and is dependent on the fractional organic carbon content of the soil. Based on the results of the SVE modeling, soil concentrations may be closely approaching the saturation limit where DNAPL is expected to exist; however, TCE concentrations observed during the Wireline CPT soil investigation were closer to the 100 mg/kg to 200 mg/kg range. Thus, it is likely that the major TCE contamination is associated with a sorbed fraction and probably a separate LNAPL phase identified during the Wireline CPT soil investigation.



TCE Vapor Phase and Soil Concentrations

Operable Unit 12 (OU 12)
Hill Air Force Base, Utah

FIGURE 7-2

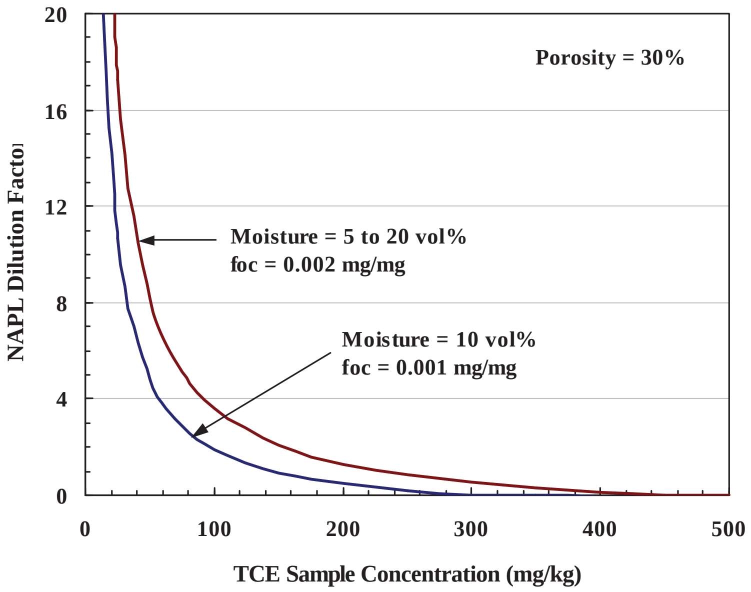


Figure 7-3. NAPL dilution factor as a function of TCE sample concentration.

7.3 Recommendations

During the OU 12 soil investigation, a separate LNAPL phase was identified in the upper portions of the vadose zone located in the suspected source area adjacent to vapor extraction wells U12-VP1 and U12-VP2. Soil samples that exhibited LNAPL also were shown to have elevated concentrations of TCE. The modeling of TCE contamination in the soil illustrated that the highest levels of soil contamination are located near the top of the screened intervals of U12-VP1 and U12-VP2. In addition, the upper nine feet of the screened interval in both wells are located in an extensive silty-sand region, similar to the highest soil contamination. These observations are manifest in the high TCE concentrations observed in the extracted vapor from U12-VP1 and U12-VP2. Because the measured concentration of TCE in the extracted soil vapor corresponds to an average vapor concentration for the entire length of the screened interval, it is impossible to delineate the relative contribution to the total measured contamination supplied by the various soil intervals spanned by the screen. However, due to the close proximity of U12-VP1 and U12-VP2 to high soil contamination and the local soil stratigraphy of their screened intervals, it is inferred that the upper few feet of the intervals (typically 30 to 40 feet bgs) for these wells yielded the bulk of the contaminated vapor.

Thus, it is recommended that vapor extraction operations be conducted using the existing extraction wells U12-VP1 and U12-VP2 to evaluate contaminant mass (including both petroleum hydrocarbon and chlorinated ethenes) removal over a 30-day period. Results obtained from the 30-day investigation should be evaluated to determine whether continued vapor extraction operations are beneficial for reduction of source zone contamination. In addition, it is recommended that any additional investigations should focus on determining the presence or absence of DNAPL in the saturated zone, and evaluating the potential presence of contaminant mass in the vicinity of the two geophysical anomalies previously identified to the northeast and southwest of the excavated drum area.

8.0 REFERENCES

Bear, J. 1979. *Hydraulics of Groundwater*. McGraw-Hill, Inc., New York

Benson, D.A. 1998. *User's Manual to VENT3D: A Three-Dimensional Multicompound, Multiphase Partitioning Vapor Transport Model*. Desert Research Institute, University of Nevada, Reno, Nev.

Burton, J.C. 1993. *Expedited Site Characterization: A Rapid, Cost-Effective Process for Preremedial Site Characterization*, Superfund XIV, Vol II, Hazardous Materials Research and Control Institue, Greenbelt, MD, 809-826.

EPA. 2001. *Development of Recommendations and Methods to Support Assessment of Soil Venting Performance and Closure*. EPA/600/R-01/070. United States Environmental Protection Agency, Office of Research and Development, Washington, DC.

Goovaerts, P. 1997. *Geostatistics for Natural Resource Evaluation.* Oxford University Press, New York.

Isaaks, E. H., and R. M. Srivastava. 1989. *Applied Geostatistics.* Oxford University Press, New York.

Jackson, R.E. and Mariner, P.E. 1995. Estimating DNAPL composition and VOC dilution from extraction well data, *Ground Water*, **33**:3, 407-414.

Johnson, P.C., M.W. Kemblowski, and J.D. Colthart. 1990. Quantitative Analysis for the Cleanup of Hydrocarbon-Contaminanted Soils by In-Situ Soil Venting. *Ground Water*, **28**:3, 413-429.

MWH. 2002a. *Draft Operable Units 5 and 12 Active Soil-Gas Survey Source Area Investigation Report*, prepared for Hill Air Force Base, Utah (June).

MWH. 2002b. *Final Operable Units 5 and 12 Historical Land Use and Source Area Review*, prepared for Hill Air Force Base, Utah (March).

Robbat, A. 1997. *A Guideline for Dynamic Workplans and Field Analytics: The Keys to Cost-Effective Site Characterization and Cleanup*, sponsored by President Clinton's Environmental Technology Initiative, through the U.S. Environmental Protection Agency, Washington, DC.

URS. 2002. *Final Work Plan for the Source Zone Delineation Demonstration Operable Unit 12*, prepared for Hill Air Force Base, Utah (September).

APPENDIX A

Field Analytical Results for the Wireline Soil Demonstration

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

(Page 1 of 18)

Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	21-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	55	57.9	55.5	53.4
	21-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	57	66.9	56.1	39
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
1	21-Aug-02	U12-1802-3	3	1856080.6	298382.5	4588.45	B	45.3	54.3	73.5	0	9.0	39.5	<17	<26	<17	<16
2	21-Aug-02	U12-1802-2	2	1856080.6	298382.5	4588.45	T	45.4	55.0	74.5	0	9.6	39.9	<17	<26	<17	<16
3	21-Aug-02	U12-1802-4	4	1856080.6	298382.5	4588.45	B	45.0	51.2	67.1	0	6.2	35.9	<17	<26	<17	<16
4	21-Aug-02	U12-1802-3D	3	1856080.6	298382.5	4588.45	T	45.4	51.6	66.6	0	6.2	35.4	<17	<26	<17	<16
	21-Aug-02	HAFB1802 V4B 225 ppb MS	---	---	---	---	---	---	---	---	---	---	---	270	216	252	216
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
5	21-Aug-02	U12-1802-5	5	1856080.6	298382.5	4588.45	B	46.1	54.0	68.5	0	7.9	35.6	<17	<26	<17	<16
6	21-Aug-02	U12-1802-4D	4	1856080.6	298382.5	4588.45	T	45.5	51.6	66.5	0	6.1	35.4	<17	<26	<17	<16
	21-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	71	73.8	71.7	49.8
7	21-Aug-02	U12-1802-14	14	1856080.6	298382.5	4588.45	B	46.1	53.4	67.3	0	7.3	35.0	<17	<26	<17	<16
8	21-Aug-02	U12-1802-13	13	1856080.6	298382.5	4588.45	T	45.2	52.8	67.6	0	7.6	35.0	<17	<26	<17	<16
9	21-Aug-02	U12-1802-15	15	1856080.6	298382.5	4588.45	B	45.4	51.8	66.4	0	6.4	35.0	<17	<26	<17	<16
10	21-Aug-02	U12-1802-14D	14	1856080.6	298382.5	4588.45	T	45.6	52.1	67.7	0	6.5	36.2	<17	<26	<17	<16
11	21-Aug-02	U12-1802-16	16	1856080.6	298382.5	4588.45	B	45.4	55.9	69.4	0	10.5	33.9	<17	<26	<17	<16
12	21-Aug-02	U12-1802-17	17	1856080.6	298382.5	4588.45	B	45.8	55.0	68.2	0	9.2	34.0	<17	<26	<17	<16
13	21-Aug-02	U12-1802-18	18	1856080.6	298382.5	4588.45	B	45.3	54.7	67.3	0	9.4	32.9	<17	<26	<17	<16
14	21-Aug-02	U12-1802-19	19	1856080.6	298382.5	4588.45	B	45.2	54.0	68.2	0	8.8	34.4	<17	<26	<17	<16
15	21-Aug-02	U12-1802-20	20	1856080.6	298382.5	4588.45	B	45.8	53.5	68.2	0	7.7	35.5	<17	<26	<17	<16
16	21-Aug-02	U12-1802-21	21	1856080.6	298382.5	4588.45	B	45.7	54.6	69.0	0	8.9	35.1	<17	<26	<17	<16
17	21-Aug-02	U12-1802-22	22	1856080.6	298382.5	4588.45	B	46.8	54.4	67.7	0	7.6	35.1	<17	<26	<17	<16
18	21-Aug-02	U12-1802-23	23	1856080.6	298382.5	4588.45	B	45.7	53.5	67.1	0	7.8	34.3	<17	<26	<17	<16
19	21-Aug-02	U12-1802-24	24	1856080.6	298382.5	4588.45	B	45.2	53.1	66.3	0	7.9	33.4	<17	<26	<17	<16
20	21-Aug-02	U12-1802-25	25	1856080.6	298382.5	4588.45	B	45.6	54.5	68.4	0	8.9	34.5	<17	<26	<17	<16
21	21-Aug-02	U12-1802-26	26	1856080.6	298382.5	4588.45	B	45.5	54.0	68.1	0	8.5	34.6	<17	<26	<17	<16
22	21-Aug-02	U12-1802-27	27	1856080.6	298382.5	4588.45	B	45.2	53.9	66.6	0	8.7	32.9	<17	<26	<17	<16
23	21-Aug-02	U12-1802-28	28	1856080.6	298382.5	4588.45	B	45.4	55.0	68.1	0	9.6	33.5	<17	<26	<17	<16
24	21-Aug-02	U12-1802-29	29	1856080.6	298382.5	4588.45	B	45.6	56.2	70.1	0	10.6	34.5	<17	<26	<17	<16
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	21-Aug-02	HAFB1802 V17 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	78	77.1	66	55.2
	21-Aug-02	0ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
25	21-Aug-02	U12-1802-30	30	1856080.6	298382.5	4588.45	B	45.6	52.7	65.9	0	7.1	33.8	<17	<26	<17	<16
26	21-Aug-02	U12-1802-31	31	1856080.6	298382.5	4588.45	B	45.3	51.7	66.4	0	6.4	35.0	<17	<26	<17	<16
27	21-Aug-02	U12-1802-32	32	1856080.6	298382.5	4588.45	B	45.9	52.7	66.3	0	6.8	34.5	<17	<26	<17	<16
28	21-Aug-02	U12-1802-33	33	1856080.6	298382.5	4588.45	B	45.3	51.8	67.2	0	6.5	35.7	<17	<26	<17	<16
29	21-Aug-02	U12-1802-34	34	1856080.6	298382.5	4588.45	B	45.5	52.5	67.0	0	7.0	35.0	<17	<26	<17	<16
30	21-Aug-02	U12-1802-35	35	1856080.6	298382.5	4588.45	B	45.5	52.7	66.9	0	7.2	34.7	<17	<26	<17	<16
31	21-Aug-02	U12-1802-36	36	1856080.6	298382.5	4588.45	B	45.9	54.5	67.9	0	8.6	34.3	<17	<26	<17	<16
32	21-Aug-02	U12-1802-37	37	1856080.6	298382.5	4588.45	B	45.8	51.4	66.3	0	5.6	35.7	<17	<26	<17	<16
33	21-Aug-02	U12-1802-38	38	1856080.6	298382.5	4588.45	B	45.7	53.3	67.7	0	7.6	35.1	<17	<26	<17	<16
	21-Aug-02	30 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	31	33	24.6	26.1
	21-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	288	NP	242.1	NP
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
34	21-Aug-02	U12-1802-39	39	1856080.6	298382.5	4588.45	B	45.8	52.9	67.0	0	7.1	34.9	<17	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
35	21-Aug-02	U12-1802-40	40	1856080.6	298382.5	4588.45	B	45.7	54.7	68.4	0	9.0	34.4	<17	<26	<17	<16
36	21-Aug-02	U12-1802-41	41	1856080.6	298382.5	4588.45	B	46.2	56.0	68.6	13	9.8	33.8	45	<26	<17	<16
37	21-Aug-02	U12-1802-42	42	1856080.6	298382.5	4588.45	B	45.8	52.8	68.4	1.5	7.0	36.4	8F	<26	<17	<16
38	21-Aug-02	U12-1802-43	43	1856080.6	298382.5	4588.45	B	45.3	56.3	68.6	12.4	11.0	32.6	37	<26	<17	<16
39	21-Aug-02	U12-1802-44	44	1856080.6	298382.5	4588.45	B	45.9	56.2	68.8	12	10.3	33.5	39	<26	<17	<16
40	21-Aug-02	U12-1802-45	45	1856080.6	298382.5	4588.45	B	45.7	56.5	68.9	14	10.8	33.1	43	<26	<17	<16
41	21-Aug-02	U12-1802-46	46	1856080.6	298382.5	4588.45	B	45.7	55.8	68.1	32	10.1	33.0	105	<26	<17	<16
42	21-Aug-02	U12-1802-47	47	1856080.6	298382.5	4588.45	B	45.8	56.9	69.5	50	11.1	33.4	150	<26	<17	<16
43	21-Aug-02	U12-1802-48	48	1856080.6	298382.5	4588.45	B	45.3	53.6	67.6	8.3	8.3	34.3	34	<26	<17	<16
44	21-Aug-02	U12-1802-49	49	1856080.6	298382.5	4588.45	B	45.2	53.3	67.0	14	8.1	33.9	59	<26	<17	<16
	21-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	236	233.1	217.5	168.3
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
45	21-Aug-02	U12-1802-50	50	1856080.6	298382.5	4588.45	B	45.5	52.2	66.3	0	6.7	34.6	<17	<26	<17	<16
46	21-Aug-02	U12-1802-51	51	1856080.6	298382.5	4588.45	B	45.8	51.9	66.0	7.3	6.1	34.9	42	<26	<17	<16
47	21-Aug-02	U12-1802-52	52	1856080.6	298382.5	4588.45	B	45.6	54.3	67.0	30	8.7	33.3	115	<26	<17	<16
48	21-Aug-02	U12-1802-53	53	1856080.6	298382.5	4588.45	B	45.5	55.2	67.2	12	9.7	32.5	40	<26	<17	<16
49	21-Aug-02	U12-1802-54	54	1856080.6	298382.5	4588.45	B	45.5	55.5	67.2	43	10.0	32.2	138	<26	<17	<16
50	21-Aug-02	U12-1802-55	55	1856080.6	298382.5	4588.45	B	46.0	55.2	67.4	11.2	9.2	33.2	40	<26	<17	<16
51	21-Aug-02	U12-1802-56	56	1856080.6	298382.5	4588.45	B	45.9	54.4	68.4	5	8.5	34.9	21	<26	<17	<16
52	21-Aug-02	U12-1802-57	57	1856080.6	298382.5	4588.45	B	45.4	52.9	67.6	0	7.5	35.1	<17	<26	<17	<16
53	21-Aug-02	U12-1802-58	58	1856080.6	298382.5	4588.45	B	45.3	55.3	69.2	19	10.0	34.2	65	<26	<17	<16
54	21-Aug-02	U12-1802-59	59	1856080.6	298382.5	4588.45	B	46.0	54.8	68.2	18	8.8	34.4	70	<26	<17	<16
55	21-Aug-02	U12-1802-60	60	1856080.6	298382.5	4588.45	B	45.6	58.2	69.6	40	12.6	32.0	102	<26	<17	<16
56	21-Aug-02	U12-1802-61	61	1856080.6	298382.5	4588.45	B	45.3	56.0	68.6	37	10.7	32.9	114	<26	<17	<16
57	21-Aug-02	U12-1802-62	62	1856080.6	298382.5	4588.45	B	45.8	55.1	68.2	21	9.3	33.9	77	<26	<17	<16
58	21-Aug-02	U12-1802-63	63	1856080.6	298382.5	4588.45	B	45.9	57.8	69.8	39	11.9	32.9	108	<26	<17	<16
59	21-Aug-02	U12-1802-64	64	1856080.6	298382.5	4588.45	B	45.1	56.1	70.2	56	11.0	34.2	174	<26	<17	<16
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	21-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	274	263.7	247.5	206.1
60	21-Aug-02	U12-1802-65	65	1856080.6	298382.5	4588.45	B	45.4	54.5	69.1	17	9.1	35.0	65	<26	<17	<16
61	21-Aug-02	U12-1802-66	66	1856080.6	298382.5	4588.45	B	46.2	56.3	68.7	0	10.1	33.6	<17	<26	<17	<16
62	21-Aug-02	U12-1802-67	67	1856080.6	298382.5	4588.45	B	46.1	55.5	67.1	0	9.4	32.7	<17	<26	<17	<16
63	21-Aug-02	U12-1802-68	68	1856080.6	298382.5	4588.45	B	46.2	58.6	70.3	0.4	12.4	32.9	<17	<26	<17	<16
64	21-Aug-02	U12-1802-69	69	1856080.6	298382.5	4588.45	B	45.5	56.4	68.1	0	10.9	32.2	<17	<26	<17	<16
	21-Aug-02	HAFB1802 V61 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	83	76.5	72	49.2
	21-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	21-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	293	NP	256.8	NP
	21-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	70	68.7	58.2	44.7
	21-Aug-02	HAFB1802 V61 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	86	78.9	73.8	48
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	22-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	184	NP	182.7	NP
	22-Aug-02	HAFB1803 V65 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	60	39.6	56.7	74.1
65	22-Aug-02	U12-1803-17	17	1856083.3	298339.9	4587.83	B	45.3	51.6	66.7	0	6.3	35.4	<17	<26	<17	<16
66	22-Aug-02	U12-1803-21	21	1856083.3	298339.9	4587.83	B	45.9	53.0	69.2	0	7.1	37.1	<17	<26	<17	<16
67	22-Aug-02	U12-1803-22	22	1856083.3	298339.9	4587.83	B	46.5	53.6	68.0	0	7.1	35.9	<17	<26	<17	<16
68	22-Aug-02	U12-1803-23	23	1856083.3	298339.9	4587.83	B	45.4	52.6	68.2	0	7.2	36.0	<17	<26	<17	<16
69	22-Aug-02	U12-1803-24	24	1856083.3	298339.9	4587.83	B	45.2	53.4	66.2	0	8.2	33.0	<17	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
70	22-Aug-02	U12-1803-25	25	1856083.3	298339.9	4587.83	B	45.4	54.8	67.6	0	9.4	33.2	<17	<26	<17	<16
71	22-Aug-02	U12-1803-26	26	1856083.3	298339.9	4587.83	B	45.7	51.4	65.8	0	5.7	35.1	<17	<26	<17	<16
72	22-Aug-02	U12-1803-27	27	1856083.3	298339.9	4587.83	B	45.5	51.3	65.8	0	5.8	35.0	<17	<26	<17	<16
73	22-Aug-02	U12-1803-28	28	1856083.3	298339.9	4587.83	B	45.4	53.1	66.7	0	7.7	34.0	<17	<26	<17	<16
74	22-Aug-02	U12-1803-29	29	1856083.3	298339.9	4587.83	B	45.1	55.9	69.1	0	10.8	33.3	<17	<26	<17	<16
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	59	50.4	54.9	51
75	22-Aug-02	U12-1803-34	34	1856083.3	298339.9	4587.83	B	45.7	54.4	67.8	0	8.7	34.1	<17	<26	<17	<16
	22-Aug-02	HAFB1803 V75 225 ppb MS	---	---	---	---	---	---	---	---	---	---	---	269	279	280.8	330
	22-Aug-02	22.5 ppbHAFB01	---	---	---	---	---	---	---	---	---	---	---	37	36.3	47.7	35.4
	22-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	226	230.1	241.5	272.4
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	66	60.9	63	52.5
	22-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	210	213.3	204.9	211.5
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
76	22-Aug-02	U12-1803-26D	26	1856083.3	298339.9	4587.83	B	45.4	54.8	67.9	4	9.4	33.5	14F	<26	<17	<16
77	22-Aug-02	U12-1803-27D	27	1856083.3	298339.9	4587.83	B	45.4	56.0	68.5	5	10.6	32.9	16F	<26	<17	<16
78	22-Aug-02	U12-1803-28D	28	1856083.3	298339.9	4587.83	B	45.7	55.7	68.8	6	10.0	33.8	20	<26	<17	<16
79	22-Aug-02	U12-1803-29D	29	1856083.3	298339.9	4587.83	B	45.8	52.7	66.4	1.4	6.9	34.5	7F	<26	<17	<16
80	22-Aug-02	U12-1803-30	30	1856083.3	298339.9	4587.83	B	45.6	53.2	67.1	2	7.6	34.5	9F	<26	<17	<16
81	22-Aug-02	U12-1803-31	31	1856083.3	298339.9	4587.83	B	45.3	54.0	68.2	3	8.7	34.5	12F	<26	<17	<16
82	22-Aug-02	U12-1803-32	32	1856083.3	298339.9	4587.83	B	45.1	53.2	66.7	3	8.1	33.6	12F	<26	<17	<16
83	22-Aug-02	U12-1803-34D	34	1856083.3	298339.9	4587.83	B	45.8	54.6	68.1	5	8.8	34.3	19	<26	<17	<16
84	22-Aug-02	U12-1803-35	35	1856083.3	298339.9	4587.83	B	45.9	53.1	66.6	2	7.2	34.4	10F	<26	<17	<16
85	22-Aug-02	U12-1803-36	36	1856083.3	298339.9	4587.83	B	45.4	50.4	66.0	0	5.0	36.0	<17	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	53	47.4	52.2	43.5
	22-Aug-02	HAFB1803 V84 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	71	63.3	71.7	65.4
86	22-Aug-02	U12-1803-37	37	1856083.3	298339.9	4587.83	B	45.4	52.8	68.7	2	7.4	36.3	10F	<26	<17	<16
87	22-Aug-02	U12-1803-38	38	1856083.3	298339.9	4587.83	B	45.3	54.5	65.7	2	9.2	31.5	7F	<26	<17	<16
88	22-Aug-02	U12-1803-39	39	1856083.3	298339.9	4587.83	B	46.0	52.3	65.5	0	6.3	34.2	<17	<26	<17	<16
89	22-Aug-02	U12-1803-41	41	1856083.3	298339.9	4587.83	B	45.7	51.9	66.6	0	6.2	35.4	<17	<26	<17	<16
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
90	22-Aug-02	U12-1803-42	42	1856083.3	298339.9	4587.83	B	45.7	51.0	66.3	0	5.3	36.0	<17	<26	<17	<16
91	22-Aug-02	U12-1803-44	44	1856083.3	298339.9	4587.83	B	45.3	53.2	67.3	0	7.9	34.4	<17	<26	<17	<16
92	22-Aug-02	U12-1803-45	45	1856083.3	298339.9	4587.83	B	46.0	52.0	66.3	0	6.0	35.3	<17	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	73	38.1	69.6	59.1
93	22-Aug-02	U12-1803-47	47	1856083.3	298339.9	4587.83	B	45.6	55.0	67.4	18	9.4	33.0	63	<26	<17	<16
94	22-Aug-02	U12-1803-48	48	1856083.3	298339.9	4587.83	B	45.8	59.0	70.3	9	13.2	32.1	22	<26	<17	<16
95	22-Aug-02	U12-1803-49	49	1856083.3	298339.9	4587.83	B	45.3	56.0	68.2	45	10.7	32.5	137	<26	<17	<16
96	22-Aug-02	U12-1803-50	50	1856083.3	298339.9	4587.83	B	45.3	53.8	66.9	7	8.5	33.4	28	<26	<17	<16
97	22-Aug-02	U12-1803-51	51	1856083.3	298339.9	4587.83	B	46.1	55.9	67.6	11	9.8	32.8	37	<26	<17	<16
98	22-Aug-02	U12-1803-52	52	1856083.3	298339.9	4587.83	B	45.8	57.0	69.7	30	11.2	33.5	90	<26	<17	<16
99	22-Aug-02	U12-1803-53	53	1856083.3	298339.9	4587.83	B	46.1	53.3	66.6	8	7.2	34.4	38	<26	<17	<16
100	22-Aug-02	U12-1803-54	54	1856083.3	298339.9	4587.83	B	45.2	55.1	68.2	8	9.9	33.3	27	<26	<17	<16
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	45.3	78	72
	22-Aug-02	HAFB1803 V78 225 ppb MS	---	---	---	---	---	---	---	---	---	---	---	284	NP	265.8	NP

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
101	22-Aug-02	U12-1803-55	55	1856083.3	298339.9	4587.83	B	45.4	56.2	67.6	38	10.8	31.8	112	<26	<17	<16
102	22-Aug-02	U12-1803-56	56	1856083.3	298339.9	4587.83	B	45.5	53.7	67.1	3	8.2	33.9	12F	<26	<17	<16
103	22-Aug-02	U12-1803-57	57	1856083.3	298339.9	4587.83	B	45.8	58.2	69.0	50	12.4	31.6	127	<26	<17	<16
104	22-Aug-02	U12-1803-58	58	1856083.3	298339.9	4587.83	B	45.1	55.8	69.0	33	10.7	33.3	103	<26	<17	<16
105	22-Aug-02	U12-1803-60	60	1856083.3	298339.9	4587.83	B	45.3	57.1	68.7	32	11.8	31.9	87	<26	<17	<16
106	22-Aug-02	U12-1803-63	63	1856083.3	298339.9	4587.83	B	45.6	54.0	68.5	13	8.4	35.1	54	<26	<17	<16
	22-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	71	58.5	79.8	74.1
	22-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	22-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	211	NP	199.5	NP
	23-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	208	194.4	208.8	216.9
	23-Aug-02	HAFB1803 V68 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	59	57.3	64.2	53.1
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
107	23-Aug-02	U12-1804-24	24	1856097.3	298266.2	4587.35	B	46.1	56.0	67.2	36	9.9	32.3	117	<26	<17	<16
108	23-Aug-02	U12-1804-25	25	1856097.3	298266.2	4587.35	B	46.0	55.4	66.9	24	9.4	32.5	83	<26	<17	<16
109	23-Aug-02	U12-1804-26	26	1856097.3	298266.2	4587.35	B	45.5	58.6	69.5	31	13.1	31.4	74	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
110	23-Aug-02	U12-1804-27	27	1856097.3	298266.2	4587.35	B	45.7	55.0	67.6	4300	9.3	33.3	154000E	<260	<170	<160
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	23-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	219	216	220.5	206.7
111	23-Aug-02	U12-1804-29	29	1856097.3	298266.2	4587.35	B	46.1	51.4	66.2	1075	5.3	35.9	73000E	<260	<170	<160
112	23-Aug-02	U12-1804-32	32	1856097.3	298266.2	4587.35	B	45.5	54.7	67.8	63	9.2	33.6	230	<26	<17	<16
113	23-Aug-02	U12-1804-34	34	1856097.3	298266.2	4587.35	B	46.1	55.1	67.9	51	9.0	33.9	192	<26	<17	<16
114	23-Aug-02	U12-1804-36	36	1856097.3	298266.2	4587.35	B	45.8	57.5	68.9	126	11.7	32.2	347	<26	<17	<16
115	23-Aug-02	U12-1804-38	38	1856097.3	298266.2	4587.35	B	45.9	55.9	67.4	31	10.0	32.4	100	<26	<17	<16
116	23-Aug-02	U12-1804-40	40	1856097.3	298266.2	4587.35	B	45.3	53.7	67.0	13	8.4	33.6	52	<26	<17	<16
117	23-Aug-02	U12-1804-42	42	1856097.3	298266.2	4587.35	B	45.5	53.6	66.1	44	8.1	33.0	179	<26	<17	<16
118	23-Aug-02	U12-1804-43	43	1856097.3	298266.2	4587.35	B	46.2	55.9	67.7	76	9.7	33.0	259	<26	<17	<16
119	23-Aug-02	U12-1804-46	46	1856097.3	298266.2	4587.35	B	45.7	54.6	67.2	78	8.9	33.3	292	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
120	23-Aug-02	U12-1804-48	48	1856097.3	298266.2	4587.35	B	46.2	55.8	67.7	30	9.6	33.1	103	<26	<17	<16
121	23-Aug-02	U12-1804-50	50	1856097.3	298266.2	4587.35	B	45.5	53.7	66.7	22	8.2	33.5	90	<26	<17	<16
122	23-Aug-02	U12-1804-52	52	1856097.3	298266.2	4587.35	B	45.1	51.7	66.7	12	6.6	35.1	64	<26	<17	<16
123	23-Aug-02	U12-1804-54	54	1856097.3	298266.2	4587.35	B	46.3	53.4	66.4	2	7.1	34.3	10F	<26	<17	<16
124	23-Aug-02	U12-1804-56	56	1856097.3	298266.2	4587.35	B	46.3	54.0	67.1	38	7.7	34.4	170	<26	<17	<16
125	23-Aug-02	U12-1804-57	57	1856097.3	298266.2	4587.35	B	45.3	54.2	69.1	1.6	8.9	35.2	6F	<26	<17	<16
126	23-Aug-02	U12-1804-58	58	1856097.3	298266.2	4587.35	B	45.4	57.3	70.0	41.1	11.9	33.1	114	<26	<17	<16
	23-Aug-02	HAFB1804 V123 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	84	57.9	72.9	60
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	64	48.9	69	53.1
127	23-Aug-02	U12-1804-60	60	1856097.3	298266.2	4587.35	B	45.1	54.3	66.9	29	9.2	32.7	103	<26	<17	<16
128	23-Aug-02	U12-1804-62	62	1856097.3	298266.2	4587.35	B	45.1	56.4	68.6	16	11.3	32.3	46	<26	<17	<16
129	23-Aug-02	U12-1804-63	63	1856097.3	298266.2	4587.35	B	45.5	55.7	67.5	10	10.2	32.3	32	<26	<17	<16
130	23-Aug-02	U12-1804-64	64	1856097.3	298266.2	4587.35	B	46.1	55.1	66.2	1	9.0	32.2	4F	<26	<17	<16
131	23-Aug-02	U12-1804-65	65	1856097.3	298266.2	4587.35	B	45.5	56.1	68.9	1	10.6	33.3	<17	<26	<17	<16
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	63	69.9	66.6	48.9
132	23-Aug-02	U12-1805-20	20	1856126.2	298236.3	4588.95	B	45.8	55.5	69.2	7	9.7	34.5	25	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
133	23-Aug-02	U12-1805-22	22	1856126.2	298236.3	4588.95	B	45.1	56.1	67.4	9	11.0	31.4	26	<26	<17	<16
134	23-Aug-02	U12-1805-23	23	1856126.2	298236.3	4588.95	B	45.7	54.2	66.9	3	8.5	33.4	12F	<26	<17	<16
135	23-Aug-02	U12-1805-24	24	1856126.2	298236.3	4588.95	B	46.1	55.6	67.4	7	9.5	32.9	24	<26	<17	<16
136	23-Aug-02	U12-1805-25	25	1856126.2	298236.3	4588.95	B	45.8	54.8	67.5	5	9.0	33.5	19	<26	<17	<16
137	23-Aug-02	U12-1805-26	26	1856126.2	298236.3	4588.95	B	45.7	55.5	68.5	8.5	9.8	33.7	29	<26	<17	<16
138	23-Aug-02	U12-1805-27	27	1856126.2	298236.3	4588.95	B	45.9	57.9	69.3	11	12.0	32.3	30	<26	<17	<16
139	23-Aug-02	U12-1805-28	28	1856126.2	298236.3	4588.95	B	46.0	56.6	67.9	12	10.6	32.3	37	<26	<17	<16
140	23-Aug-02	U12-1805-29	29	1856126.2	298236.3	4588.95	B	45.4	50.9	65.0	0	5.5	34.5	<17	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	63	70.5	59.1	48.6
	23-Aug-02	HAFB1804 V130 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	81	80.1	79.5	60
141	23-Aug-02	U12-1805-31	31	1856126.2	298236.3	4588.95	B	46.0	55.3	67.8	3	9.3	33.5	11F	<26	<17	<16
142	23-Aug-02	U12-1805-32	32	1856126.2	298236.3	4588.95	B	45.7	54.2	67.1	6	8.5	33.6	24	<26	<17	<16
143	23-Aug-02	U12-1805-33	33	1856126.2	298236.3	4588.95	B	45.7	55.4	67.6	4	9.7	32.9	14F	<26	<17	<16
144	23-Aug-02	U12-1805-34	34	1856126.2	298236.3	4588.95	B	45.8	52.0	67.4	2	6.2	36.2	12F	<26	<17	<16
145	23-Aug-02	U12-1805-35	35	1856126.2	298236.3	4588.95	B	46.0	54.7	67.1	1.5	8.7	33.4	6F	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
146	23-Aug-02	U12-1805-37	37	1856126.2	298236.3	4588.95	B	45.7	51.2	65.4	2	5.5	34.9	13F	<26	<17	<16
147	23-Aug-02	U12-1805-38	38	1856126.2	298236.3	4588.95	B	45.5	51.2	66.0	2	5.7	35.3	12F	<26	<17	<16
	23-Aug-02	30 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	29	33.6	27.6	20.4
148	23-Aug-02	OU12-1805-43	43	1856126.2	298236.3	4588.95	B	45.5	51.0	66.0	2	5.5	35.5	13F	<26	<17	<16
149	23-Aug-02	OU12-1805-44	44	1856126.2	298236.3	4588.95	B	45.8	52.5	66.2	0	6.7	34.5	<17	<26	<17	<16
150	23-Aug-02	OU12-1805-45	45	1856126.2	298236.3	4588.95	B	45.6	56.1	69.8	13	10.5	34.3	42	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
151	23-Aug-02	U12-1805-46	46	1856126.2	298236.3	4588.95	B	45.4	53.6	67.5	3	8.2	34.3	13F	<26	<17	<16
152	23-Aug-02	U12-1805-47	47	1856126.2	298236.3	4588.95	B	45.8	53.5	66.9	9	7.7	34.2	40	<26	<17	<16
153	23-Aug-02	U12-1805-48	48	1856126.2	298236.3	4588.95	B	45.8	55.0	67.7	7	9.2	33.5	25	<26	<17	<16
154	23-Aug-02	U12-1805-49	49	1856126.2	298236.3	4588.95	B	45.6	56.0	69.3	22	10.4	33.9	72	<26	<17	<16
155	23-Aug-02	U12-1805-50	50	1856126.2	298236.3	4588.95	B	45.6	56.0	68.5	30	10.4	33.1	95	<26	<17	<16
156	23-Aug-02	U12-1805-51	51	1856126.2	298236.3	4588.95	B	45.4	55.0	66.7	16	9.6	32.1	54	<26	<17	<16
157	23-Aug-02	U12-1805-52	52	1856126.2	298236.3	4588.95	B	45.0	52.5	67.3	1	7.5	34.8	5F	<26	<17	<16
158	23-Aug-02	U12-1805-53	53	1856126.2	298236.3	4588.95	B	45.1	50.4	66.2	3	5.3	35.9	20	<26	<17	<16
159	23-Aug-02	U12-1805-54	54	1856126.2	298236.3	4588.95	B	45.8	53.8	67.3	10	8.0	34.3	43	<26	<17	<16
160	23-Aug-02	U12-1805-55	55	1856126.2	298236.3	4588.95	B	45.7	52.2	65.8	9	6.5	34.3	47	<26	<17	<16
161	23-Aug-02	U12-1805-56	56	1856126.2	298236.3	4588.95	B	45.8	54.9	67.9	9	9.1	33.8	33	<26	<17	<16
162	23-Aug-02	U12-1805-57	57	1856126.2	298236.3	4588.95	B	45.6	54.3	67.1	7	8.7	33.4	27	<26	<17	<16
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	63	62.4	69.9	56.1
	23-Aug-02	HAFB1805 V157 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	70	70.2	75	58.5
163	23-Aug-02	U12-1805-58	58	1856126.2	298236.3	4588.95	B	45.6	52.8	67.0	2	7.2	34.8	10F	<26	<17	<16
164	23-Aug-02	U12-1805-59	59	1856126.2	298236.3	4588.95	B	45.6	56.0	68.8	0	10.4	33.4	<17	<26	<17	<16
165	23-Aug-02	U12-1805-60	60	1856126.2	298236.3	4588.95	B	45.9	52.6	66.4	0	6.7	34.7	<17	<26	<17	<16
166	23-Aug-02	U12-1805-61	61	1856126.2	298236.3	4588.95	B	45.5	53.8	67.0	0	8.3	33.7	<17	<26	<17	<16
	23-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	23-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	276	NP	241.8	NP
167	23-Aug-02	U12-1805-62	62	1856126.2	298236.3	4588.95	B	45.3	53.8	66.0	3	8.5	32.5	11F	<26	<17	<16
168	23-Aug-02	U12-1805-63	63	1856126.2	298236.3	4588.95	B	45.7	55.5	67.3	0	9.8	32.5	<17	<26	<17	<16
169	23-Aug-02	U12-1805-64	64	1856126.2	298236.3	4588.95	B	45.8	59.1	70.4	0	13.3	32.1	<17	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
170	23-Aug-02	U12-1805-65	65	1856126.2	298236.3	4588.95	B	45.3	58.7	69.2	0	13.4	30.8	<17	<26	<17	<16
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	58	61.8	58.2	30.6
	23-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	194	NP	180	NP
	23-Aug-02	HAFB1805 V169 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	73	70.8	66.6	49.2
	23-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	62	63.9	65.4	62.7
	24-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	53	49.8	51	33
	24-Aug-02	375 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	392	374.7	405	461.4
	24-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	234	NP	231.9	NP
	24-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
171	24-Aug-02	U12-1806-14	14	1856054.2	298302.1	4587.39	B	45.4	51.7	67.1	0	6.3	35.8	<17	<26	<17	<16
172	24-Aug-02	U12-1806-15	15	1856054.2	298302.1	4587.39	B	45.6	51.2	66.2	0	5.6	35.6	<17	<26	<17	<16
173	24-Aug-02	U12-1806-16	16	1856054.2	298302.1	4587.39	B	45.5	54.4	67.5	0	8.9	33.6	<17	<26	<17	<16
174	24-Aug-02	U12-1806-17	17	1856054.2	298302.1	4587.39	B	45.6	53.9	66.9	0	8.3	33.6	<17	<26	<17	<16
175	24-Aug-02	U12-1806-18	18	1856054.2	298302.1	4587.39	B	45.0	53.7	67.1	0	8.7	33.4	<17	<26	<17	<16
176	24-Aug-02	U12-1806-19	19	1856054.2	298302.1	4587.39	B	45.9	53.5	66.8	0	7.6	34.2	<17	<26	<17	<16
177	24-Aug-02	U12-1806-21	21	1856054.2	298302.1	4587.39	B	45.5	54.7	67.7	0	9.2	33.5	<17	<26	<17	<16
178	24-Aug-02	U12-1806-22	22	1856054.2	298302.1	4587.39	B	44.9	52.2	65.8	0	7.3	33.5	<17	<26	<17	<16
	24-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	71	83.1	72	54.6
179	24-Aug-02	U12-1806-23	23	1856054.2	298302.1	4587.39	B	45.6	57.9	68.5	0	12.3	31.2	<17	<26	<17	<16
180	24-Aug-02	U12-1806-24	24	1856054.2	298302.1	4587.39	B	45.3	55.6	67.2	0	10.3	31.9	<17	<26	<17	<16
181	24-Aug-02	U12-1806-25	25	1856054.2	298302.1	4587.39	B	45.7	55.9	66.9	0	10.2	31.7	<17	<26	<17	<16
182	24-Aug-02	U12-1806-26	26	1856054.2	298302.1	4587.39	B	45.5	56.0	67.6	4	10.5	32.1	12F	<26	<17	<16
183	24-Aug-02	U12-1806-27	27	1856054.2	298302.1	4587.39	B	45.4	55.3	67.1	4	9.9	32.2	13F	<26	<17	<16
184	24-Aug-02	U12-1806-28	28	1856054.2	298302.1	4587.39	B	45.2	55.3	69.2	4	10.1	34.1	14F	<26	<17	<16
185	24-Aug-02	U12-1806-29	29	1856054.2	298302.1	4587.39	B	45.3	56.6	68.9	0	11.3	32.6	<17	<26	<17	<16
186	24-Aug-02	U12-1806-31	31	1856054.2	298302.1	4587.39	B	45.2	52.4	67.7	0	7.2	35.5	<17	<26	<17	<16
187	24-Aug-02	U12-1806-33	33	1856054.2	298302.1	4587.39	B	45.2	52.9	66.9	0	7.7	34.2	<17	<26	<17	<16
	24-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	24-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	56	52.5	56.7	42.3
188	24-Aug-02	U12-1806-34	34	1856054.2	298302.1	4587.39	B	45.2	54.7	66.9	0	9.5	32.4	<17	<26	<17	<16
189	24-Aug-02	U12-1806-35	35	1856054.2	298302.1	4587.39	B	45.9	55.3	67.2	0	9.4	32.8	<17	<26	<17	<16
190	24-Aug-02	U12-1806-36	36	1856054.2	298302.1	4587.39	B	45.6	53.5	66.2	0	7.9	33.3	<17	<26	<17	<16
191	24-Aug-02	U12-1806-38	38	1856054.2	298302.1	4587.39	B	45.4	52.2	65.1	4	6.8	33.3	20	<26	<17	<16
192	24-Aug-02	U12-1806-39	39	1856054.2	298302.1	4587.39	B	45.2	57.9	68.9	32	12.7	31.2	79	<26	<17	<16
	24-Aug-02	HAFB1806 V187 60 ppb MS	---	---	---	---	---	---	---	---	---	---	---	65	52.5	52.8	30.9
193	24-Aug-02	U12-1806-40	40	1856054.2	298302.1	4587.39	B	45.3	50.8	66.0	0	5.5	35.5	<17	<26	<17	<16
194	24-Aug-02	U12-1806-42	42	1856054.2	298302.1	4587.39	B	44.9	55.3	68.3	24	10.4	32.9	76	<26	<17	<16
195	24-Aug-02	U12-1806-43	43	1856054.2	298302.1	4587.39	B	44.8	55.2	67.1	18	10.4	31.7	55	<26	<17	<16
196	24-Aug-02	U12-1806-44	44	1856054.2	298302.1	4587.39	B	45.1	56.0	66.7	26	10.9	30.8	73	<26	<17	<16
197	24-Aug-02	U12-1806-45	45	1856054.2	298302.1	4587.39	B	45.4	56.5	67.3	8	11.1	31.2	22	<26	<17	<16
198	24-Aug-02	U12-1806-46	46	1856054.2	298302.1	4587.39	B	45.5	57.0	68.2	29	11.5	31.7	80	<26	<17	<16
	24-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	63	57	63.6	52.5
199	24-Aug-02	U12-1806-48	48	1856054.2	298302.1	4587.39	B	45.0	54.7	67.6	35	9.7	32.9	119	<26	<17	<16
200	24-Aug-02	U12-1806-49	49	1856054.2	298302.1	4587.39	B	45.1	53.6	67.6	3	8.5	34.1	12F	<26	<17	<16
201	24-Aug-02	U12-1806-50	50	1856054.2	298302.1	4587.39	B	45.6	55.9	68.3	100	10.3	33.0	320	<26	<17	<16
	24-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
202	24-Aug-02	U12-1806-53	53	1856054.2	298302.1	4587.39	B	45.6	55.7	67.5	92	10.1	32.4	295	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
203	24-Aug-02	U12-1806-54	54	1856054.2	298302.1	4587.39	B	45.5	58.3	71.4	96	12.8	33.6	252	<26	<17	<16
204	24-Aug-02	U12-1806-55	55	1856054.2	298302.1	4587.39	B	45.2	55.7	67.6	99	10.5	32.1	303	<26	<17	<16
205	24-Aug-02	U12-1806-56	56	1856054.2	298302.1	4587.39	B	44.9	55.8	67.2	109	10.9	31.3	313	<26	<17	<16
206	24-Aug-02	U12-1806-57	57	1856054.2	298302.1	4587.39	B	45.5	55.6	67.5	84	10.1	32.4	269	<26	<17	<16
207	24-Aug-02	U12-1806-58	58	1856054.2	298302.1	4587.39	B	45.7	53.7	67.5	19	8.0	34.5	82	<26	<17	<16
208	24-Aug-02	U12-1806-59	59	1856054.2	298302.1	4587.39	B	45.5	57.0	69.3	98	11.5	32.8	280	<26	<17	<16
209	24-Aug-02	U12-1806-60	60	1856054.2	298302.1	4587.39	B	45.0	54.9	67.4	30	9.9	32.5	98	<26	<17	<16
	24-Aug-02	HAFB1806 V181 225 ppb MS	---	---	---	---	---	---	---	---	---	---	---	238	225.9	235.5	243.6
	24-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	232	224.7	234.3	251.4
	24-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
210	24-Aug-02	U12-1806-61	61	1856054.2	298302.1	4587.39	B	45.5	53.3	66.5	5	7.8	33.7	22	<26	<17	<16
211	24-Aug-02	U12-1806-62	62	1856054.2	298302.1	4587.39	B	45.1	54.2	66.3	7	9.1	32.2	25	<26	<17	<16
212	24-Aug-02	U12-1806-63	63	1856054.2	298302.1	4587.39	B	45.7	56.2	67.9	8	10.5	32.4	25	<26	<17	<16
213	24-Aug-02	U12-1806-64	64	1856054.2	298302.1	4587.39	B	45.8	53.6	66.3	0	7.8	33.5	<17	<26	<17	<16
214	24-Aug-02	U12-1806-65	65	1856054.2	298302.1	4587.39	B	45.6	59.2	69.4	0	13.6	30.8	<17	<26	<17	<16
	24-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	57	61.5	57.9	38.7
	26-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	228	NP	215.1	NP
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
215	26-Aug-02	U12-1807-22	22	1856098.8	298294.3	4587.19	B	45.8	52.0	65.6	0	6.2	34.4	<17	<26	<17	<16
216	26-Aug-02	U12-1807-23	23	1856098.8	298294.3	4587.19	B	45.7	54.3	66.5	17	8.6	32.9	65	<26	<17	<16
217	26-Aug-02	U12-1807-24	24	1856098.8	298294.3	4587.19	B	45.5	53.7	67.4	0	8.2	34.2	<17	<26	<17	<16
218	26-Aug-02	U12-1807-25	25	1856098.8	298294.3	4587.19	B	45.2	55.1	67.2	700	9.9	32.3	2284	<26	<17	<16
219	26-Aug-02	U12-1807-26	26	1856098.8	298294.3	4587.19	B	45.5	53.4	65.4	3	7.9	32.5	12F	<26	<17	<16
220	26-Aug-02	U12-1807-27	27	1856098.8	298294.3	4587.19	B	45.7	53.0	67.4	221	7.3	35.1	1063	<26	<17	<16
221	26-Aug-02	U12-1807-28	28	1856098.8	298294.3	4587.19	B	45.0	50.1	65.7	273	5.1	35.6	1906	<26	<17	<16
222	26-Aug-02	U12-1807-29	29	1856098.8	298294.3	4587.19	B	45.2	53.2	69.0	310	8.0	36.0	1395	<26	<17	<16
223	26-Aug-02	U12-1807-30	30	1856098.8	298294.3	4587.19	B	45.8	56.2	69.9	1010	10.4	34.5	3350	<26	<17	<16
224	26-Aug-02	U12-1807-31	31	1856098.8	298294.3	4587.19	B	45.7	56.1	68.6	1060	10.4	33.2	3384	<26	<17	<16
225	26-Aug-02	U12-1807-32	32	1856098.8	298294.3	4587.19	B	45.7	56.1	68.3	1250	10.4	32.9	3954	<26	<17	<16
	26-Aug-02	375 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	369	479.7	381	366
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
226	26-Aug-02	U12-1807-33	33	1856098.8	298294.3	4587.19	B	46.1	56.2	68.9	4300	10.1	33.8	144000E	<260	<170	<160
227	26-Aug-02	U12-1807-34	34	1856098.8	298294.3	4587.19	B	45.4	54.0	67.5	293	8.6	33.9	1155	<26	<17	<16
228	26-Aug-02	U12-1807-35	35	1856098.8	298294.3	4587.19	B	45.8	56.5	69.2	1050	10.7	33.5	3287	<26	<17	<16
229	26-Aug-02	U12-1807-36	36	1856098.8	298294.3	4587.19	B	45.1	53.7	66.7	740	8.6	33.1	2848	<26	<17	<16
230	26-Aug-02	U12-1807-37	37	1856098.8	298294.3	4587.19	B	45.2	54.6	67.8	316	9.4	33.4	1123	<26	<17	<16
231	26-Aug-02	U12-1807-38	38	1856098.8	298294.3	4587.19	B	45.6	56.6	69.6	172	11.0	33.6	525	<26	<17	<16
232	26-Aug-02	U12-1807-39	39	1856098.8	298294.3	4587.19	B	45.7	57.0	69.7	302	11.3	33.4	893	<26	<17	<16
233	26-Aug-02	U12-1807-40	40	1856098.8	298294.3	4587.19	B	45.8	53.3	67.4	29	7.5	34.9	135	<26	<17	<16
234	26-Aug-02	U12-1807-41	41	1856098.8	298294.3	4587.19	B	45.8	55.5	67.9	47	9.7	33.2	161	<26	<17	<16
235	26-Aug-02	U12-1807-42	42	1856098.8	298294.3	4587.19	B	45.6	55.2	66.5	198	9.6	31.9	658	<26	<17	<16
	26-Aug-02	1500 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	1485	1554	1434	1356
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	26-Aug-02	HAFB1806 V215 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	72	73.8	67.5	50.1
236	26-Aug-02	U12-1807-43	43	1856098.8	298294.3	4587.19	B	46.0	57.6	69.0	155	11.6	32.4	433	<26	<17	<16
237	26-Aug-02	U12-1807-44	44	1856098.8	298294.3	4587.19	B	45.6	55.8	67.6	59	10.2	32.4	187	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
238	26-Aug-02	U12-1807-45	45	1856098.8	298294.3	4587.19	B	45.6	53.2	67.4	2	7.6	34.8	9F	<26	<17	<16
239	26-Aug-02	U12-1807-48	48	1856098.8	298294.3	4587.19	B	45.9	56.2	69.1	7	10.3	33.8	23	<26	<17	<16
	26-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	259	NP	236.7	NP
240	26-Aug-02	U12-1807-50	50	1856098.8	298294.3	4587.19	B	45.5	57.0	68.5	132	11.5	32.0	367	<26	<17	<16
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
241	26-Aug-02	U12-1807-51	51	1856098.8	298294.3	4587.19	B	45.6	56.2	67.5	12	10.6	31.9	36	<26	<17	<16
242	26-Aug-02	U12-1807-53	53	1856098.8	298294.3	4587.19	B	45.8	57.8	68.6	41	12.0	31.6	108	<26	<17	<16
243	26-Aug-02	U12-1807-54	54	1856098.8	298294.3	4587.19	B	45.8	58.4	68.8	87	12.6	31.2	215	<26	<17	<16
244	26-Aug-02	U12-1807-55	55	1856098.8	298294.3	4587.19	B	45.5	53.7	67.7	13	8.2	34.5	55	<26	<17	<16
245	26-Aug-02	U12-1807-56	56	1856098.8	298294.3	4587.19	B	45.7	55.0	65.3	53	9.3	31.0	177	<26	<17	<16
246	26-Aug-02	U12-1807-57	57	1856098.8	298294.3	4587.19	B	45.5	55.2	68.0	18	9.7	33.3	62	<26	<17	<16
247	26-Aug-02	U12-1807-58	58	1856098.8	298294.3	4587.19	B	45.1	53.8	66.7	2	8.7	33.0	8F	<26	<17	<16
248	26-Aug-02	U12-1807-59	59	1856098.8	298294.3	4587.19	B	45.0	54.9	55.6	80	9.9	20.7	167	<26	<17	<16
249	26-Aug-02	U12-1807-60	60	1856098.8	298294.3	4587.19	B	45.4	55.3	66.4	69	9.9	31.5	220	<26	<17	<16
250	26-Aug-02	U12-1807-61	61	1856098.8	298294.3	4587.19	B	45.4	55.3	66.9	55	9.9	32.0	178	<26	<17	<16
	26-Aug-02	225 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	223	214.2	214.5	204
	26-Aug-02	HAFB1807 V247 225ppb MS	---	---	---	---	---	---	---	---	---	---	---	235	233.1	228.6	198
251	26-Aug-02	U12-1807-62	62	1856098.8	298294.3	4587.19	B	45.6	54.9	66.0	63	9.3	31.7	215	<26	<17	<16
252	26-Aug-02	U12-1807-63	63	1856098.8	298294.3	4587.19	B	45.8	54.8	67.0	30	9.0	33.0	110	<26	<17	<16
253	26-Aug-02	U12-1807-64	64	1856098.8	298294.3	4587.19	B	45.8	56.0	67.4	81	10.2	32.2	256	<26	<17	<16
254	26-Aug-02	U12-1807-65	65	1856098.8	298294.3	4587.19	B	46.0	56.1	67.9	51	10.1	32.8	166	<26	<17	<16
255	26-Aug-02	U12-1807-66	66	1856098.8	298294.3	4587.19	B	45.8	56.2	68.7	38	10.4	33.3	122	<26	<17	<16
256	26-Aug-02	U12-1807-67	67	1856098.8	298294.3	4587.19	B	45.1	55.9	69.5	4	10.8	33.7	12F	<26	<17	<16
257	26-Aug-02	U12-1807-68	68	1856098.8	298294.3	4587.19	B	45.3	55.9	69.1	2	10.6	33.5	6F	<26	<17	<16
258	26-Aug-02	U12-1807-69	69	1856098.8	298294.3	4587.19	B	45.5	52.7	66.7	1	7.2	34.5	5F	<26	<17	<16
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	60	60.3	59.1	56.7
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	75	70.2	66	47.1
259	26-Aug-02	U12-1808-21	21	1856101.7	298230.6	4588.13	B	45.7	59.0	68.7	18	13.3	30.4	41	<26	<17	<16
260	26-Aug-02	U12-1808-22	22	1856101.7	298230.6	4588.13	B	45.9	54.0	66.9	2	8.1	33.8	8F	<26	<17	<16
261	26-Aug-02	U12-1808-23	23	1856101.7	298230.6	4588.13	B	45.5	56.3	67.2	7	10.8	31.4	20	<26	<17	<16
262	26-Aug-02	U12-1808-24	24	1856101.7	298230.6	4588.13	B	45.1	54.5	67.9	8	9.4	33.5	29	<26	<17	<16
263	26-Aug-02	U12-1808-25	25	1856101.7	298230.6	4588.13	B	46.0	56.6	68.2	6	10.6	32.6	18	<26	<17	<16
264	26-Aug-02	U12-1808-26	26	1856101.7	298230.6	4588.13	B	46.0	55.4	67.6	3	9.4	33.2	11F	<26	<17	<16
265	26-Aug-02	U12-1808-27	27	1856101.7	298230.6	4588.13	B	45.9	55.5	67.6	8	9.6	33.0	28	<26	<17	<16
266	26-Aug-02	U12-1808-28	28	1856101.7	298230.6	4588.13	B	45.6	56.2	67.1	8	10.6	31.5	24	<26	<17	<16
267	26-Aug-02	U12-1808-29	29	1856101.7	298230.6	4588.13	B	45.3	56.2	67.3	21	10.9	31.4	60	<26	<17	<16
268	26-Aug-02	U12-1808-30	30	1856101.7	298230.6	4588.13	B	45.6	54.9	64.9	17	9.3	30.6	56	<26	<17	<16
269	26-Aug-02	U12-1808-30D	30	1856101.7	298230.6	4588.13	B	45.2	55.3	67.8	8	10.1	32.7	26	<26	<17	<16
270	26-Aug-02	U12-1808-31	31	1856101.7	298230.6	4588.13	B	45.1	57.1	70.0	25	12.0	33.0	69	<26	<17	<16
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	69	57.6	61.8	59.7
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
271	26-Aug-02	U12-1808-32	32	1856101.7	298230.6	4588.13	B	45.2	53.8	67.2	13	8.6	33.6	51	<26	<17	<16
272	26-Aug-02	U12-1808-33	33	1856101.7	298230.6	4588.13	B	45.6	56.5	67.2	32	10.9	31.3	92	<26	<17	<16
273	26-Aug-02	U12-1808-34	34	1856101.7	298230.6	4588.13	B	45.5	54.2	66.0	9	8.7	32.3	33	<26	<17	<16
274	26-Aug-02	U12-1808-35	35	1856101.7	298230.6	4588.13	B	45.8	52.9	65.5	10	7.1	33.4	47	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
275	26-Aug-02	U12-1808-36	36	1856101.7	298230.6	4588.13	B	45.5	54.4	67.0	33	8.9	33.1	123	<26	<17	<16
276	26-Aug-02	U12-1808-37	37	1856101.7	298230.6	4588.13	B	45.5	53.1	66.1	21	7.6	33.5	93	<26	<17	<16
277	26-Aug-02	U12-1808-38	38	1856101.7	298230.6	4588.13	B	45.8	54.3	66.6	10	8.5	33.1	39	<26	<17	<16
278	26-Aug-02	U12-1808-39	39	1856101.7	298230.6	4588.13	B	45.4	56.1	67.3	25	10.7	31.6	74	<26	<17	<16
279	26-Aug-02	U12-1808-40	40	1856101.7	298230.6	4588.13	B	45.5	55.0	66.0	38	9.5	31.5	126	<26	<17	<16
280	26-Aug-02	U12-1808-41	41	1856101.7	298230.6	4588.13	B	45.0	53.1	67.0	13	8.1	33.9	54	<26	<17	<16
	26-Aug-02	HAFB1808 V260 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	66	59.1	55.2	37.2
281	26-Aug-02	U12-1808-42	42	1856101.7	298230.6	4588.13	B	45.8	55.5	66.0	18	9.7	31.3	58	<26	<17	<16
282	26-Aug-02	U12-1808-43	43	1856101.7	298230.6	4588.13	B	45.2	55.3	67.4	33	10.1	32.3	106	<26	<17	<16
283	26-Aug-02	U12-1808-44	44	1856101.7	298230.6	4588.13	B	45.6	55.6	67.8	9	10.0	32.8	30	<26	<17	<16
284	26-Aug-02	U12-1808-45	45	1856101.7	298230.6	4588.13	B	45.2	52.9	67.7	11	7.7	35.0	50	<26	<17	<16
285	26-Aug-02	U12-1808-46	46	1856101.7	298230.6	4588.13	B	45.4	54.0	66.3	21	8.6	32.7	80	<26	<17	<16
286	26-Aug-02	U12-1808-47	47	1856101.7	298230.6	4588.13	B	44.9	53.3	65.8	9	8.4	32.4	35	<26	<17	<16
287	26-Aug-02	U12-1808-48	48	1856101.7	298230.6	4588.13	B	45.5	51.9	65.3	4	6.4	33.9	21	<26	<17	<16
288	26-Aug-02	U12-1808-49	49	1856101.7	298230.6	4588.13	B	45.4	55.7	67.2	33	10.3	31.9	102	<26	<17	<16
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
289	26-Aug-02	U12-1808-50	50	1856101.7	298230.6	4588.13	B	45.8	52.9	67.1	10	7.1	35.0	49	<26	<17	<16
290	26-Aug-02	U12-1808-51	51	1856101.7	298230.6	4588.13	B	45.2	50.7	65.0	5	5.5	34.5	31	<26	<17	<16
291	26-Aug-02	U12-1808-52	52	1856101.7	298230.6	4588.13	B	45.1	55.1	67.4	24	10.0	32.4	78	<26	<17	<16
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	65.7	57.3	33.9
292	26-Aug-02	U12-1808-53	53	1856101.7	298230.6	4588.13	B	45.0	58.4	69.5	47	13.4	31.1	109	<26	<17	<16
293	26-Aug-02	U12-1808-54	54	1856101.7	298230.6	4588.13	B	45.3	55.0	66.4	30	9.7	31.7	98	<26	<17	<16
294	26-Aug-02	U12-1808-55	55	1856101.7	298230.6	4588.13	B	45.3	55.3	66.9	25	10.0	31.9	80	<26	<17	<16
295	26-Aug-02	U12-1808-56	56	1856101.7	298230.6	4588.13	B	45.3	52.7	64.2	15	7.4	31.8	64	<26	<17	<16
296	26-Aug-02	U12-1808-57	57	1856101.7	298230.6	4588.13	B	44.9	54.6	66.3	16	9.7	31.6	52	<26	<17	<16
297	26-Aug-02	U12-1808-58	58	1856101.7	298230.6	4588.13	B	45.2	55.1	66.2	20	9.9	31.3	63	<26	<17	<16
298	26-Aug-02	U12-1808-59	59	1856101.7	298230.6	4588.13	B	45.6	57.2	67.9	28	11.6	31.3	76	<26	<17	<16
	26-Aug-02	HAFB1809 V290 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	68	61.2	54.3	39
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
299	26-Aug-02	U12-1808-60	60	1856101.7	298230.6	4588.13	B	45.0	54.7	67.4	16	9.7	32.7	54	<26	<17	<16
300	26-Aug-02	U12-1808-61	61	1856101.7	298230.6	4588.13	B	45.2	57.8	68.4	15	12.6	30.8	37	<26	<17	<16
301	26-Aug-02	U12-1808-62	62	1856101.7	298230.6	4588.13	B	45.2	55.7	68.4	8	10.5	32.9	25	<26	<17	<16
302	26-Aug-02	U12-1808-63	63	1856101.7	298230.6	4588.13	B	45.7	56.6	67.8	3	10.9	31.9	9F	<26	<17	<16
304	26-Aug-02	U12-1808-64	64	1856101.7	298230.6	4588.13	B	45.2	60.0	70.3	1	14.8	30.5	<17	<26	<17	<16
	26-Aug-02	HAFB1809 V304 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	85	82.8	77.7	75
	26-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	306	NP	288.3	NP
	26-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	61	63	59.7	31.8
	26-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	62	66.9	61.8	38.4
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	53	60.6	52.8	36.9
	27-Aug-02	HAFB1807 V217 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	79	67.8	58.5	41.7
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
306	27-Aug-02	U12-1809-22	22	1856149.3	298264.5	4589.26	B	45.5	54.6	66.0	0	9.1	31.9	<17	<26	<17	<16
307	27-Aug-02	U12-1809-23	23	1856149.3	298264.5	4589.26	B	45.4	53.6	66.1	3	8.2	32.9	12F	<26	<17	<16
308	27-Aug-02	U12-1809-24	24	1856149.3	298264.5	4589.26	B	45.3	53.5	66.9	2	8.2	33.7	8F	<26	<17	<16
309	27-Aug-02	U12-1809-25	25	1856149.3	298264.5	4589.26	B	45.8	55.9	66.9	8	10.1	31.8	25	<26	<17	<16
310	27-Aug-02	U12-1809-26	26	1856149.3	298264.5	4589.26	B	45.8	56.3	67.0	14	10.5	31.5	42	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
311	27-Aug-02	U12-1809-27	27	1856149.3	298264.5	4589.26	B	45.5	56.6	67.3	16	11.1	31.2	45	<26	<17	<16
312	27-Aug-02	U12-1809-28	28	1856149.3	298264.5	4589.26	B	45.2	53.2	66.8	4	8.0	33.8	17	<26	<17	<16
313	27-Aug-02	U12-1809-29	29	1856149.3	298264.5	4589.26	B	45.5	54.3	67.7	8	8.8	33.9	31	<26	<17	<16
314	27-Aug-02	U12-1809-30	30	1856149.3	298264.5	4589.26	B	45.2	54.3	66.6	10	9.1	32.5	36	<26	<17	<16
315	27-Aug-02	U12-1809-31	31	1856149.3	298264.5	4589.26	B	45.0	54.3	68.5	7	9.3	34.2	26	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	51.3	55.8	45.3
316	27-Aug-02	U12-1809-32	32	1856149.3	298264.5	4589.26	B	45.8	56.5	67.7	7	10.7	32.0	21	<26	<17	<16
317	27-Aug-02	U12-1809-33	33	1856149.3	298264.5	4589.26	B	45.2	53.4	64.5	6	8.2	31.3	23	<26	<17	<16
318	27-Aug-02	U12-1809-34	34	1856149.3	298264.5	4589.26	B	45.0	50.0	64.8	1	5.0	34.8	7F	<26	<17	<16
319	27-Aug-02	U12-1809-35	35	1856149.3	298264.5	4589.26	B	45.5	52.6	66.1	5	7.1	34.0	24	<26	<17	<16
320	27-Aug-02	U12-1809-36	36	1856149.3	298264.5	4589.26	B	45.5	51.7	65.5	4	6.2	34.3	22	<26	<17	<16
321	27-Aug-02	U12-1809-37	37	1856149.3	298264.5	4589.26	B	45.5	53.9	67.2	11	8.4	33.8	44	<26	<17	<16
322	27-Aug-02	U12-1809-38	38	1856149.3	298264.5	4589.26	B	45.5	54.8	67.2	12	9.3	32.9	42	<26	<17	<16
323	27-Aug-02	U12-1809-39	39	1856149.3	298264.5	4589.26	B	45.6	51.9	66.1	3	6.3	34.8	17	<26	<17	<16
324	27-Aug-02	U12-1809-40	40	1856149.3	298264.5	4589.26	B	45.2	53.0	65.9	8	7.8	33.1	34	<26	<17	<16
325	27-Aug-02	U12-1809-41	41	1856149.3	298264.5	4589.26	B	45.0	53.4	66.3	8	8.4	32.9	31	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	51.6	55.8	45.3
	27-Aug-02	HAFB1809 V306 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	73	74.7	63.6	50.7
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
326	27-Aug-02	U12-1809-42	42	1856149.3	298264.5	4589.26	B	45.3	53.1	66.2	6	7.8	33.4	26	<26	<17	<16
327	27-Aug-02	U12-1809-43	43	1856149.3	298264.5	4589.26	B	45.6	55.1	66.3	18	9.5	31.8	60	<26	<17	<16
328	27-Aug-02	U12-1809-44	44	1856149.3	298264.5	4589.26	B	45.3	53.5	66.2	7	8.2	33.0	28	<26	<17	<16
329	27-Aug-02	U12-1809-45	45	1856149.3	298264.5	4589.26	B	45.5	52.7	65.8	5	7.2	33.6	23	<26	<17	<16
330	27-Aug-02	U12-1809-46	46	1856149.3	298264.5	4589.26	B	44.9	55.6	68.3	25	10.7	32.6	76	<26	<17	<16
331	27-Aug-02	U12-1809-47	47	1856149.3	298264.5	4589.26	B	45.9	52.8	65.6	5	6.9	33.7	24	<26	<17	<16
332	27-Aug-02	U12-1809-48	48	1856149.3	298264.5	4589.26	B	45.3	54.2	66.5	17	8.9	32.6	62	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	78	84	68.4	65.4
333	27-Aug-02	U12-1809-49	49	1856149.3	298264.5	4589.26	B	46.5	55.9	67.8	28	9.4	33.4	99	<26	<17	<16
334	27-Aug-02	U12-1809-50	50	1856149.3	298264.5	4589.26	B	46.0	54.7	67.0	41	8.7	33.3	157	<26	<17	<16
335	27-Aug-02	U12-1809-51	51	1856149.3	298264.5	4589.26	B	46.7	53.1	64.3	8	6.4	32.9	41	<26	<17	<16
336	27-Aug-02	U12-1809-52	52	1856149.3	298264.5	4589.26	B	45.6	52.6	64.9	4	7.0	32.9	19	<26	<17	<16
337	27-Aug-02	U12-1809-53	53	1856149.3	298264.5	4589.26	B	45.5	52.1	66.2	7	6.6	34.6	37	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	69	71.1	62.4	54
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
338	27-Aug-02	U12-1809-54	54	1856149.3	298264.5	4589.26	B	45.1	51.6	65.5	9	6.5	34.0	47	<26	<17	<16
339	27-Aug-02	U12-1809-55	55	1856149.3	298264.5	4589.26	B	46.0	54.9	67.3	18	8.9	33.4	68	<26	<17	<16
340	27-Aug-02	U12-1809-56	56	1856149.3	298264.5	4589.26	B	45.5	54.6	66.2	11	9.1	32.1	39	<26	<17	<16
341	27-Aug-02	U12-1809-57	57	1856149.3	298264.5	4589.26	B	45.6	54.3	67.1	10	8.7	33.4	38	<26	<17	<16
342	27-Aug-02	U12-1809-58	58	1856149.3	298264.5	4589.26	B	45.5	51.6	66.5	2	6.1	35.4	12F	<26	<17	<16
343	27-Aug-02	U12-1809-59	59	1856149.3	298264.5	4589.26	B	45.3	53.3	66.5	5	8.0	33.5	21	<26	<17	<16
344	27-Aug-02	U12-1809-60	60	1856149.3	298264.5	4589.26	B	45.6	54.7	66.9	10	9.1	32.8	36	<26	<17	<16
345	27-Aug-02	U12-1809-61	61	1856149.3	298264.5	4589.26	B	45.6	53.9	67.8	5	8.3	34.5	21	<26	<17	<16
346	27-Aug-02	U12-1809-62	62	1856149.3	298264.5	4589.26	B	45.7	54.0	67.2	3	8.3	33.9	12F	<26	<17	<16
347	27-Aug-02	U12-1809-63	63	1856149.3	298264.5	4589.26	B	45.5	55.3	68.9	11	9.8	34.1	38	<26	<17	<16
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	61	66.3	49.8	39

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	57	57.9	51.3	39.9
	27-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	258	NP	241.8	NP
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
348	27-Aug-02	U12-1810-21	21	1856133.5	298301.6	4588.11	B	45.6	56.3	67.1	33	10.7	31.4	97	<26	<17	<16
349	27-Aug-02	U12-1810-22	22	1856133.5	298301.6	4588.11	B	45.1	55.6	66.4	440	10.5	30.9	1295	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	63	61.8	51	39
350	27-Aug-02	U12-1810-23	23	1856133.5	298301.6	4588.11	B	45.3	57.3	66.7	97	12.0	29.7	240	<26	<17	<16
351	27-Aug-02	U12-1810-24	24	1856133.5	298301.6	4588.11	B	45.8	56.3	68.1	68	10.5	32.6	211	<26	<17	<16
352	27-Aug-02	U12-1810-25	25	1856133.5	298301.6	4588.11	B	46.1	53.8	67.9	6	7.7	35.2	27	<26	<17	<16
353	27-Aug-02	U12-1810-26	26	1856133.5	298301.6	4588.11	B	45.4	54.9	66.9	5	9.5	32.4	17	<26	<17	<16
354	27-Aug-02	U12-1810-27	27	1856133.5	298301.6	4588.11	B	45.2	55.1	68.0	35	9.9	33.1	117	<26	<17	<16
355	27-Aug-02	U12-1810-28	28	1856133.5	298301.6	4588.11	B	45.4	54.7	67.1	33	9.3	32.8	116	<26	<17	<16
356	27-Aug-02	U12-1810-29	29	1856133.5	298301.6	4588.11	B	46.7	58.5	68.9	37	11.8	32.1	101	<26	<17	<16
357	27-Aug-02	U12-1810-30	30	1856133.5	298301.6	4588.11	B	46.9	56.1	66.5	20	9.2	32.3	70	<26	<17	<16
358	27-Aug-02	U12-1810-31	31	1856133.5	298301.6	4588.11	B	45.3	52.8	65.4	3	7.5	32.9	13F	<26	<17	<16
359	27-Aug-02	U12-1810-32	32	1856133.5	298301.6	4588.11	B	45.6	54.1	68.0	13	8.5	34.5	53	<26	<17	<16
360	27-Aug-02	U12-1810-33	33	1856133.5	298301.6	4588.11	B	45.7	56.5	68.9	12	10.8	33.1	37	<26	<17	<16
361	27-Aug-02	U12-1810-34	34	1856133.5	298301.6	4588.11	B	45.3	53.9	66.2	8	8.6	32.6	30	<26	<17	<16
362	27-Aug-02	U12-1810-35	35	1856133.5	298301.6	4588.11	B	46.5	56.2	67.2	15	9.7	32.5	50	<26	<17	<16
363	27-Aug-02	U12-1810-36	36	1856133.5	298301.6	4588.11	B	45.8	55.0	65.8	10	9.2	31.6	34	<26	<17	<16
364	27-Aug-02	U12-1810-37	37	1856133.5	298301.6	4588.11	B	45.5	59.7	70.0	15	14.2	30.8	33	<26	<17	<16
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	60	56.4	52.2	36.9
365	27-Aug-02	U12-1810-38	38	1856133.5	298301.6	4588.11	B	45.5	54.8	65.0	12	9.3	30.7	40	<26	<17	<16
366	27-Aug-02	U12-1810-39	39	1856133.5	298301.6	4588.11	B	46.5	54.3	65.8	3	7.8	33.0	13F	<26	<17	<16
367	27-Aug-02	U12-1810-40	40	1856133.5	298301.6	4588.11	B	45.6	53.9	66.2	4	8.3	32.9	16F	<26	<17	<16
368	27-Aug-02	U12-1810-41	41	1856133.5	298301.6	4588.11	B	45.8	54.5	65.3	4	8.7	31.6	15F	<26	<17	<16
	27-Aug-02	HAFB1810 V358 60ppb MS												66	66.6	51	42.9
369	27-Aug-02	U12-1810-42	42	1856133.5	298301.6	4588.11	B	46.3	55.1	68.0	5	8.8	34.2	19	<26	<17	<16
370	27-Aug-02	U12-1810-43	43	1856133.5	298301.6	4588.11	B	46.3	58.5	70.0	11	12.2	32.8	30	<26	<17	<16
371	27-Aug-02	U12-1810-44	44	1856133.5	298301.6	4588.11	B	46.5	60.7	70.8	26	14.2	31.6	58	<26	<17	<16
372	27-Aug-02	U12-1810-45	45	1856133.5	298301.6	4588.11	B	46.0	54.5	67.0	4	8.5	33.5	16F	<26	<17	<16
373	27-Aug-02	U12-1810-46	46	1856133.5	298301.6	4588.11	B	45.1	53.9	66.0	5	8.8	32.2	18	<26	<17	<16
374	27-Aug-02	U12-1810-47	47	1856133.5	298301.6	4588.11	B	45.9	58.8	68.9	27	12.9	31.0	65	<26	<17	<16
	27-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	59	60.6	47.4	37.2
375	27-Aug-02	U12-1810-48	48	1856133.5	298301.6	4588.11	B	45.8	58.3	67.5	22	12.5	30.0	53	<26	<17	<16
376	27-Aug-02	U12-1810-49	49	1856133.5	298301.6	4588.11	B	45.2	53.8	66.8	14	8.6	33.2	54	<26	<17	<16
377	27-Aug-02	U12-1810-50	50	1856133.5	298301.6	4588.11	B	45.5	57.3	68.9	29	11.8	32.1	79	<26	<17	<16
378	27-Aug-02	U12-1810-51	51	1856133.5	298301.6	4588.11	B	45.6	55.0	67.7	12	9.4	33.3	43	<26	<17	<16
379	27-Aug-02	U12-1810-52	52	1856133.5	298301.6	4588.11	B	45.5	53.6	65.9	16	8.1	32.8	65	<26	<17	<16
380	27-Aug-02	U12-1810-53	53	1856133.5	298301.6	4588.11	B	45.4	55.2	66.5	40	9.8	31.7	129	<26	<17	<16
381	27-Aug-02	U12-1810-54	54	1856133.5	298301.6	4588.11	B	45.7	57.5	68.9	48	11.8	32.1	131	<26	<17	<16
382	27-Aug-02	U12-1810-55	55	1856133.5	298301.6	4588.11	B	45.6	56.6	67.9	36	11.0	31.9	104	<26	<17	<16
383	27-Aug-02	U12-1810-56	56	1856133.5	298301.6	4588.11	B	45.6	56.0	68.4	59	10.4	33.0	187	<26	<17	<16
384	27-Aug-02	U12-1810-57	57	1856133.5	298301.6	4588.11	B	45.5	53.6	67.3	3	8.1	34.2	13F	<26	<17	<16
	27-Aug-02	HAFB1810 V366 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	74	68.1	53.1	38.1

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
385	27-Aug-02	U12-1810-58	58	1856133.5	298301.6	4588.11	B	45.5	53.2	67.7	2	7.7	35.0	9F	<26	<17	<16
386	27-Aug-02	U12-1810-59	59	1856133.5	298301.6	4588.11	B	45.5	53.8	66.9	2	8.3	33.6	8F	<26	<17	<16
387	27-Aug-02	U12-1810-60	60	1856133.5	298301.6	4588.11	B	46.0	56.7	69.9	24	10.7	34.2	77	<26	<17	<16
388	27-Aug-02	U12-1810-61	61	1856133.5	298301.6	4588.11	B	45.6	57.4	67.4	17	11.8	30.6	44	<26	<17	<16
	27-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	27-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	200	NP	168.9	NP
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	28-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	226	NP	195.3	NP
389	28-Aug-02	U12-1811-22	22	1856155.6	298330.3	4588.97	B	46.3	56.6	67.5	1	10.3	32.2	<17	<26	<17	<16
390	28-Aug-02	U12-1811-23	23	1856155.6	298330.3	4588.97	B	45.8	54.3	66.6	0	8.5	33.1	<17	<26	<17	<16
391	28-Aug-02	U12-1811-24	24	1856155.6	298330.3	4588.97	B	45.6	54.2	67.8	0	8.6	34.2	<17	<26	<17	<16
392	28-Aug-02	U12-1811-25	25	1856155.6	298330.3	4588.97	B	46.0	56.2	68.0	6	10.2	32.8	19	<26	<17	<16
393	28-Aug-02	U12-1811-26	26	1856155.6	298330.3	4588.97	B	45.6	56.6	68.4	2	11.0	32.4	6F	<26	<17	<16
394	28-Aug-02	U12-1811-27	27	1856155.6	298330.3	4588.97	B	45.2	57.2	68.3	8	12.0	31.3	21	<26	<17	<16
395	28-Aug-02	U12-1811-28	28	1856155.6	298330.3	4588.97	B	44.7	56.2	68.4	8	11.5	31.9	22	<26	<17	<16
396	28-Aug-02	U12-1811-29	29	1856155.6	298330.3	4588.97	B	45.1	54.6	66.3	11	9.5	31.8	37	<26	<17	<16
397	28-Aug-02	U12-1811-30	30	1856155.6	298330.3	4588.97	B	45.5	53.4	65.2	0	7.9	32.3	<17	<26	<17	<16
398	28-Aug-02	U12-1811-31	31	1856155.6	298330.3	4588.97	B	45.6	55.2	68.4	3	9.6	33.8	11F	<26	<17	<16
399	28-Aug-02	U12-1811-32	32	1856155.6	298330.3	4588.97	B	45.5	53.7	68.1	4	8.2	34.9	17	<26	<17	<16
400	28-Aug-02	U12-1811-33	33	1856155.6	298330.3	4588.97	B	45.6	56.3	68.3	0	10.7	32.6	<17	<26	<17	<16
401	28-Aug-02	U12-1811-34	34	1856155.6	298330.3	4588.97	B	45.2	55.1	67.9	3	9.9	33.0	10F	<26	<17	<16
	28-Aug-02	HAFB1811 V389 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	68	75.3	79.2	59.7
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	78.9	81	60.6
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
402	28-Aug-02	U12-1811-35	35	1856155.6	298330.3	4588.97	B	45.1	55.6	67.3	11	10.5	31.8	33	<26	<17	<16
403	28-Aug-02	U12-1811-36	36	1856155.6	298330.3	4588.97	B	45.3	53.7	67.4	6	8.4	34.0	24	<26	<17	<16
404	28-Aug-02	U12-1811-37	37	1856155.6	298330.3	4588.97	B	45.9	53.4	66.0	4	7.5	33.5	18	<26	<17	<16
405	28-Aug-02	U12-1811-38	38	1856155.6	298330.3	4588.97	B	45.5	55.1	66.6	14	9.6	32.0	47	<26	<17	<16
406	28-Aug-02	U12-1811-39	39	1856155.6	298330.3	4588.97	B	45.9	55.4	67.1	5	9.5	32.6	17	<26	<17	<16
407	28-Aug-02	U12-1811-40	40	1856155.6	298330.3	4588.97	B	46.0	54.4	67.0	5	8.4	33.6	20	<26	<17	<16
408	28-Aug-02	U12-1811-41	41	1856155.6	298330.3	4588.97	B	45.2	53.7	66.3	4	8.5	32.8	15F	<26	<17	<16
409	28-Aug-02	U12-1811-42	42	1856155.6	298330.3	4588.97	B	45.2	52.1	66.4	3	6.9	34.5	15F	<26	<17	<16
410	28-Aug-02	U12-1811-43	43	1856155.6	298330.3	4588.97	B	45.3	53.7	67.1	0	8.4	33.7	<17	<26	<17	<16
411	28-Aug-02	U12-1811-44	44	1856155.6	298330.3	4588.97	B	45.7	56.5	67.8	7	10.8	32.0	21	<26	<17	<16
412	28-Aug-02	U12-1811-45	45	1856155.6	298330.3	4588.97	B	45.7	55.8	68.0	2	10.1	32.9	7F	<26	<17	<16
413	28-Aug-02	U12-1811-46	46	1856155.6	298330.3	4588.97	B	45.6	52.6	65.2	5	7.0	33.2	24	<26	<17	<16
414	28-Aug-02	U12-1811-47	47	1856155.6	298330.3	4588.97	B	45.3	54.7	67.4	6	9.4	33.0	21	<26	<17	<16
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	52	45	66.3	48.3
	28-Aug-02	HAFB1811 V391 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	62	59.1	78.6	56.1
415	28-Aug-02	U12-1811-48	48	1856155.6	298330.3	4588.97	B	45.2	55.4	67.3	26	10.2	32.1	82	<26	<17	<16
416	28-Aug-02	U12-1811-49	49	1856155.6	298330.3	4588.97	B	45.4	54.8	68.0	19	9.4	33.6	68	<26	<17	<16
417	28-Aug-02	U12-1811-50	50	1856155.6	298330.3	4588.97	B	45.4	53.4	66.3	10	8.0	33.3	42	<26	<17	<16
418	28-Aug-02	U12-1811-51	51	1856155.6	298330.3	4588.97	B	45.5	56.0	67.3	22	10.5	31.8	67	<26	<17	<16
419	28-Aug-02	U12-1811-52	52	1856155.6	298330.3	4588.97	B	45.2	58.7	68.3	26	13.5	29.8	57	<26	<17	<16
420	28-Aug-02	U12-1811-53	53	1856155.6	298330.3	4588.97	B	45.9	51.2	65.2	1	5.3	34.9	7F	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
421	28-Aug-02	U12-1811-54	54	1856155.6	298330.3	4588.97	B	45.3	52.5	66.0	1	7.2	33.8	5F	<26	<17	<16
422	28-Aug-02	U12-1811-55	55	1856155.6	298330.3	4588.97	B	45.1	51.2	65.4	2	6.1	34.3	11F	<26	<17	<16
423	28-Aug-02	U12-1811-56	56	1856155.6	298330.3	4588.97	B	45.7	53.2	65.9	1	7.5	33.4	5F	<26	<17	<16
424	28-Aug-02	U12-1811-57	57	1856155.6	298330.3	4588.97	B	45.5	55.6	66.8	31	10.1	31.7	97	<26	<17	<16
425	28-Aug-02	U12-1811-58	58	1856155.6	298330.3	4588.97	B	45.3	55.2	67.7	16	9.9	32.8	53	<26	<17	<16
426	28-Aug-02	U12-1811-59	59	1856155.6	298330.3	4588.97	B	45.6	52.9	65.6	15	7.3	33.3	68	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	57	65.7	63.3	49.5
	28-Aug-02	HAFB1811 V397 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	62	72.6	68.7	44.4
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
427	28-Aug-02	U12-1811-60	60	1856155.6	298330.3	4588.97	B	45.5	54.4	68.7	22	8.9	34.8	86	<26	<17	<16
428	28-Aug-02	U12-1811-61	61	1856155.6	298330.3	4588.97	B	45.8	58.4	68.7	27	12.6	31.1	67	<26	<17	<16
429	28-Aug-02	U12-1811-62	62	1856155.6	298330.3	4588.97	B	45.3	55.4	66.5	15	10.1	31.4	47	<26	<17	<16
430	28-Aug-02	U12-1811-63	63	1856155.6	298330.3	4588.97	B	45.3	56.4	68.3	18	11.1	32.2	52	<26	<17	<16
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	52	66.3	64.5	38.7
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	54	65.7	67.5	39.9
	28-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	206	NP	170.4	NP
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
431	28-Aug-02	U12-1812-21	21	1856025.9	298325.4	4588.11	B	45.9	53.1	66.1	0	7.2	33.9	<17	<26	<17	<16
432	28-Aug-02	U12-1812-26	26	1856025.9	298325.4	4588.11	B	45.8	55.9	68.5	0	10.1	33.4	<17	<26	<17	<16
433	28-Aug-02	U12-1812-31	31	1856025.9	298325.4	4588.11	B	45.8	53.1	65.9	0	7.3	33.6	<17	<26	<17	<16
434	28-Aug-02	U12-1812-36	36	1856025.9	298325.4	4588.11	B	45.9	54.6	67.9	0	8.7	34.2	<17	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	56	65.7	69.6	42.9
435	28-Aug-02	U12-1812-41	41	1856025.9	298325.4	4588.11	B	46.0	54.3	66.9	0	8.3	33.6	<17	<26	<17	<16
436	28-Aug-02	U12-1812-42	42	1856025.9	298325.4	4588.11	B	45.7	53.4	66.8	0	7.7	34.1	<17	<26	<17	<16
437	28-Aug-02	U12-1812-43	43	1856025.9	298325.4	4588.11	B	45.3	56.1	66.3	0	10.8	30.5	<17	<26	<17	<16
438	28-Aug-02	U12-1812-44	44	1856025.9	298325.4	4588.11	B	45.9	54.7	67.4	1	8.8	33.6	<17	<26	<17	<16
439	28-Aug-02	U12-1812-45	45	1856025.9	298325.4	4588.11	B	46.2	58.8	67.8	6	12.6	30.2	14F	<26	<17	<16
440	28-Aug-02	U12-1812-46	46	1856025.9	298325.4	4588.11	B	45.1	55.6	69.3	4	10.5	33.8	13F	<26	<17	<16
441	28-Aug-02	U12-1812-47	47	1856025.9	298325.4	4588.11	B	45.6	53.8	65.1		8.2	31.9	<17	<26	<17	<16
442	28-Aug-02	U12-1812-48	48	1856025.9	298325.4	4588.11	B	45.5	54.0	63.4		8.5	29.9	<17	<26	<17	<16
443	28-Aug-02	U12-1812-49	49	1856025.9	298325.4	4588.11	B	45.8	57.0	68.4	3	11.2	32.2	9F			
	28-Aug-02	HAFB1812 V300 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	84	66.6	56.4	44.4
444	28-Aug-02	U12-1812-50	50	1856025.9	298325.4	4588.11	B	45.4	54.2	65.8	8	8.8	32.0	29	<26	<17	<16
445	28-Aug-02	U12-1812-51	51	1856025.9	298325.4	4588.11	B	45.3	55.2	65.5	22	9.9	30.6	68	<26	<17	<16
446	28-Aug-02	U12-1812-52	52	1856025.9	298325.4	4588.11	B	46.0	54.3	66.6	1	8.3	33.3	<17	<26	<17	<16
447	28-Aug-02	U12-1812-53	53	1856025.9	298325.4	4588.11	B	45.8	50.9	63.5	0	5.1	33.4	<17	<26	<17	<16
448	28-Aug-02	U12-1812-54	54	1856025.9	298325.4	4588.11	B	45.9	52.5	65.3	0	6.6	33.7	<17	<26	<17	<16
449	28-Aug-02	U12-1812-55	55	1856025.9	298325.4	4588.11	B	45.5	51.9	65.1	0	6.4	33.7	<17	<26	<17	<16
450	28-Aug-02	U12-1812-56	56	1856025.9	298325.4	4588.11	B	45.7	51.8	65.4	0	6.1	34.3	<17	<26	<17	<16
	28-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	56	66.3	69.6	42.9
451	28-Aug-02	U12-1812-57	57	1856025.9	298325.4	4588.11	B	45.0	51.5	68.1	0	6.5	36.6	<17	<26	<17	<16
452	28-Aug-02	U12-1812-58	58	1856025.9	298325.4	4588.11	B	45.2	53.9	54.9	11	8.7	21.2	27	<26	<17	<16
453A	28-Aug-02	U12-1812-59	59	1856025.9	298325.4	4588.11	B	45.2	57.0	67.5	23	11.8	30.7	60	<26	<17	<16
453B	28-Aug-02	U12-1812-60	60	1856025.9	298325.4	4588.11	B	46.0	54.4	64.0	29	8.4	30.6	106	<26	<17	<16
454	28-Aug-02	U12-1812-61	61	1856025.9	298325.4	4588.11	B	45.8	56.5	67.8	42	10.7	32.1	126	<26	<17	<16

TABLE A-1

FIELD ANALYTICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
455	28-Aug-02	U12-1812-62	62	1856025.9	298325.4	4588.11	B	45.7	54.7	65.5	16	9.0	31.5	56	<26	<17	<16
456	28-Aug-02	U12-1812-63	63	1856025.9	298325.4	4588.11	B	45.4	55.4	68.1	37	10.0	33.1	122	<26	<17	<16
457	28-Aug-02	U12-1812-64	64	1856025.9	298325.4	4588.11	B	45.6	53.5	66.4	25	7.9	33.5	106	<26	<17	<16
458	28-Aug-02	U12-1812-65	65	1856025.9	298325.4	4588.11	B	45.5	55.5	67.7	50	10.0	32.7	164	<26	<17	<16
	28-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	59	79.8	73.2	56.1
459	28-Aug-02	U12-1812-68	68	1856025.9	298325.4	4588.11	B	46.1	54.0	65.6	2	7.9	32.7	8F	<26	<17	<16
460	28-Aug-02	U12-1812-70	70	1856025.9	298325.4	4588.11	B	45.4	54.2	67.1	1	8.8	33.3	<17	<26	<17	<16
461	28-Aug-02	U12-1812-69	69	1856025.9	298325.4	4588.11	B	45.3	55.9	67.8	2	10.6	32.2	6F	<26	<17	<16
	28-Aug-02	HAFB1812 V359 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	68	78.3	75.3	43.2
	28-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	226	NP	201.6	NP
	29-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	309	NP	203.7	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
462	29-Aug-02	U12-1813-21	21	1856066.3	298254.9	4587.23	B	45.5	57.4	67.6	0	11.9	30.7	<17	<26	<17	<16
463	29-Aug-02	U12-1813-22	22	1856066.3	298254.9	4587.23	B	45.5	55.6	67.4	6	10.1	32.3	19	<26	<17	<16
464	29-Aug-02	U12-1813-23	23	1856066.3	298254.9	4587.23	B	46.1	57.2	67.6	4	11.1	31.5	11F	<26	<17	<16
465	29-Aug-02	U12-1813-24	24	1856066.3	298254.9	4587.23	B	45.6	55.4	67.3	4	9.8	32.5	13F	<26	<17	<16
466	29-Aug-02	U12-1813-25	25	1856066.3	298254.9	4587.23	B	45.6	56.8	67.1	7	11.2	30.9	19	<26	<17	<16
467	29-Aug-02	U12-1813-26	26	1856066.3	298254.9	4587.23	B	45.8	54.1	67.1	5	8.3	33.8	20	<26	<17	<16
468	29-Aug-02	U12-1813-27	27	1856066.3	298254.9	4587.23	B	46.2	56.7	67.9	0	10.5	32.4	<17	<26	<17	<16
469	29-Aug-02	U12-1813-28	28	1856066.3	298254.9	4587.23	B	45.5	56.2	68.1	5	10.7	32.4	15F	<26	<17	<16
470	29-Aug-02	U12-1813-29	29	1856066.3	298254.9	4587.23	B	45.4	54.1	66.5	5	8.7	32.8	19	<26	<17	<16
471	29-Aug-02	U12-1813-30	30	1856066.3	298254.9	4587.23	B	45.6	56.7	67.6	20	11.1	31.5	57	<26	<17	<16
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	64	55.8	51.6	NP
472	29-Aug-02	U12-1813-31	31	1856066.3	298254.9	4587.23	B	45.5	55.9	68.3	8	10.4	32.9	25	<26	<17	<16
473	29-Aug-02	U12-1813-32	32	1856066.3	298254.9	4587.23	B	45.4	55.6	67.8	15	10.2	32.6	48	<26	<17	<16
474	29-Aug-02	U12-1813-33	33	1856066.3	298254.9	4587.23	B	45.5	53.9	67.2	9	8.4	33.8	36	<26	<17	<16
475	29-Aug-02	U12-1813-34	34	1856066.3	298254.9	4587.23	B	46.0	53.7	66.6	2	7.7	33.9	9F	<26	<17	<16
476	29-Aug-02	U12-1813-35	35	1856066.3	298254.9	4587.23	B	45.3	54.0	66.1	12	8.7	32.4	45	<26	<17	<16
477	29-Aug-02	U12-1813-36	36	1856066.3	298254.9	4587.23	B	45.3	54.8	67.9	10	9.5	33.4	35	<26	<17	<16
478	29-Aug-02	U12-1813-37	37	1856066.3	298254.9	4587.23	B	45.4	57.2	69.1	32	11.8	32.3	88	<26	<17	<16
479	29-Aug-02	U12-1813-38	38	1856066.3	298254.9	4587.23	B	46.1	54.7	66.5	6	8.6	32.9	23	<26	<17	<16
480	29-Aug-02	U12-1813-39	39	1856066.3	298254.9	4587.23	B	45.4	56.5	67.2	48	11.1	31.1	134	<26	<17	<16
481	29-Aug-02	U12-1813-40	40	1856066.3	298254.9	4587.23	B	45.6	57.5	67.3	47	11.9	30.4	120	<26	<17	<16
	29-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	264	NP	191.4	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
482	29-Aug-02	U12-1813-41	41	1856066.3	298254.9	4587.23	B	45.5	56.3	68.1	47	10.8	32.3	141	<26	<17	<16
483	29-Aug-02	U12-1813-42	42	1856066.3	298254.9	4587.23	B	45.4	58.3	68.6	59	12.9	30.7	140	<26	<17	<16
484	29-Aug-02	U12-1813-43	43	1856066.3	298254.9	4587.23	B	46.0	58.0	67.9	75	12.0	30.9	193	<26	<17	<16
485	29-Aug-02	U12-1813-44	44	1856066.3	298254.9	4587.23	B	45.4	53.4	65.3	1	8.0	32.3	<17	<26	<17	<16
486	29-Aug-02	U12-1813-45	45	1856066.3	298254.9	4587.23	B	45.3	56.9	68.3	33	11.6	31.7	90	<26	<17	<16
487	29-Aug-02	U12-1813-46	46	1856066.3	298254.9	4587.23	B	45.2	55.9	68.2	82	10.7	32.5	249	<26	<17	<16
488	29-Aug-02	U12-1813-47	47	1856066.3	298254.9	4587.23	B	45.6	55.9	67.2	68	10.3	31.9	211	<26	<17	<16
489	29-Aug-02	U12-1813-48	48	1856066.3	298254.9	4587.23	B	45.5	51.9	66.7	7	6.4	35.3	39	<26	<17	<16
490	29-Aug-02	U12-1813-49	49	1856066.3	298254.9	4587.23	B	45.6	55.4	66.9	39	9.8	32.1	128	<26	<17	<16
491	29-Aug-02	U12-1813-50	50	1856066.3	298254.9	4587.23	B	45.8	54.3	65.9	30	8.5	32.4	114	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	69	58.8	54.9	NP

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
492	29-Aug-02	U12-1813-51	51	1856066.3	298254.9	4587.23	B	45.6	53.9	65.2	35	8.3	31.9	135	<26	<17	<16
493	29-Aug-02	U12-1813-52	52	1856066.3	298254.9	4587.23	B	46.0	53.3	66.9	8	7.3	34.6	38	<26	<17	<16
494	29-Aug-02	U12-1813-53	53	1856066.3	298254.9	4587.23	B	45.9	57.1	69.1	34	11.2	32.9	100	<26	<17	<16
495	29-Aug-02	U12-1813-54	54	1856066.3	298254.9	4587.23	B	45.8	54.2	65.7	6	8.4	32.3	23	<26	<17	<16
496	29-Aug-02	U12-1813-55	55	1856066.3	298254.9	4587.23	B	45.0	53.5	66.6	15	8.5	33.1	58	<26	<17	<16
497	29-Aug-02	U12-1813-56	56	1856066.3	298254.9	4587.23	B	45.7	56.1	67.9	48	10.4	32.5	150	<26	<17	<16
498	29-Aug-02	U12-1813-57	57	1856066.3	298254.9	4587.23	B	45.8	57.6	67.5	55	11.8	30.7	143	<26	<17	<16
499	29-Aug-02	U12-1813-58	58	1856066.3	298254.9	4587.23	B	45.6	54.4	67.9	38	8.8	34.1	147	<26	<17	<16
500	29-Aug-02	U12-1813-59	59	1856066.3	298254.9	4587.23	B	45.2	54.9	66.0	23	9.7	31.3	74	<26	<17	<16
501	29-Aug-02	U12-1813-60	60	1856066.3	298254.9	4587.23	B	46.0	58.1	68.9	33	12.1	31.8	87	<26	<17	<16
502	29-Aug-02	U12-1813-61	61	1856066.3	298254.9	4587.23	B	45.5	57.9	70.6	24	12.4	33.2	64	<26	<17	<16
503	29-Aug-02	U12-1813-62	62	1856066.3	298254.9	4587.23	B	45.6	55.5	67.6	9	9.9	32.7	30	<26	<17	<16
504	29-Aug-02	U12-1813-63	63	1856066.3	298254.9	4587.23	B	45.7	55.1	67.3	4	9.4	32.9	14F	<26	<17	<16
505	29-Aug-02	U12-1813-64	64	1856066.3	298254.9	4587.23	B	46.2	55.8	68.2	2	9.6	33.6	7F	<26	<17	<16
506	29-Aug-02	U12-1813-65	65	1856066.3	298254.9	4587.23	B	45.8	58.5	69.6	0	12.7	31.9	<17	<26	<17	<16
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	48	48.3	59.1	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	69	59.7	60.9	NP
	29-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	317	NP	249.3	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	HAFB1813 V506 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	68	67.5	77.4	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
507	29-Aug-02	U12-1814-21	21	1856031.5	298242.7	4587.14	B	46.1	56.3	68.5	0	10.2	33.3	<17	<26	<17	<16
508	29-Aug-02	U12-1814-22	22	1856031.5	298242.7	4587.14	B	45.9	55.1	67.5	0	9.2	33.3	<17	<26	<17	<16
509	29-Aug-02	U12-1814-23	23	1856031.5	298242.7	4587.14	B	45.5	54.6	67.6	0	9.1	33.5	<17	<26	<17	<16
510	29-Aug-02	U12-1814-24	24	1856031.5	298242.7	4587.14	B	45.9	51.9	64.9	0	6.0	33.9	<17	<26	<17	<16
511	29-Aug-02	U12-1814-25	25	1856031.5	298242.7	4587.14	B	45.0	53.5	66.2	0	8.5	32.7	<17	<26	<17	<16
512	29-Aug-02	U12-1814-26	26	1856031.5	298242.7	4587.14	B	46.2	54.1	67.1	0	7.9	34.2	<17	<26	<17	<16
513	29-Aug-02	U12-1814-27	27	1856031.5	298242.7	4587.14	B	45.5	55.1	66.3	0	9.6	31.7	<17	<26	<17	<16
514	29-Aug-02	U12-1814-28	28	1856031.5	298242.7	4587.14	B	46.7	53.4	66.2	0	6.7	34.5	<17	<26	<17	<16
515	29-Aug-02	U12-1814-29	29	1856031.5	298242.7	4587.14	B	45.8	53.1	65.1	0	7.3	32.8	<17	<26	<17	<16
516	29-Aug-02	U12-1814-30	30	1856031.5	298242.7	4587.14	B	46.3	55.3	67.6	0	9.0	33.6	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	52	54.3	59.1	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
517	29-Aug-02	U12-1814-31	31	1856031.5	298242.7	4587.14	B	45.2	56.7	68.3	1	11.5	31.8	<17	<26	<17	<16
518	29-Aug-02	U12-1814-32	32	1856031.5	298242.7	4587.14	B	45.7	54.0	66.4	0	8.3	33.1	<17	<26	<17	<16
519	29-Aug-02	U12-1814-33	33	1856031.5	298242.7	4587.14	B	46.0	55.8	67.6	0	9.8	32.8	<17	<26	<17	<16
520	29-Aug-02	U12-1814-34	34	1856031.5	298242.7	4587.14	B	45.6	57.4	68.9	0	11.8	32.1	<17	<26	<17	<16
521	29-Aug-02	U12-1814-35	35	1856031.5	298242.7	4587.14	B	46.0	57.3	67.8	1	11.3	31.5	<17	<26	<17	<16
522	29-Aug-02	U12-1814-36	36	1856031.5	298242.7	4587.14	B	45.9	54.8	67.1	0	8.9	33.2	<17	<26	<17	<16
523	29-Aug-02	U12-1814-37	37	1856031.5	298242.7	4587.14	B	46.2	55.3	67.9	0	9.1	33.8	<17	<26	<17	<16
524	29-Aug-02	U12-1814-38	38	1856031.5	298242.7	4587.14	B	45.3	53.7	66.9	2	8.4	33.5	8F	<26	<17	<16
525	29-Aug-02	U12-1814-39	39	1856031.5	298242.7	4587.14	B	46.1	55.8	67.9	4	9.7	33.2	14F	<26	<17	<16
526	29-Aug-02	U12-1814-40	40	1856031.5	298242.7	4587.14	B	46.1	53.8	66.2	3	7.7	33.5	13F	<26	<17	<16
527	29-Aug-02	U12-1814-41	41	1856031.5	298242.7	4587.14	B	46.3	52.5	63.8	0	6.2	32.6	<17	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
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Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	29-Aug-02	HAFB1814 V507 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	57	69.3	61.5	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
528	29-Aug-02	U12-1814-42	42	1856031.5	298242.7	4587.14	B	45.9	55.9	66.2	11	10.0	31.2	34	<26	<17	<16
529	29-Aug-02	U12-1814-43	43	1856031.5	298242.7	4587.14	B	45.5	52.6	63.7	7	7.1	31.6	31	<26	<17	<16
530	29-Aug-02	U12-1814-44	44	1856031.5	298242.7	4587.14	B	45.5	56.8	67.0	20	11.3	30.7	54	<26	<17	<16
531	29-Aug-02	U12-1814-45	45	1856031.5	298242.7	4587.14	B	46.2	54.4	67.3	2	8.2	34.1	8F	<26	<17	<16
532	29-Aug-02	U12-1814-46	46	1856031.5	298242.7	4587.14	B	46.4	57.1	67.1	18	10.7	31.4	53	<26	<17	<16
533	29-Aug-02	U12-1814-47	47	1856031.5	298242.7	4587.14	B	45.5	55.9	69.4	20	10.4	34.0	65	<26	<17	<16
534	29-Aug-02	U12-1814-48	48	1856031.5	298242.7	4587.14	B	46.0	57.0	68.9	51	11.0	32.9	153	<26	<17	<16
535	29-Aug-02	U12-1814-49	49	1856031.5	298242.7	4587.14	B	46.4	54.3	67.1	13	7.9	34.2	56	<26	<17	<16
536	29-Aug-02	U12-1814-50	50	1856031.5	298242.7	4587.14	B	45.6	53.8	67.4	5	8.2	34.2	21	<26	<17	<16
537	29-Aug-02	U12-1814-51	51	1856031.5	298242.7	4587.14	B	46.3	54.7	66.6	19	8.4	33.2	75	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	80	66.9	66.9	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
538	29-Aug-02	U12-1814-52	52	1856031.5	298242.7	4587.14	B	46.0	56.9	69.5	72	10.9	33.6	222	<26	<17	<16
539	29-Aug-02	U12-1814-53	53	1856031.5	298242.7	4587.14	B	45.9	55.9	67.9	23	10.0	32.9	76	<26	<17	<16
540	29-Aug-02	U12-1814-54	54	1856031.5	298242.7	4587.14	B	46.1	56.3	67.9	26	10.2	32.7	83	<26	<17	<16
541	29-Aug-02	U12-1814-55	55	1856031.5	298242.7	4587.14	B	45.3	56.4	68.0	44	11.1	31.9	126	<26	<17	<16
542	29-Aug-02	U12-1814-56	56	1856031.5	298242.7	4587.14	B	45.5	59.8	68.5	96	14.3	29.2	196	<26	<17	<16
543	29-Aug-02	U12-1814-57	57	1856031.5	298242.7	4587.14	B	45.5	54.4	67.5	45	8.9	33.6	170	<26	<17	<16
544	29-Aug-02	U12-1814-58	58	1856031.5	298242.7	4587.14	B	45.7	55.0	65.9	35	9.3	31.6	119	<26	<17	<16
545	29-Aug-02	U12-1814-59	59	1856031.5	298242.7	4587.14	B	46.0	56.5	67.3	50	10.5	31.8	151	<26	<17	<16
546	29-Aug-02	U12-1814-60	60	1856031.5	298242.7	4587.14	B	45.3	54.8	66.7	46	9.5	32.2	156	<26	<17	<16
547	29-Aug-02	U12-1814-61	61	1856031.5	298242.7	4587.14	B	45.5	56.5	66.5	32	11.0	30.5	89	<26	<17	<16
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	62	56.7	64.5	NP
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	48	55.2	57.9	NP
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	78	79.2	69.6	NP
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	74	58.8	63	NP
	29-Aug-02	HAFB1814 V509 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	76	74.1	70.5	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	225 ppb VOC Mix1A	---	---	---	---	---	---	---	---	---	---	---	237	NP	220.8	NP
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	64	66.6	69.9	NP
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
548	29-Aug-02	U12-1815-21	21	1856009.8	298236.8	4586.96	B	45.9	59.3	69.0	0	13.4	30.6	<17	<26	<17	<16
549	29-Aug-02	U12-1815-26	26	1856009.8	298236.8	4586.96	B	45.3	52.7	66.3	0	7.4	33.9	<17	<26	<17	<16
550	29-Aug-02	U12-1815-31	31	1856009.8	298236.8	4586.96	B	45.7	54.6	66.1	0	8.9	32.2	<17	<26	<17	<16
551	29-Aug-02	U12-1815-36	36	1856009.8	298236.8	4586.96	B	46.0	55.8	66.3	0	9.8	31.5	<17	<26	<17	<16
552	29-Aug-02	U12-1815-41	41	1856009.8	298236.8	4586.96	B	46.5	55.0	66.0	0	8.5	32.5	<17	<26	<17	<16
553	29-Aug-02	U12-1815-42	42	1856009.8	298236.8	4586.96	B	45.9	53.2	65.1	0	7.3	32.8	<17	<26	<17	<16
554	29-Aug-02	U12-1815-43	43	1856009.8	298236.8	4586.96	B	45.9	53.0	66.5	0	7.1	34.4	<17	<26	<17	<16
555	29-Aug-02	U12-1815-44	44	1856009.8	298236.8	4586.96	B	46.3	57.1	67.9	0	10.8	32.1	<17	<26	<17	<16
556	29-Aug-02	U12-1815-45	45	1856009.8	298236.8	4586.96	B	46.5	55.6	65.7	0	9.1	31.6	<17	<26	<17	<16
	29-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	29-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	72	63.3	53.7	NP
557	29-Aug-02	U12-1815-46	46	1856009.8	298236.8	4586.96	B	46.2	55.2	66.7	0	9.0	32.7	<17	<26	<17	<16
558	29-Aug-02	U12-1815-47	47	1856009.8	298236.8	4586.96	B	46.4	55.0	67.2	2	8.6	33.6	8F	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH

(Page 17 of 18)

Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
559	29-Aug-02	U12-1815-48	48	1856009.8	298236.8	4586.96	B	45.9	54.1	67.1	0	8.2	33.9	<17	<26	<17	<16
560	29-Aug-02	U12-1815-49	49	1856009.8	298236.8	4586.96	B	46.3	57.1	67.1	2	10.8	31.3	6F	<26	<17	<16
561	30-Aug-02	U12-1815-50	50	1856009.8	298236.8	4586.96	B	46.0	54.6	67.6	0	8.6	34.0	<17	<26	<17	<16
562	30-Aug-02	U12-1815-51	51	1856009.8	298236.8	4586.96	B	46.5	56.4	67.1	4	9.9	32.2	13F	<26	<17	<16
563	30-Aug-02	U12-1815-52	52	1856009.8	298236.8	4586.96	B	45.5	53.7	66.4	3	8.2	33.2	12F	<26	<17	<16
564	30-Aug-02	U12-1815-53	53	1856009.8	298236.8	4586.96	B	45.8	52.7	66.3	0	6.9	34.4	<17	<26	<17	<16
565	30-Aug-02	U12-1815-54	54	1856009.8	298236.8	4586.96	B	46.5	57.0	67.3	3	10.5	31.8	9F	<26	<17	<16
566	30-Aug-02	U12-1815-55	55	1856009.8	298236.8	4586.96	B	45.6	57.0	68.3	4	11.4	31.9	11F	<26	<17	<16
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	30-Aug-02	HAFB1815 V548 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	82	87.3	83.7	NP
567	30-Aug-02	U12-1815-56	56	1856009.8	298236.8	4586.96	B	46.5	54.5	67.0	5	8.0	34.0	21	<26	<17	<16
568	30-Aug-02	U12-1815-57	57	1856009.8	298236.8	4586.96	B	45.6	56.2	67.1	15	10.6	31.5	45	<26	<17	<16
569	30-Aug-02	U12-1815-58	58	1856009.8	298236.8	4586.96	B	46.2	58.7	69.7	25	12.5	32.2	64	<26	<17	<16
570	30-Aug-02	U12-1815-59	59	1856009.8	298236.8	4586.96	B	46.1	55.0	66.3	19	8.9	32.4	69	<26	<17	<16
571	30-Aug-02	U12-1815-60	60	1856009.8	298236.8	4586.96	B	45.9	56.3	68.2	20	10.4	32.8	63	<26	<17	<16
572	30-Aug-02	U12-1815-61	61	1856009.8	298236.8	4586.96	B	46.0	56.7	68.6	20	10.7	32.9	61	<26	<17	<16
573	30-Aug-02	U12-1815-62	62	1856009.8	298236.8	4586.96	B	46.2	56.1	67.3	21	9.9	32.4	69	<26	<17	<16
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	30-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	60	82.2	68.7	NP
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	30-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	73	75.9	71.1	NP
	30-Aug-02	HAFB1815 V549 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	91	82.2	80.1	NP
574	30-Aug-02	U12-1816-41	41	1856017.9	298208.0	4587.02	B	45.6	56.1	67.7	0	10.5	32.2	<17	<26	<17	<16
575	30-Aug-02	U12-1816-42	42	1856017.9	298208.0	4587.02	B	45.1	55.6	68.5	0	10.5	33.0	<17	<26	<17	<16
576	30-Aug-02	U12-1816-43	43	1856017.9	298208.0	4587.02	B	44.7	52.5	67.3	0	7.8	34.5	<17	<26	<17	<16
577	30-Aug-02	U12-1816-44	44	1856017.9	298208.0	4587.02	B	46.0	56.4	68.4	0	10.4	33.0	<17	<26	<17	<16
578	30-Aug-02	U12-1816-45	45	1856017.9	298208.0	4587.02	B	45.7	54.9	66.0	0	9.2	31.8	<17	<26	<17	<16
579	30-Aug-02	U12-1816-46	46	1856017.9	298208.0	4587.02	B	45.2	53.6	68.0	0	8.4	34.6	<17	<26	<17	<16
580	30-Aug-02	U12-1816-47	47	1856017.9	298208.0	4587.02	B	45.0	55.1	67.8	0	10.1	32.7	<17	<26	<17	<16
581	30-Aug-02	U12-1816-48	48	1856017.9	298208.0	4587.02	B	45.9	58.6	69.4	2	12.7	31.7	5F	<26	<17	<16
582	30-Aug-02	U12-1816-49	49	1856017.9	298208.0	4587.02	B	46.3	54.2	67.7	0	7.9	34.8	<17	<26	<17	<16
583	30-Aug-02	U12-1816-50	50	1856017.9	298208.0	4587.02	B	45.1	54.7	67.3	0	9.6	32.7	<17	<26	<17	<16
584	30-Aug-02	U12-1816-51	51	1856017.9	298208.0	4587.02	B	45.5	55.0	67.0	0	9.5	32.5	<17	<26	<17	<16
585	30-Aug-02	U12-1816-52	52	1856017.9	298208.0	4587.02	B	45.6	55.1	68.0	2	9.5	33.5	7F	<26	<17	<16
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	30-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	67	63.6	58.8	NP
586	30-Aug-02	U12-1816-53	53	1856017.9	298208.0	4587.02	B	45.9	55.0	68.0	0	9.1	33.9	<17	<26	<17	<16
587	30-Aug-02	U12-1816-54	54	1856017.9	298208.0	4587.02	B	45.7	58.3	68.1	5	12.6	30.5	12F	<26	<17	<16
588	30-Aug-02	U12-1816-55	55	1856017.9	298208.0	4587.02	B	46.5	56.9	67.8	3	10.4	32.4	9F	<26	<17	<16
589	30-Aug-02	U12-1816-56	56	1856017.9	298208.0	4587.02	B	45.7	55.9	67.0	0	10.2	31.8	<17	<26	<17	<16
590	30-Aug-02	U12-1816-57	57	1856017.9	298208.0	4587.02	B	46.1	53.9	66.8	2	7.8	34.0	9F	<26	<17	<16
591	30-Aug-02	U12-1816-58	58	1856017.9	298208.0	4587.02	B	45.2	55.9	68.8	4	10.7	33.1	12F	<26	<17	<16
592	30-Aug-02	U12-1816-59	59	1856017.9	298208.0	4587.02	B	45.6	54.6	66.0	4	9.0	32.0	14F	<26	<17	<16
593	30-Aug-02	U12-1816-60	60	1856017.9	298208.0	4587.02	B	45.6	54.8	66.3	4	9.2	32.1	14F	<26	<17	<16
594	30-Aug-02	U12-1816-61	61	1856017.9	298208.0	4587.02	B	45.6	53.0	64.9	6	7.4	32.5	26	<26	<17	<16
595	30-Aug-02	U12-1816-62	62	1856017.9	298208.0	4587.02	B	45.8	56.6	65.8	18	10.8	30.0	50	<26	<17	<16
596	30-Aug-02	U12-1816-63	63	1856017.9	298208.0	4587.02	B	45.1	56.1	66.3	23	11.0	30.3	63	<26	<17	<16

TABLE A-1

FIELD ANALYICAL RESULTS FOR WIRELINE SOIL SAMPLES
SOURCE ZONE DELINEATION DEMONSTRATION
OPERABLE UNIT 12
HILL AIR FORCE BASE, UTAH
(Page 18 of 18)

Vial No.	Date	Sample ID	Depth (ft bgs)	Easting (ft)	Northing (ft)	Ground Elevation (ft amsl)	T/B	Tare Weight (g)	Tare + Soil Weight (g)	Final Weight (g)	Extractant TCE Conc. (µg/L)	Soil Mass (g)	Extractant Volume (ml)	Soil TCE Conc. (µg/kg)	Soil PCE Conc. (µg/kg)	Soil DCE Conc. (µg/kg)	Soil VC Conc. (µg/kg)
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
	30-Aug-02	60 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	68	70.2	68.4	
597	30-Aug-02	U12-1817-21	21	1856102.3	298254.9	4587.62	B	35.2	42.7	250 µl	0	7.5	10.0	<800	<1280	<800	<752
	30-Aug-02	HAFB1816 V582 60ppb MS	---	---	---	---	---	---	---	---	---	---	---	91	84.6	75	NP
	30-Aug-02	0 ppb HAFB01	---	---	---	---	---	---	---	---	---	---	---	<17	<26	<17	<16
598	30-Aug-02	U12-1817-27	27	1856102.3	298254.9	4587.62	B	35.4	45.0	250 µl	5	9.6	10.0	833	<1280	<800	<752
599	30-Aug-02	U12-1817-28	28	1856102.3	298254.9	4587.62	B	34.8	45.0	50 µl	152	10.2	10.0	119216	<6400	<4000	<3760
600	30-Aug-02	U12-1817-29	29	1856102.3	298254.9	4587.62	B	34.4	47.5	50 µl	216	13.1	10.0	131908	<6400	<4000	<3760
601	30-Aug-02	U12-1817-30	30	1856102.3	298254.9	4587.62	B	35.8	48.4	50 µl	200	12.6	10.0	126984	<6400	<4000	<3760
602	30-Aug-02	U12-1817-31	31	1856102.3	298254.9	4587.62	B	35.3	46.7	100 µl	189	11.4	10.0	66316	<3200	<2000	<1880
603	30-Aug-02	U12-1817-32	32	1856102.3	298254.9	4587.62	B	35.6	49.3	250 µl	6	13.7	10.0	701F	<1280	<800	<752
604	30-Aug-02	U12-1817-33	33	1856102.3	298254.9	4587.62	B	35.2	50.8	250 µl	4	15.6	10.0	410F	<1280	<800	<752
605	30-Aug-02	U12-1817-34	34	1856102.3	298254.9	4587.62	B	35.3	41.7	250 µl	2	6.4	10.0	500F	<1280	<800	<752
606	30-Aug-02	U12-1817-36	36	1856102.3	298254.9	4587.62	B	35.1	45.0	250 µl	6	9.9	10.0	970	<1280	<800	<752
607	30-Aug-02	U12-1817-37	37	1856102.3	298254.9	4587.62	B	35.4	41.6	250 µl	0	6.2	10.0	<800	<1280	<800	<752
608	30-Aug-02	U12-1817-38	38	1856102.3	298254.9	4587.62	B	35.4	43.3	250 µl	0	7.9	10.0	<800	<1280	<800	<752
609	30-Aug-02	U12-1817-39	39	1856102.3	298254.9	4587.62	B	35.5	42.9	250 µl	0	7.4	10.0	<800	<1280	<800	<752

Notes:

TCE = Trichlorothene

PCE = Tetrachloroethene

DCE = Dichloroethene

VC = Vinyl Chloride

Easting and Northing obtained from GPS survey. Ground elevation estimated by interpolation of existing surveyed elevations.

Reporting limits were calculated assuming a 1/3 dilution for analysis performed on distilled water using 95% confidence interval.

F data qualifier indicates analyte was positively identified but reported concentration is estimated: reported concentration is less than the reporting limit but greater than the method detection limit.

E data qualifier indicates data are estimated due to associated QC issues..

NP indicates analyte not present in calibration or check standard mixture.

T/B indicates whether the soil sample was collected from the top (T) or bottom (B) of the Wireline CPT soil sampler.

0 ppb HAFB01 is used to denote a reagent water blank

60 ppb HAFB01, 225 ppb HAFB01, etc indicate calibration check standards, QC limits are +/- 50% (i.e. 90 to 30 ppb for 60 ppb HAFB01 check).

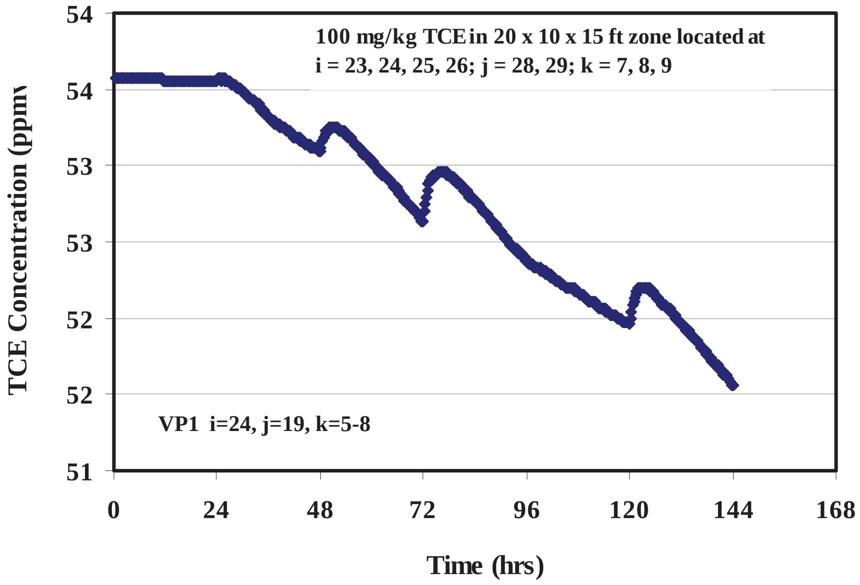
225 ppb VOC Mix 1A indicates an external performance evaluation check standard, QC limits are +/- 50%.

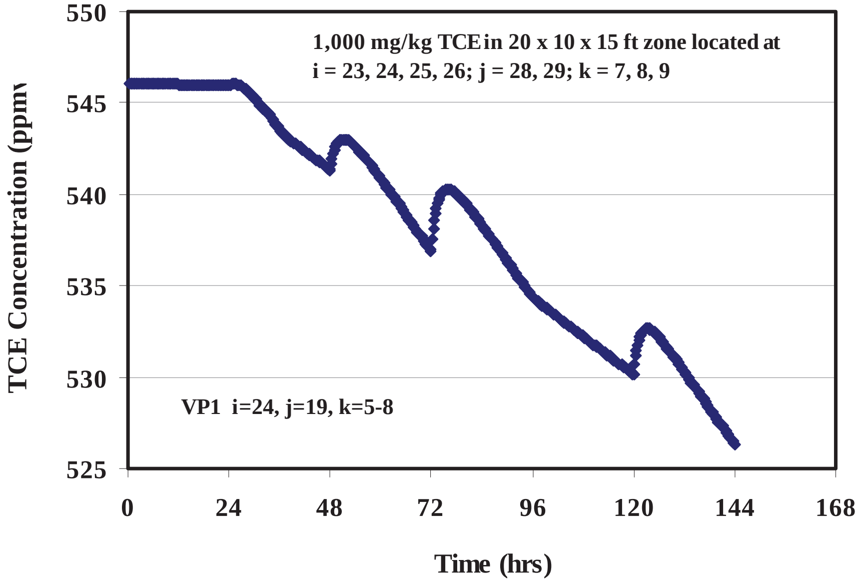
MS is used to indicate a matrix spike sample, for example; HAFB1816 V582 60ppb MS denotes a 60 ppb MS of sample HAFB1816 Vial 582, QC limits are +/- 50%.

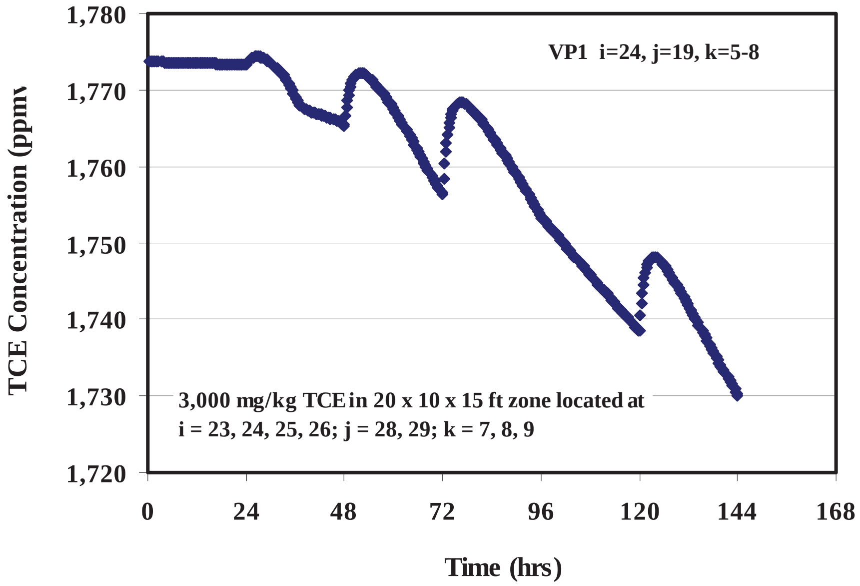
APPENDIX B

Simulated TCE Vapor-Phase Concentration Profiles for OU 12 SVE Demonstration

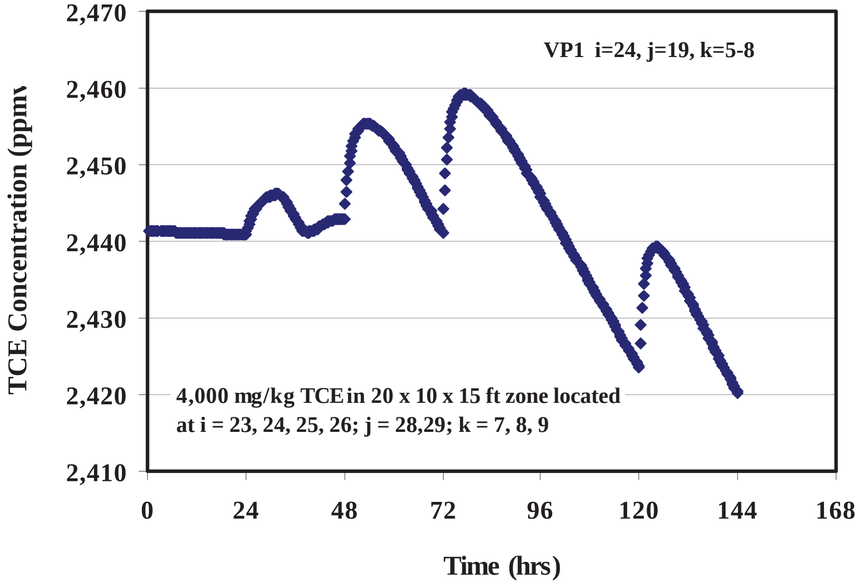
U12-PV1
Source Area #1

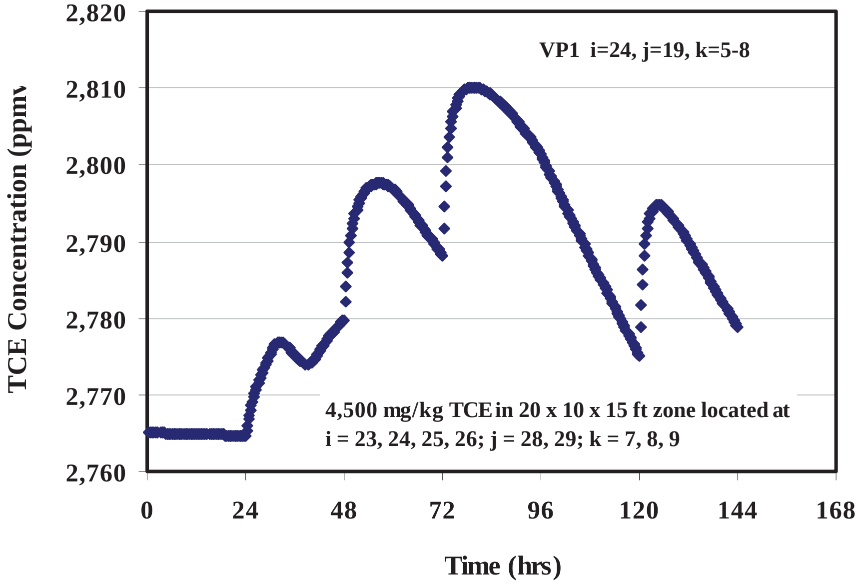


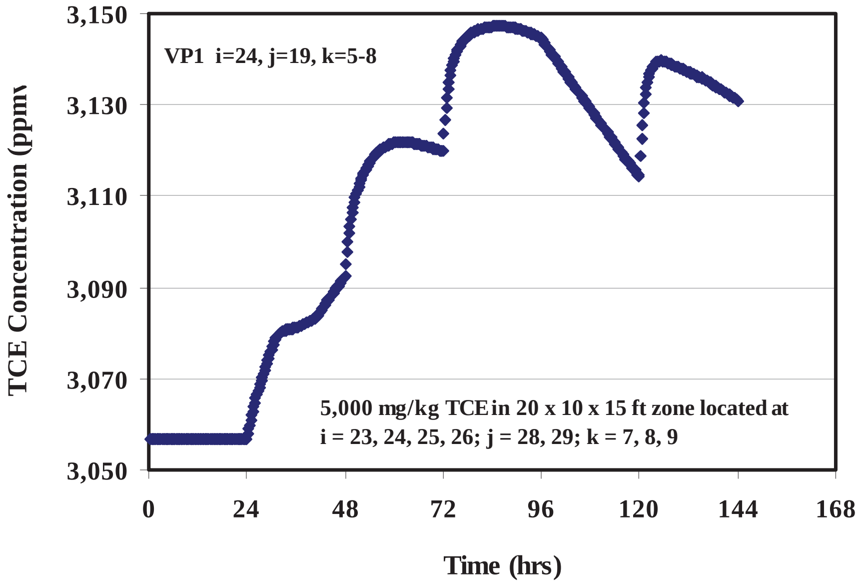




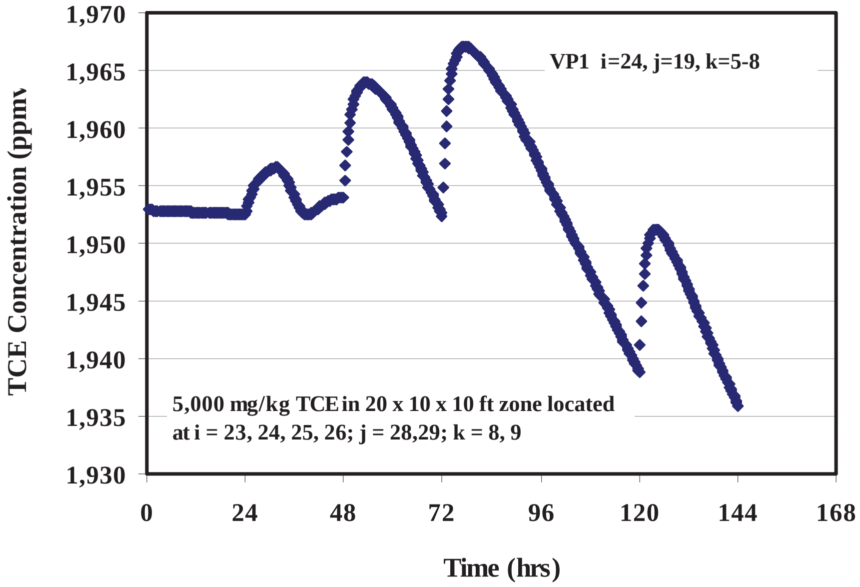
U12-PV1
Source Area #1

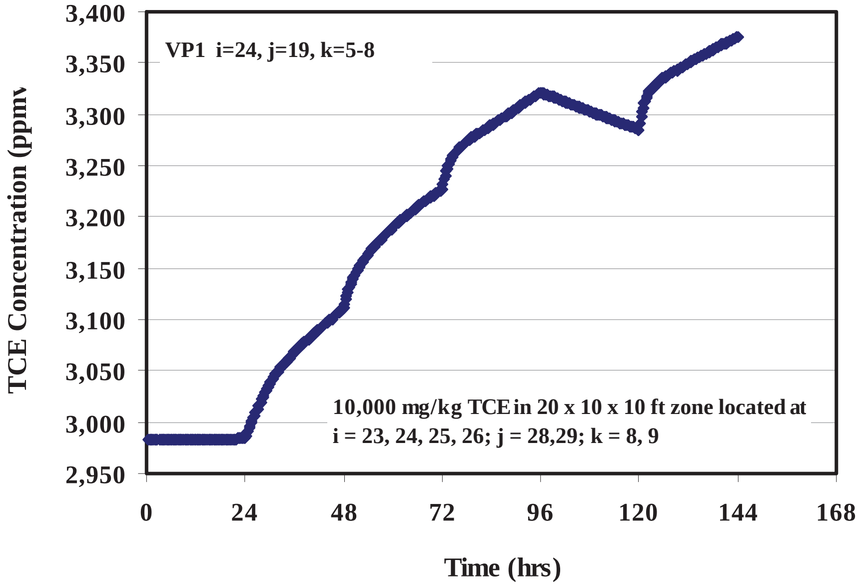




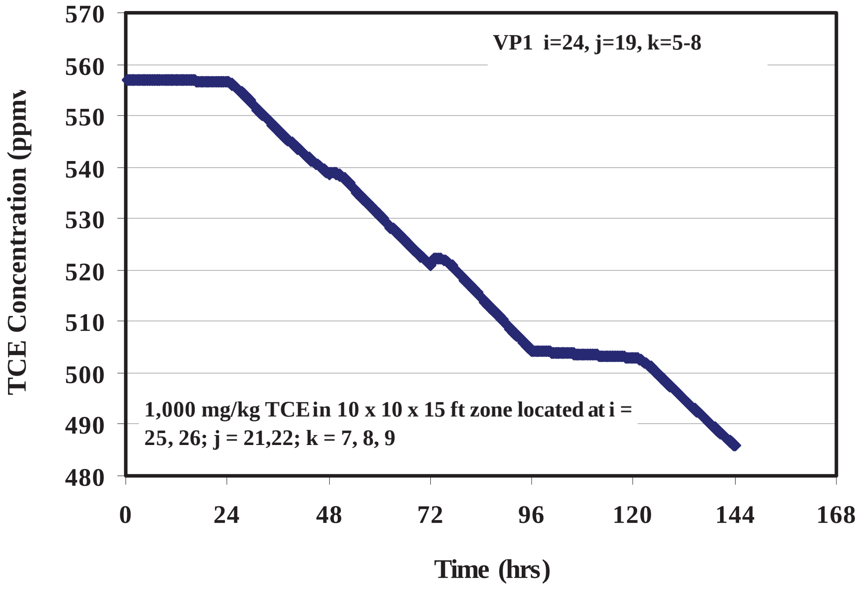


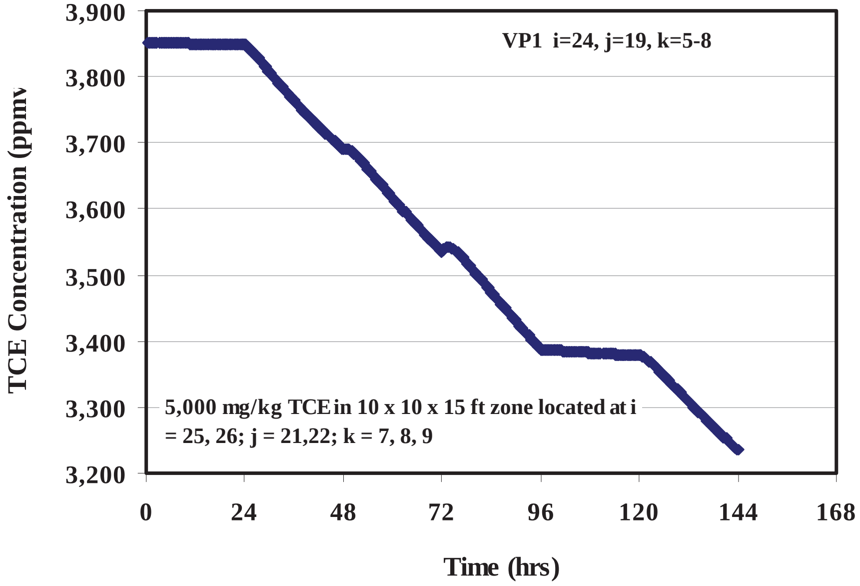
U12-PV1
Source Area #1

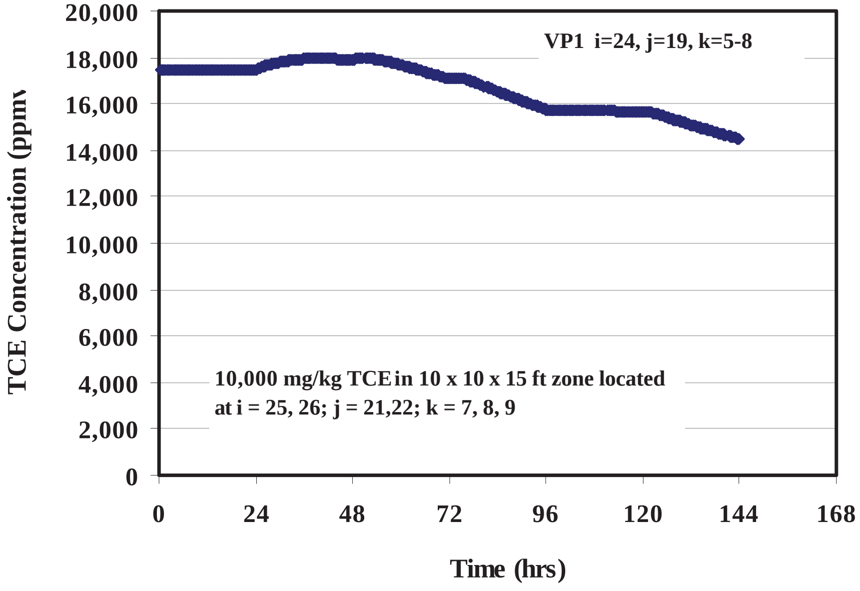




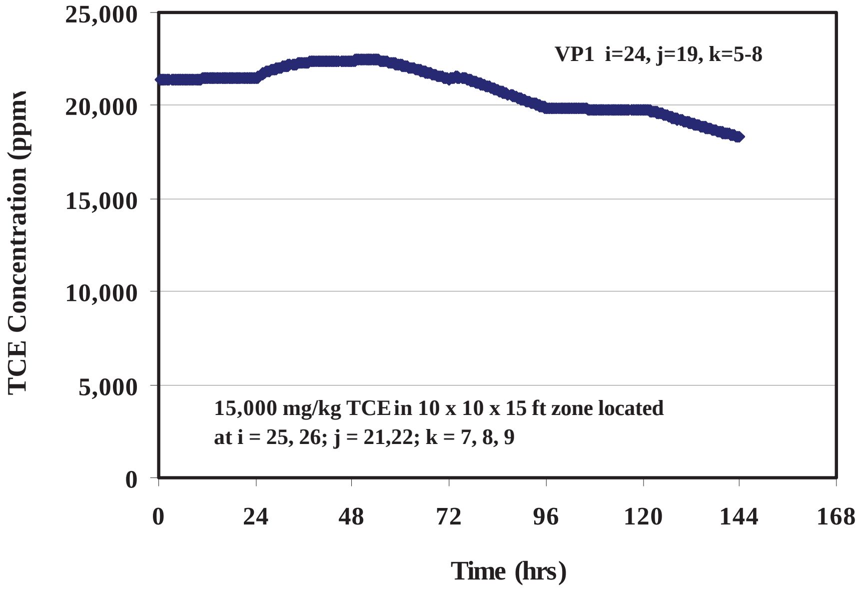
U12-PV1
Source Area #2



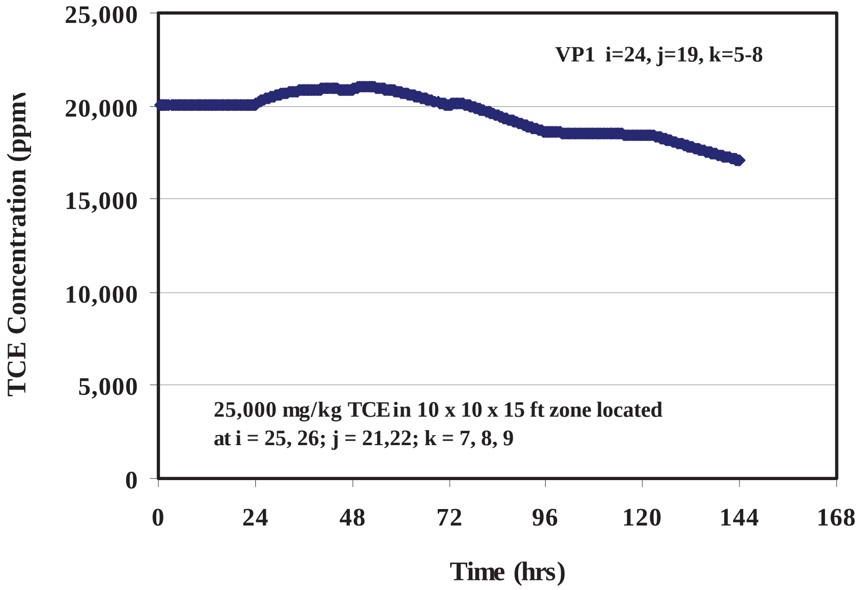




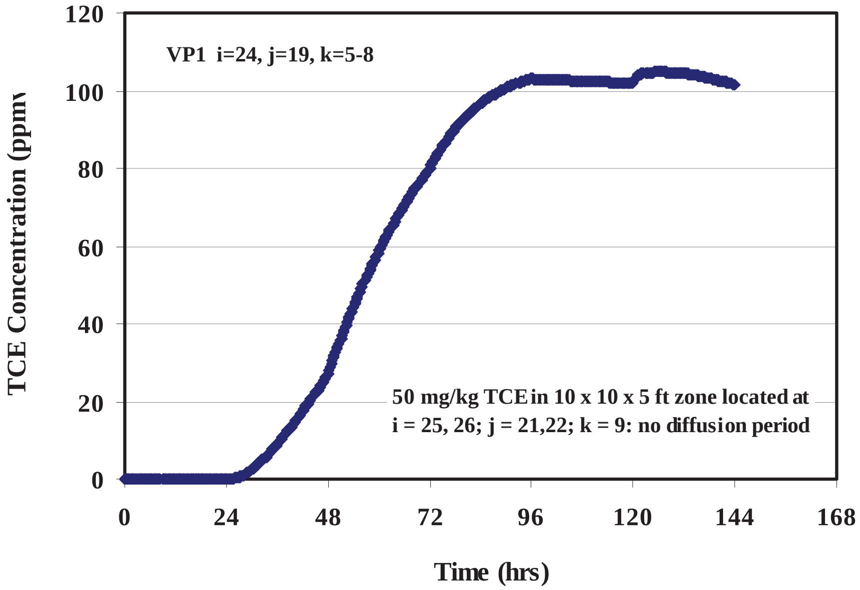
U12-PV1
Source Area #2



15,000 mg/kg TCE in 10 x 10 x 15 ft zone located
at i = 25, 26; j = 21,22; k = 7, 8, 9

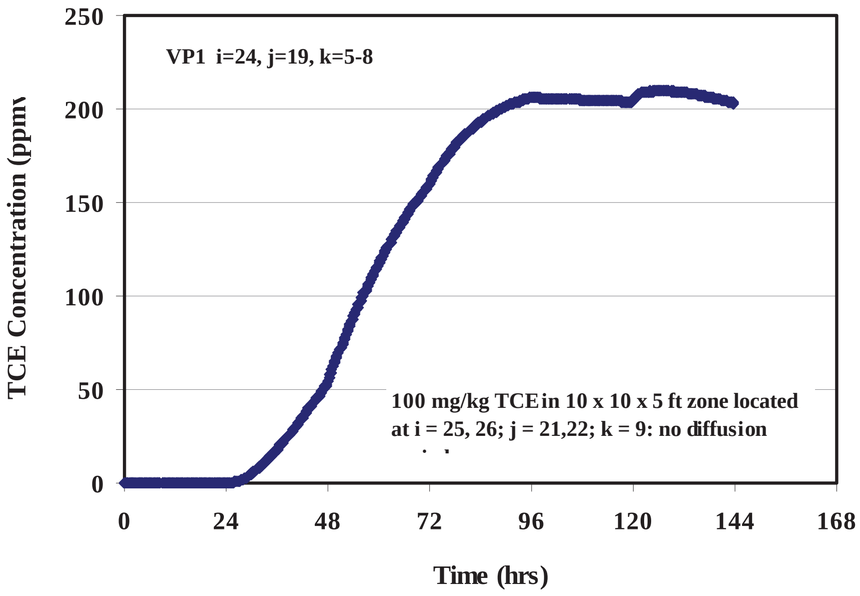


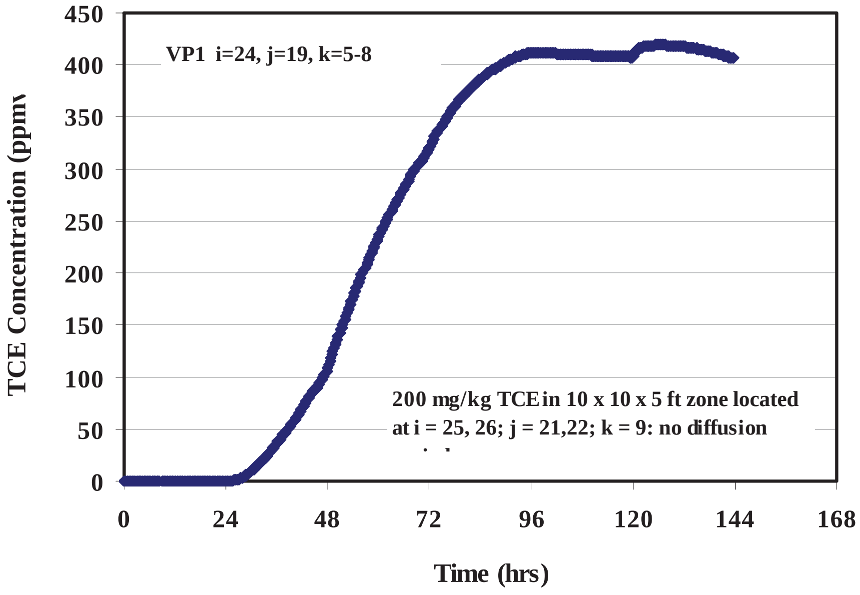
25,000 mg/kg TCE in 10 x 10 x 15 ft zone located
at i = 25, 26; j = 21,22; k = 7, 8, 9

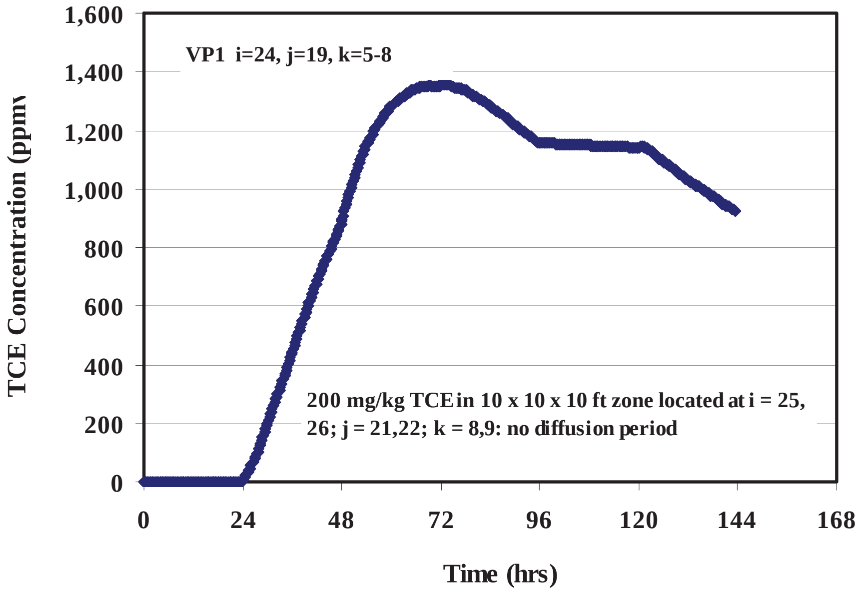


50 mg/kg TCE in 10 x 10 x 5 ft zone located at
i = 25, 26; j = 21,22; k = 9: no diffusion period

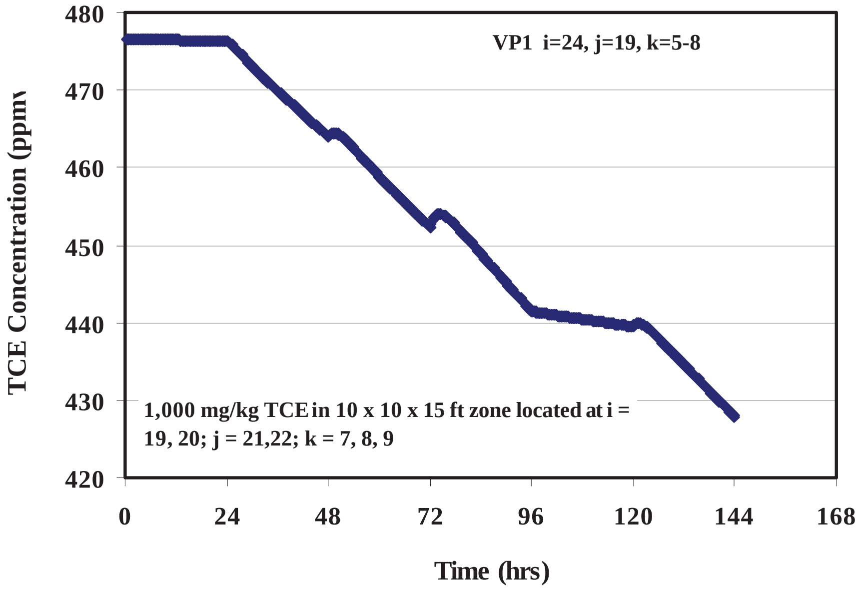
U12-PV1
Source Area #2

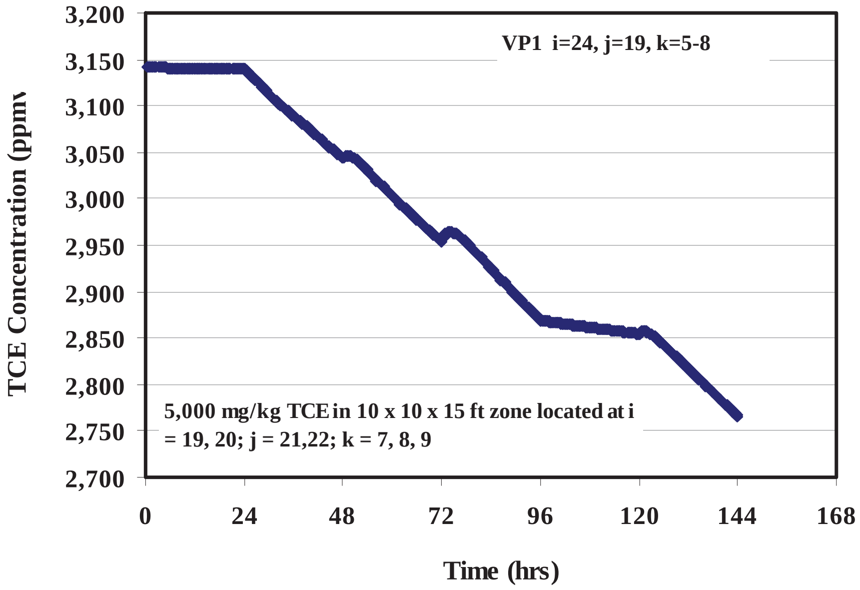


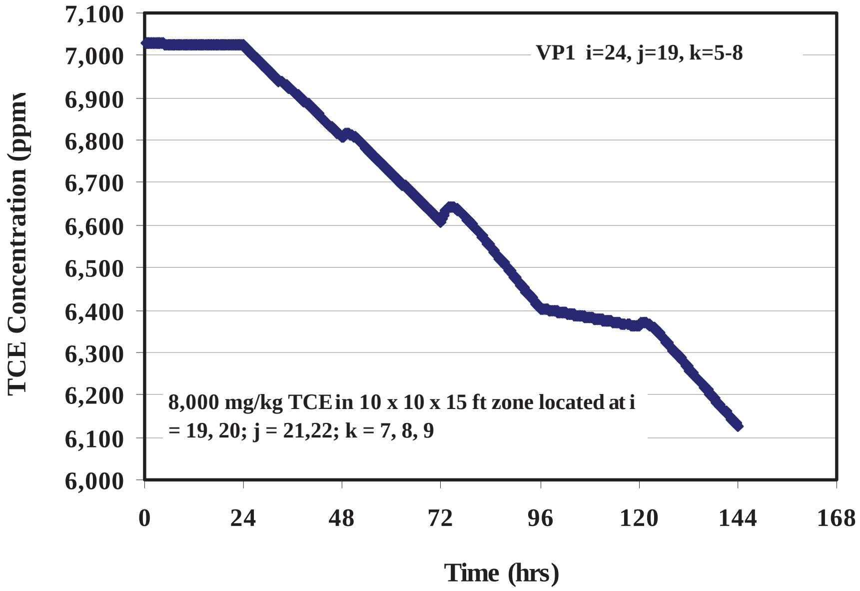




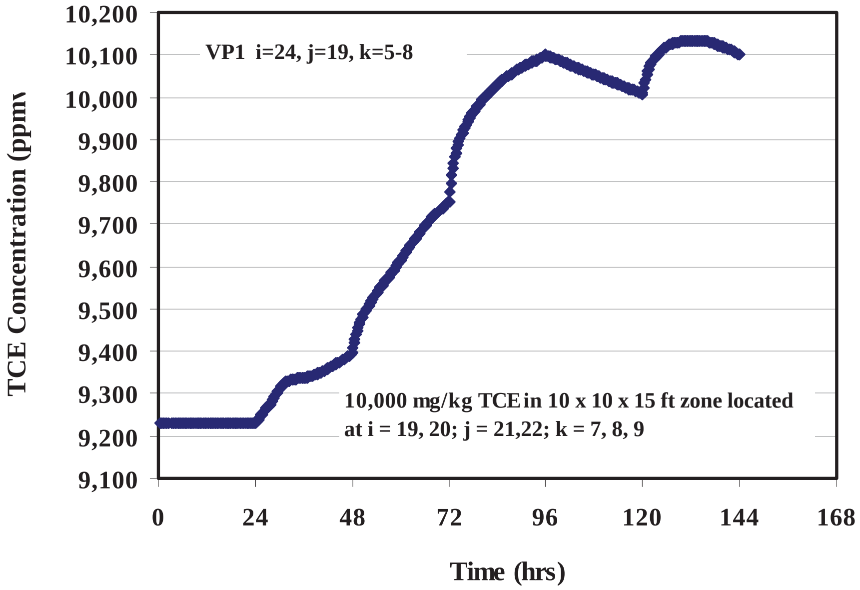
U12-PV1
Source Area #3



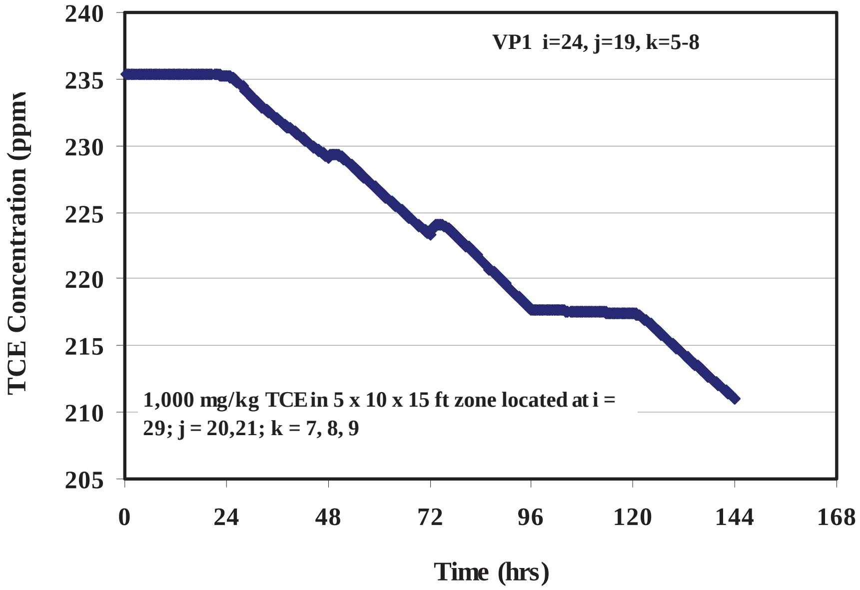


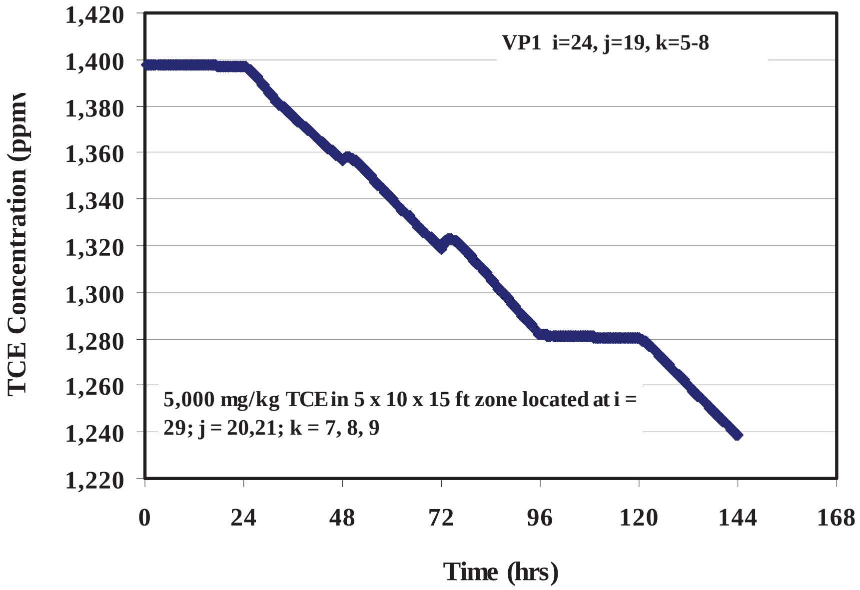


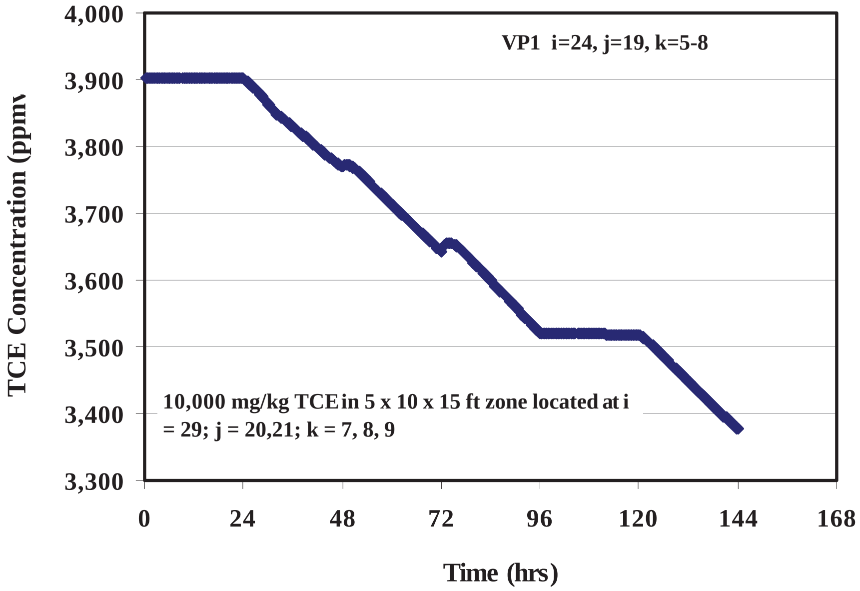
U12-PV1
Source Area #3



U12-PV1
Source Area #4







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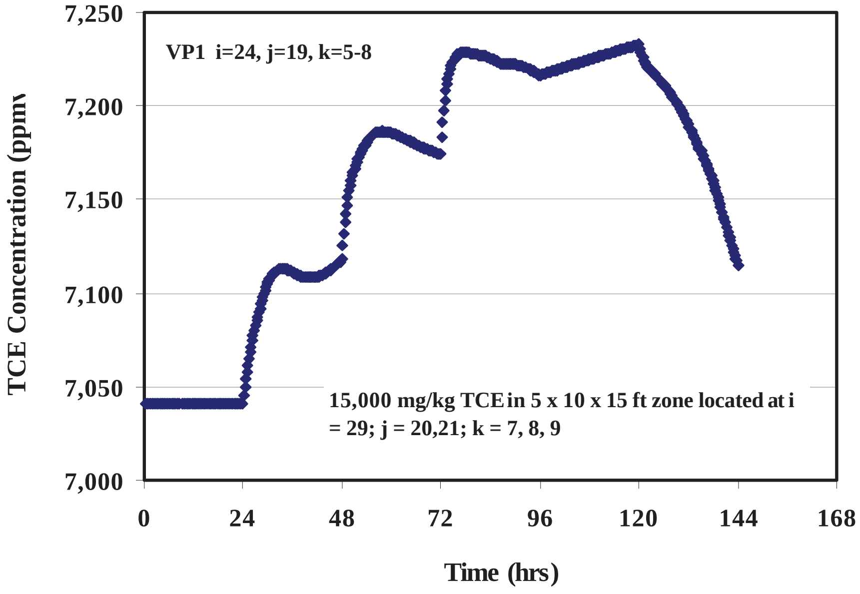

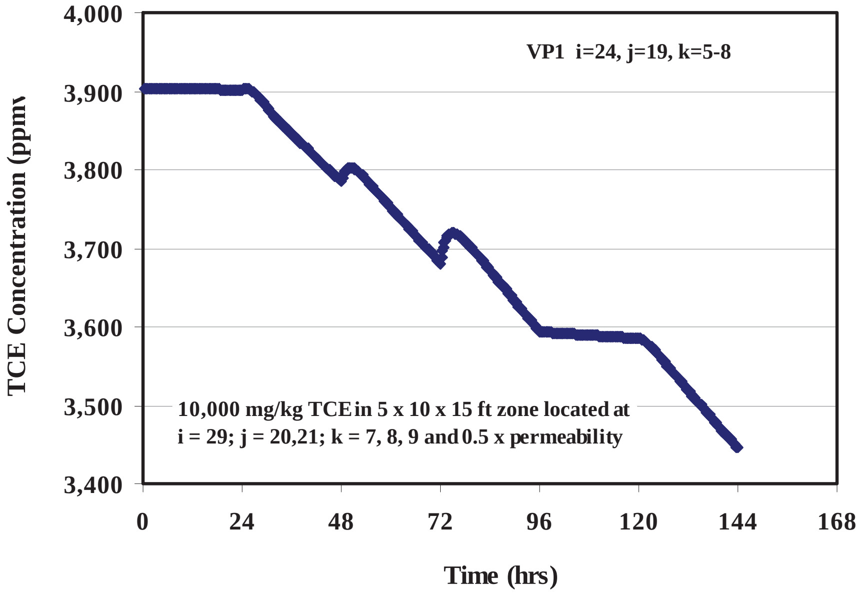

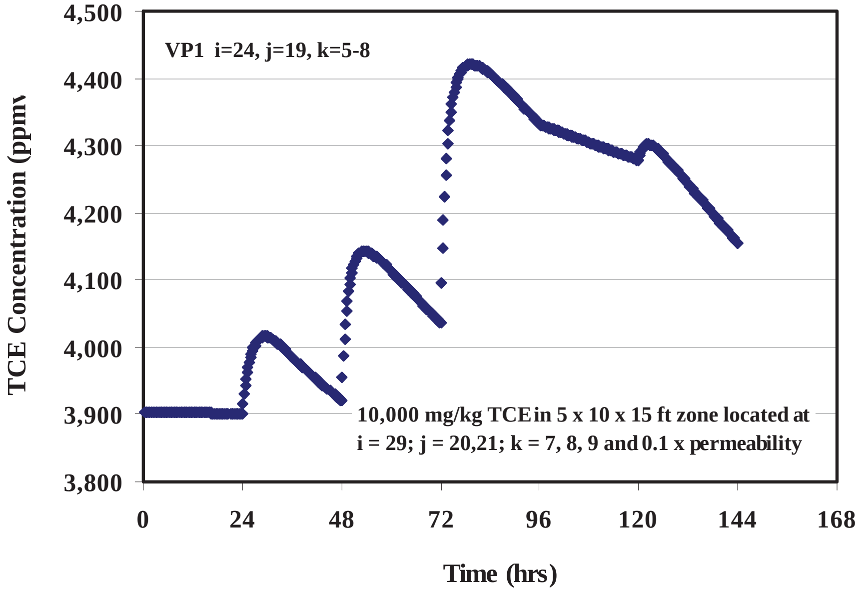

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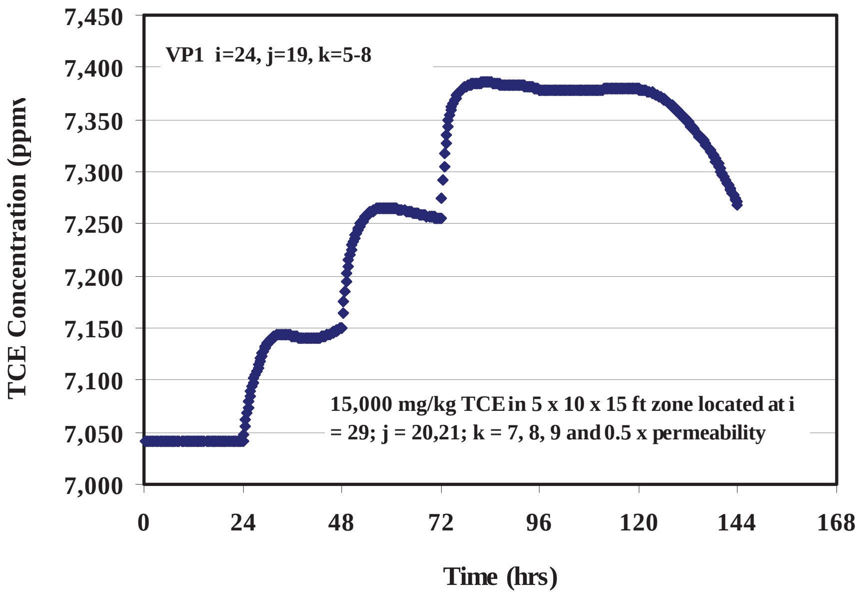

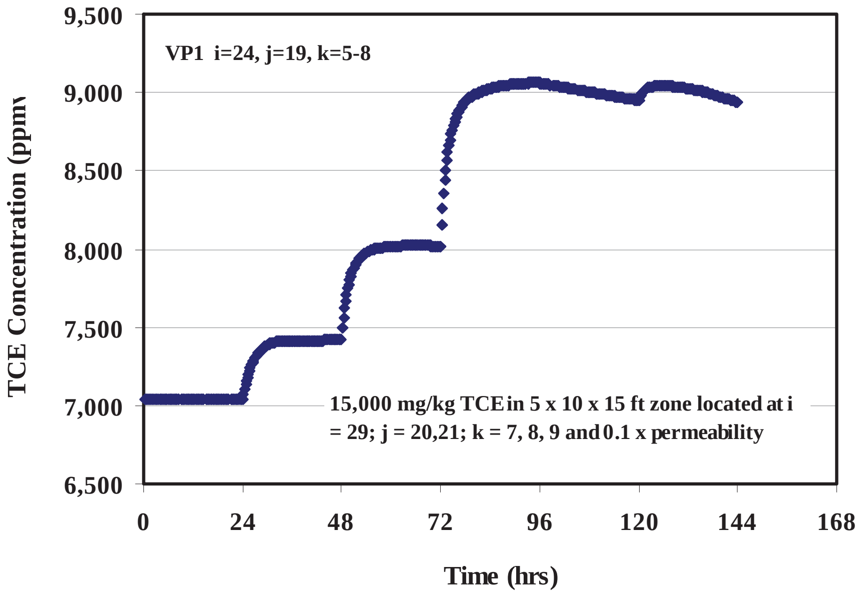

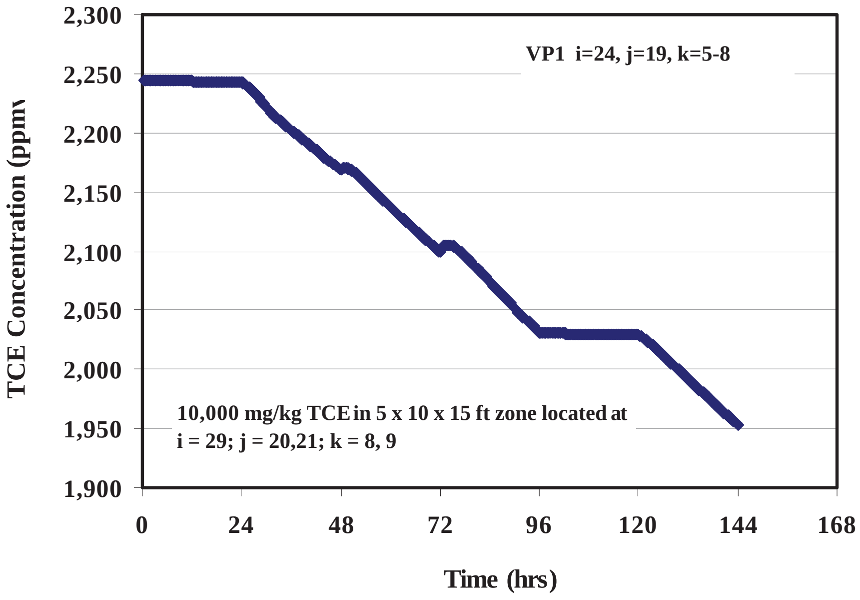

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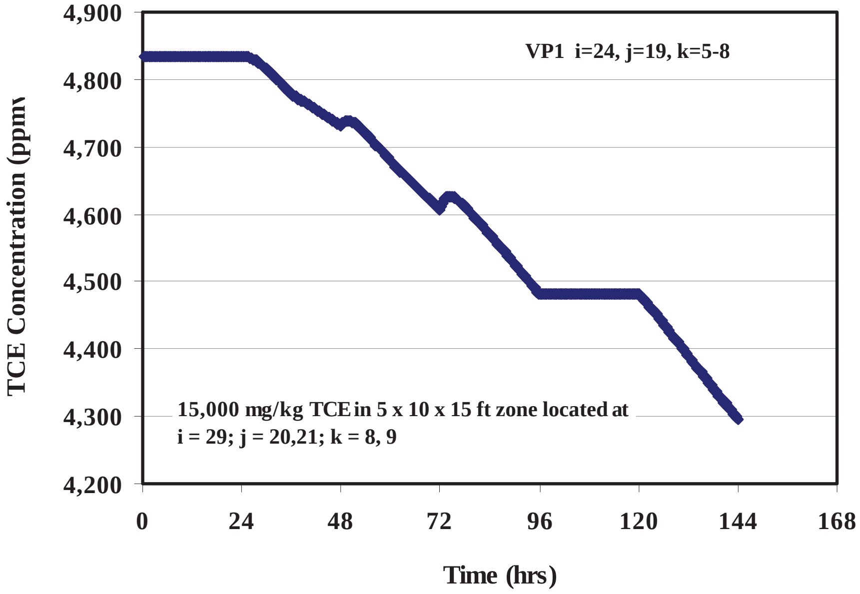
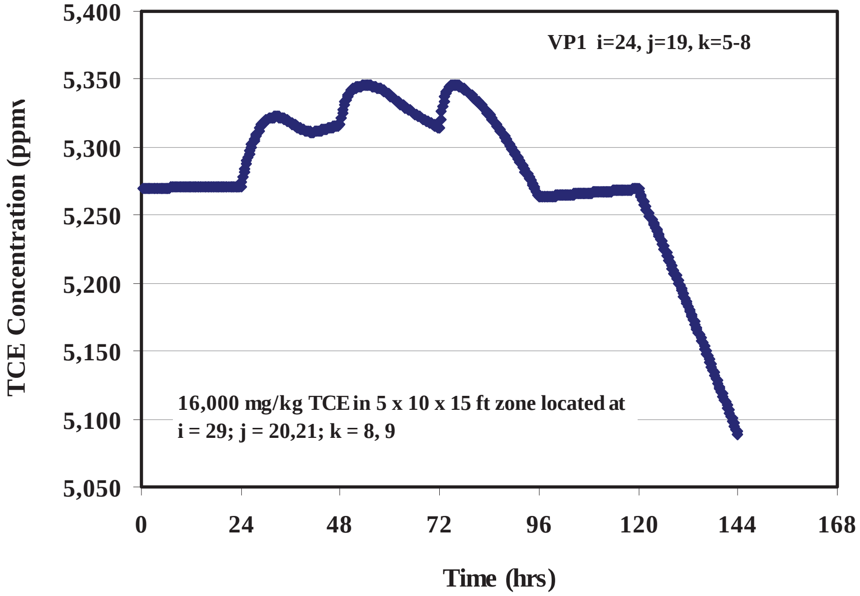
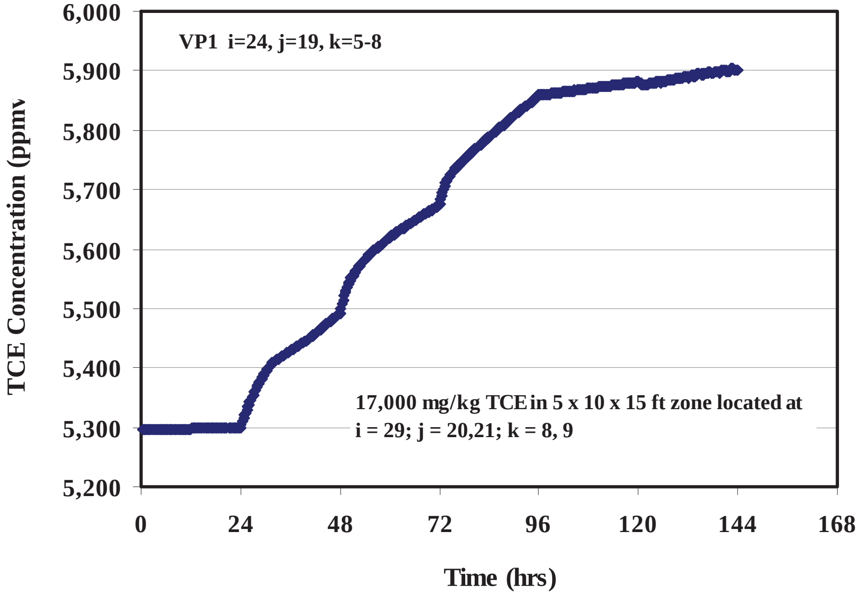
Source Area #4







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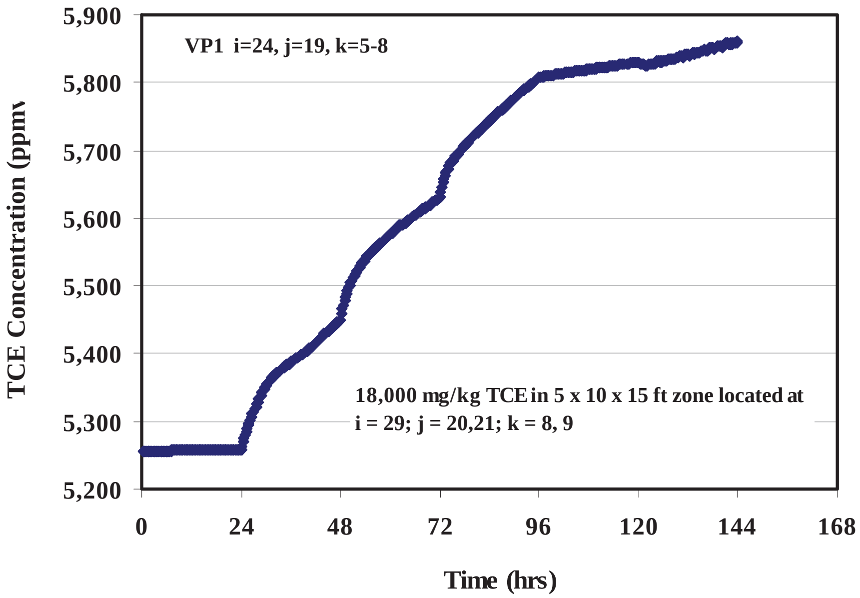

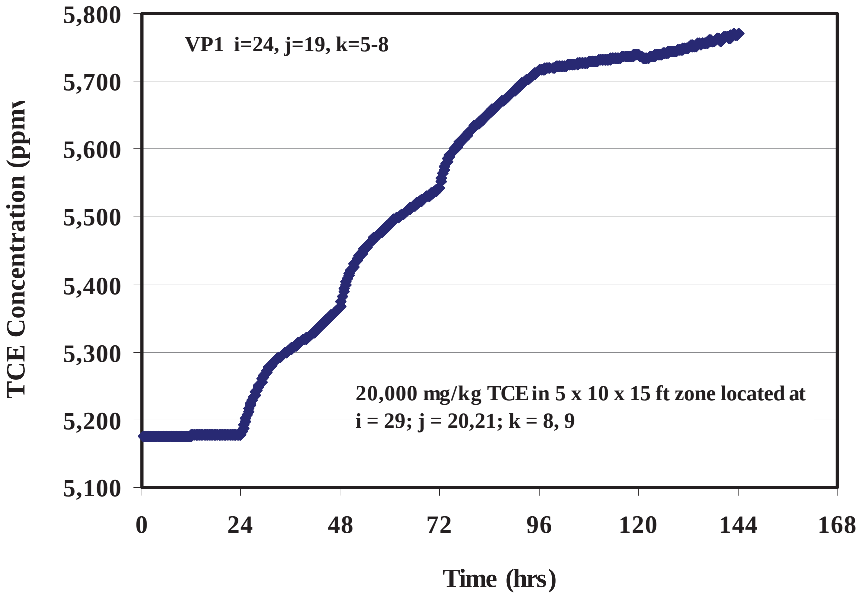

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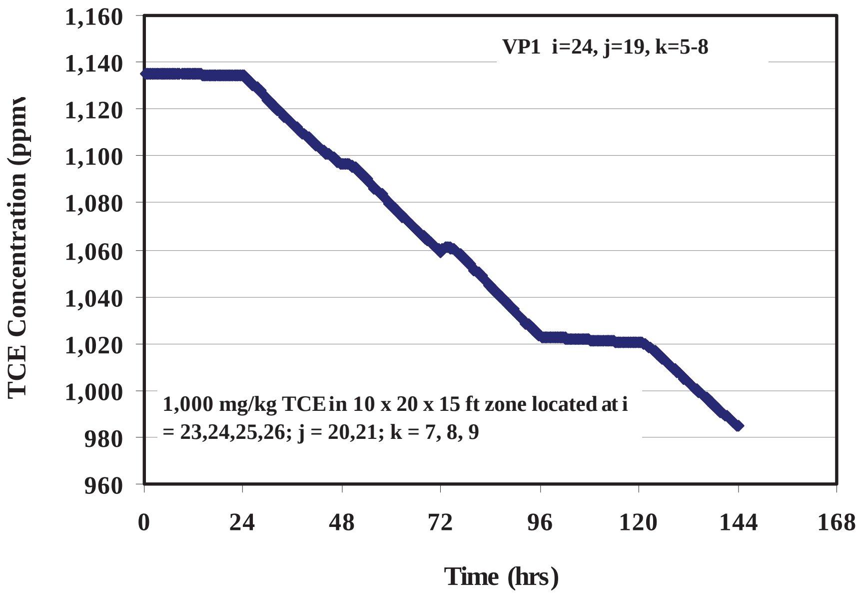
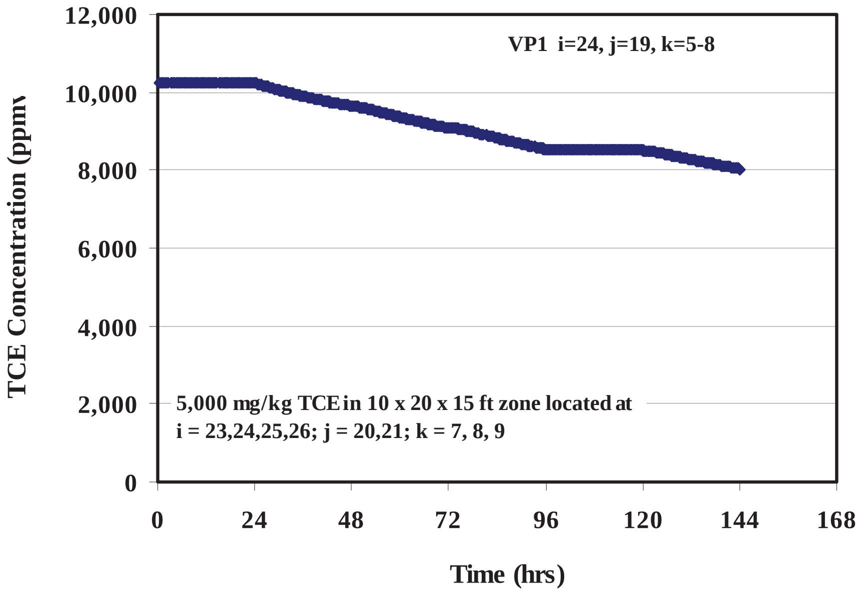
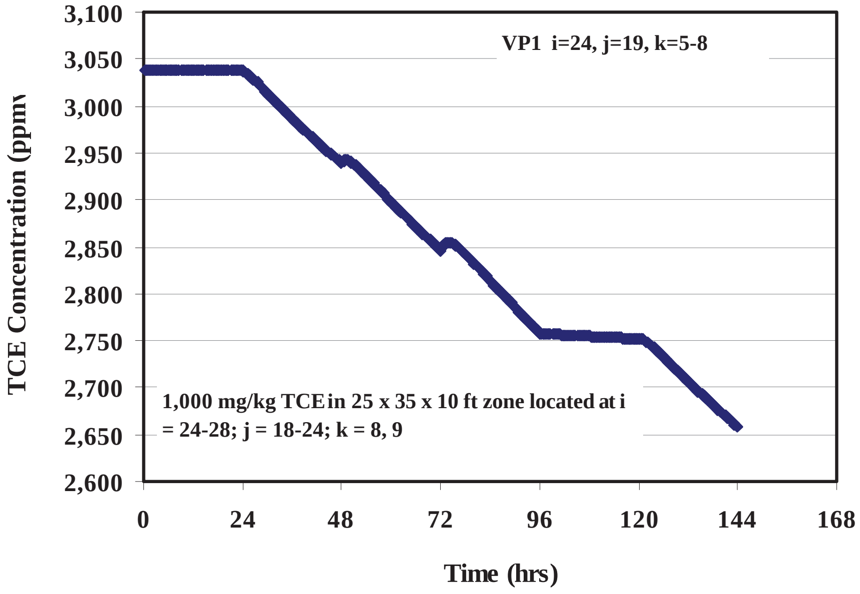
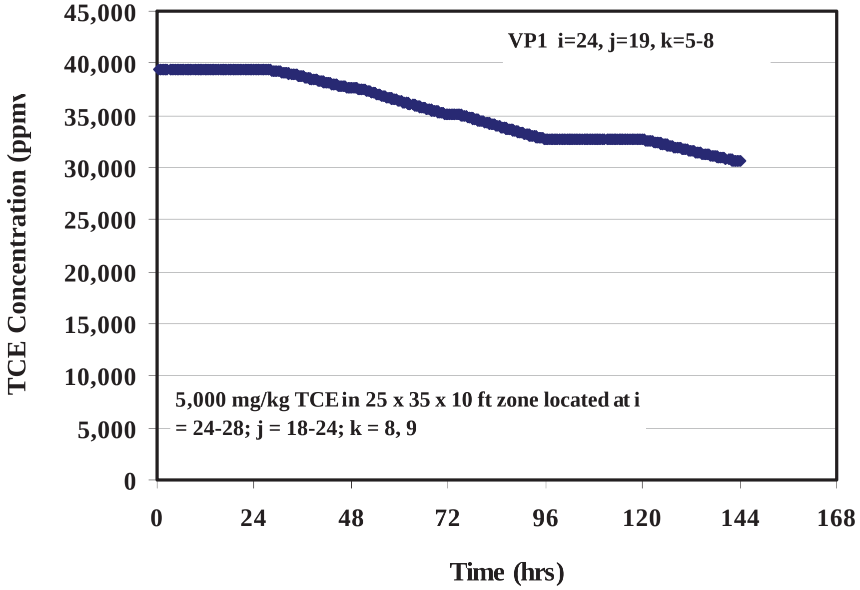
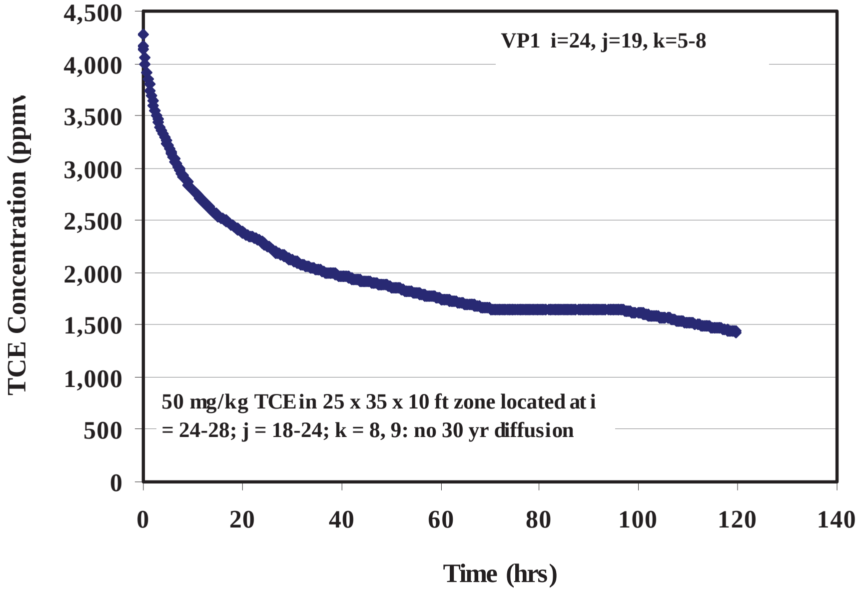




U12-PV1
Source Area #6







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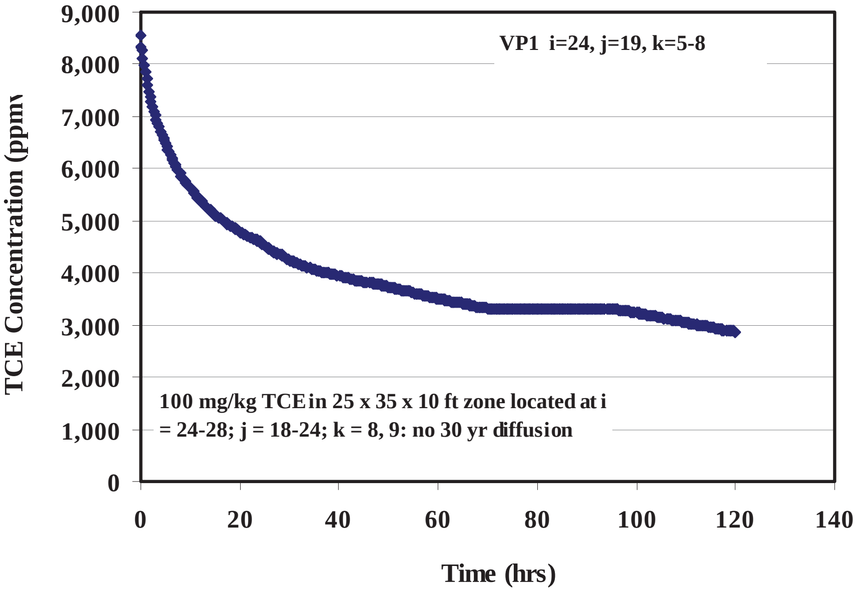
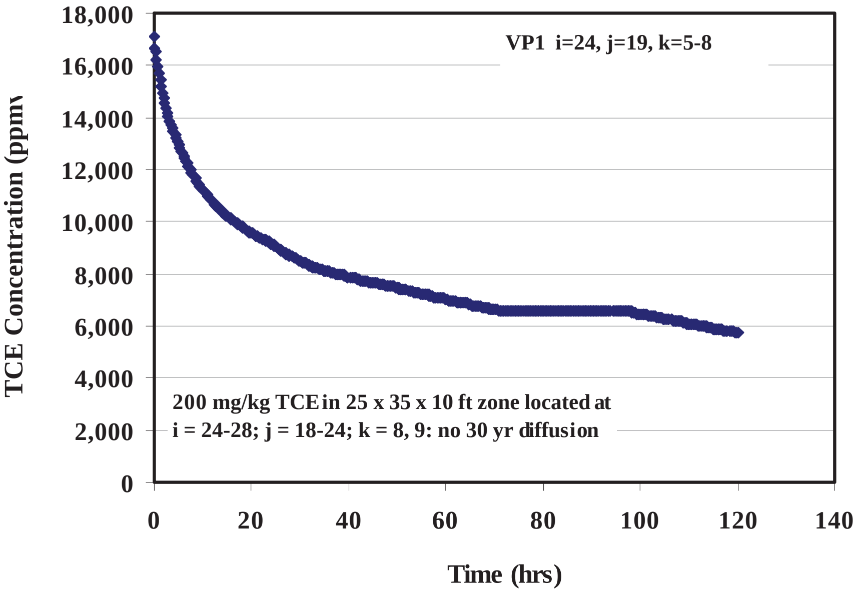
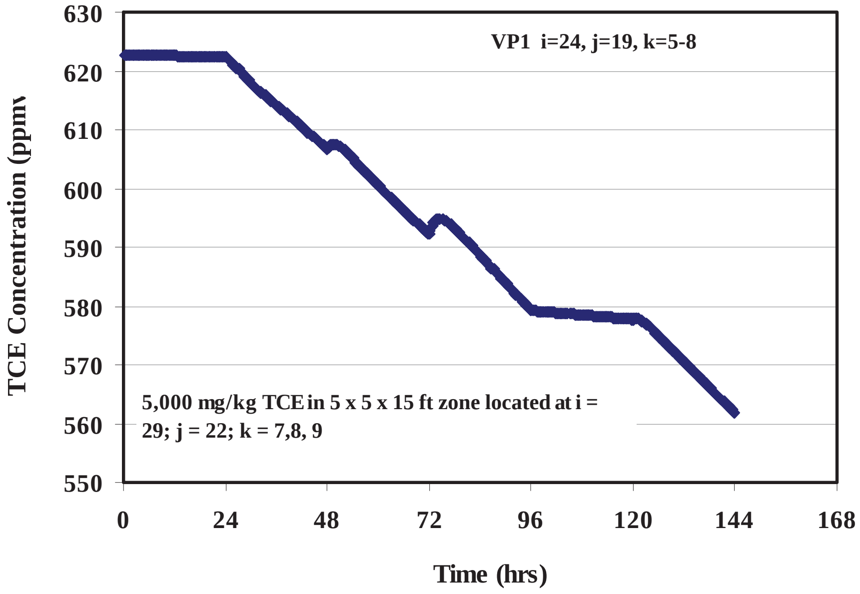
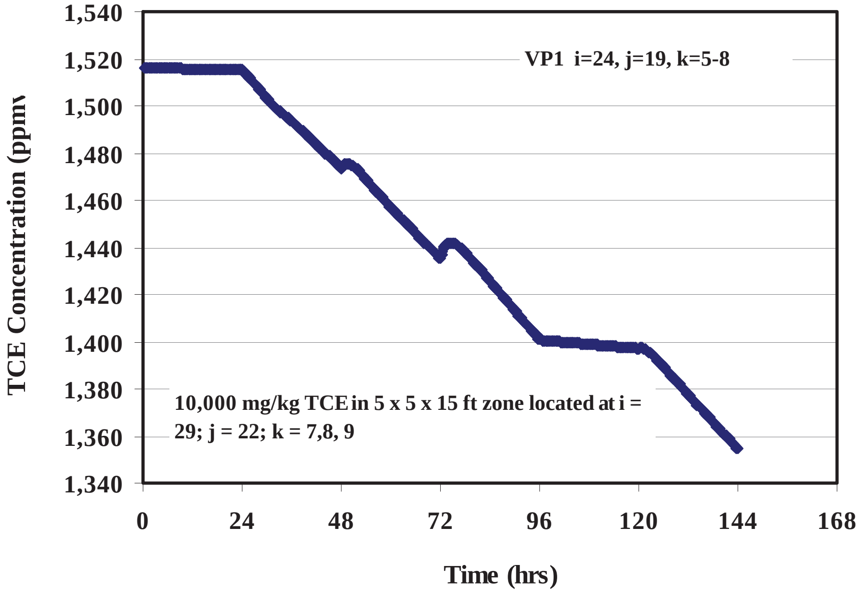
Source Area #6

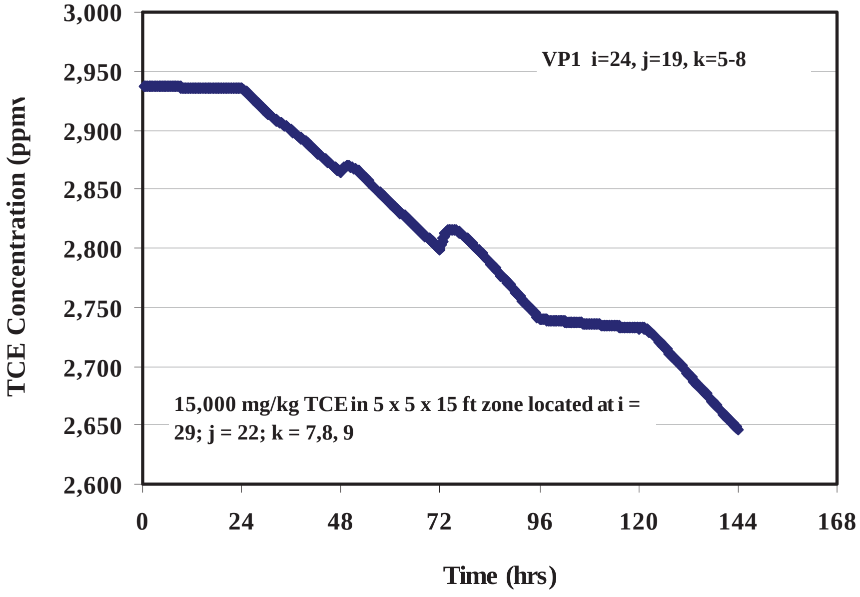




U12-PV1
Source Area #7







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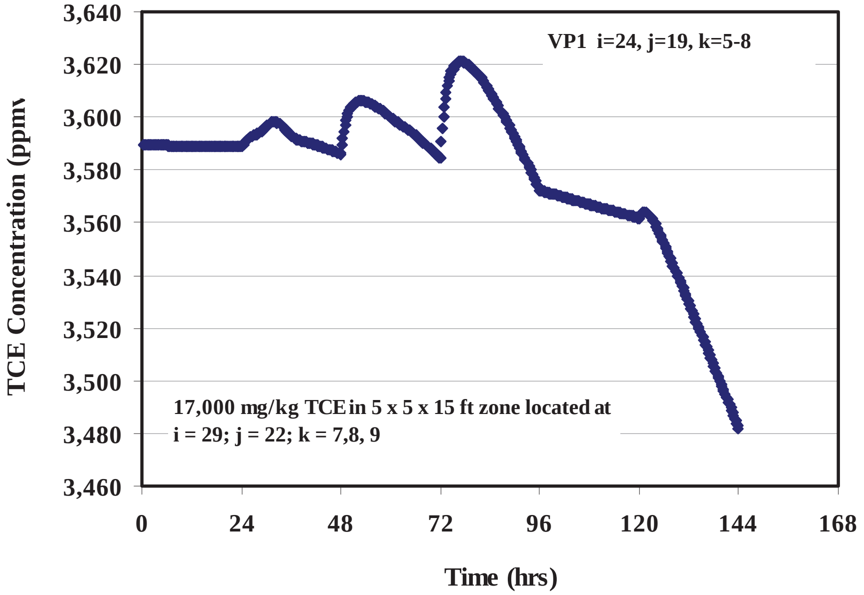

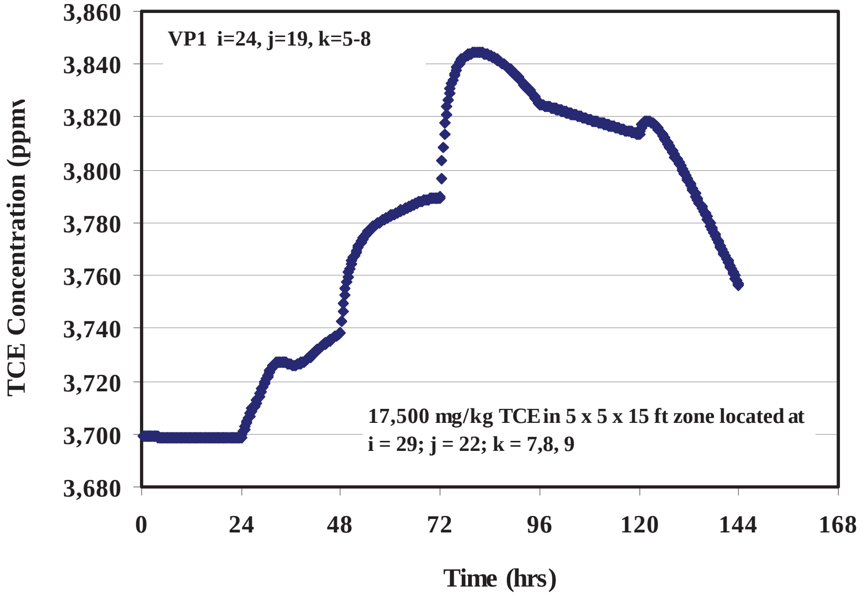

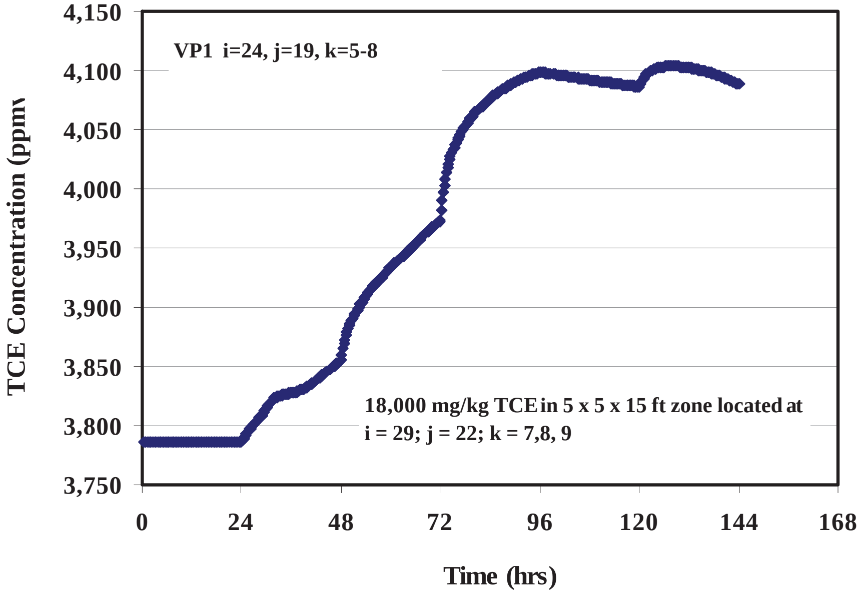

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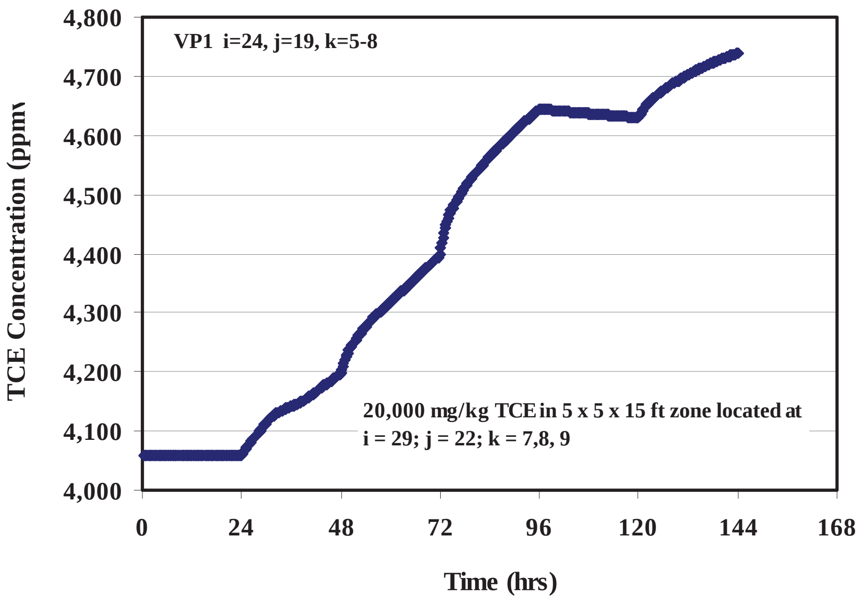
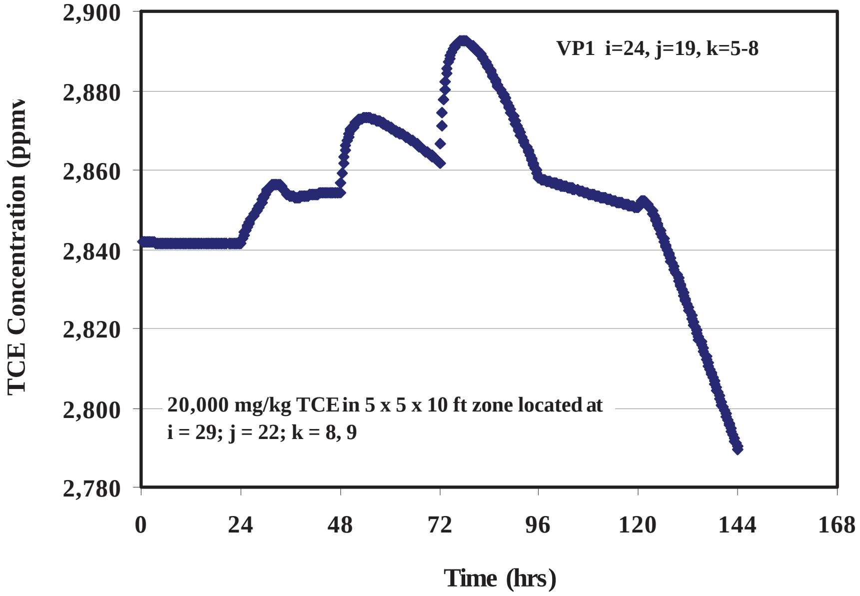
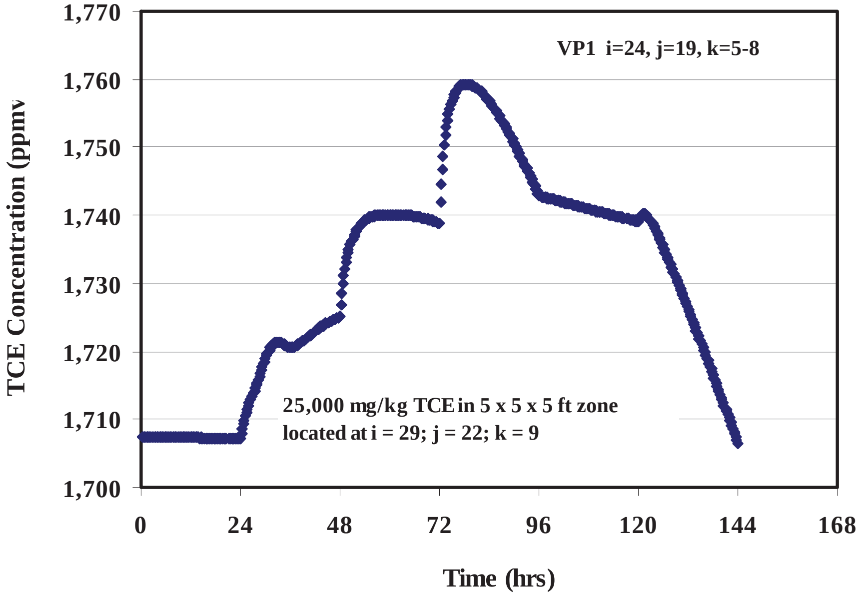
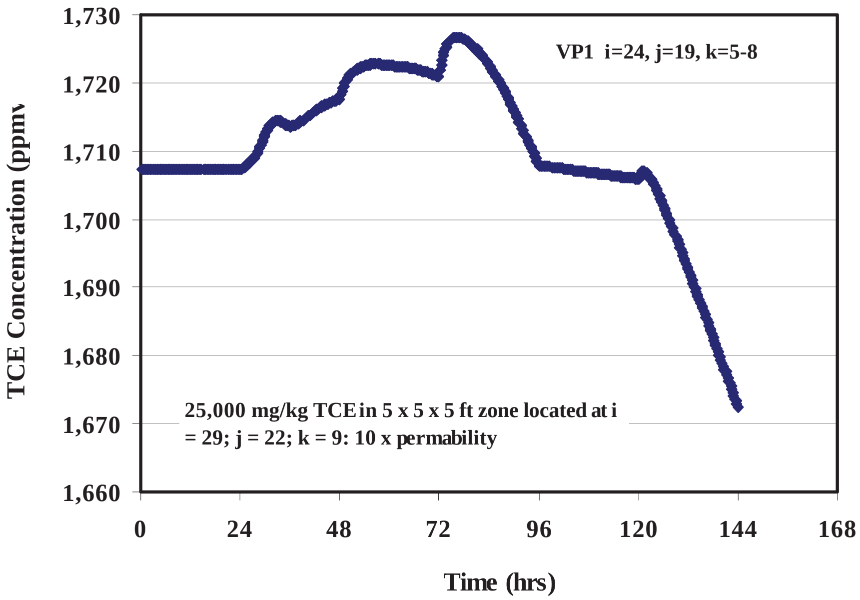
Source Area #7

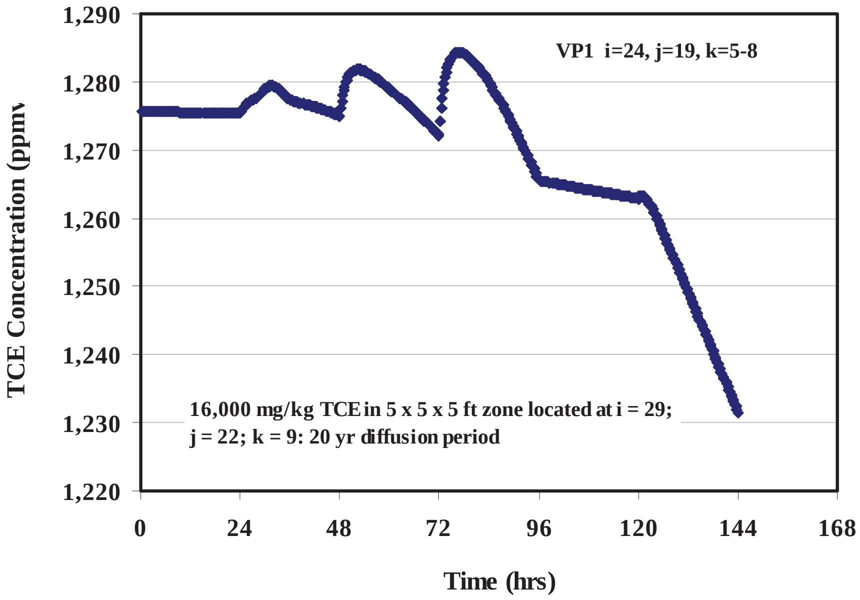


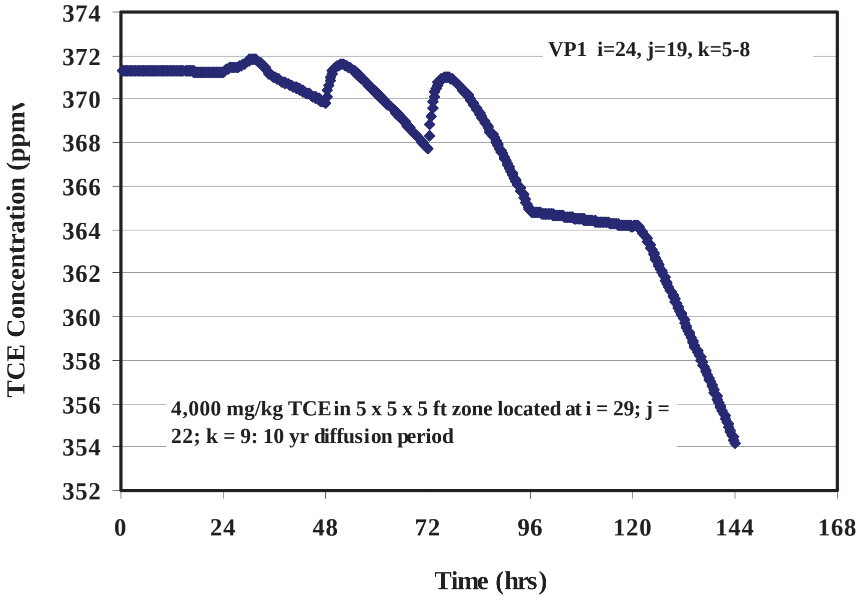




U12-PV1
Source Area #7







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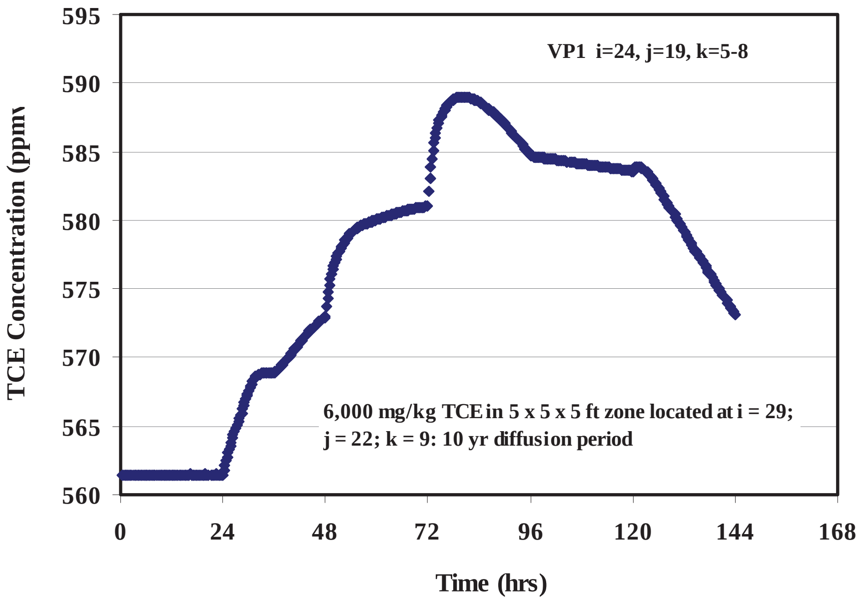
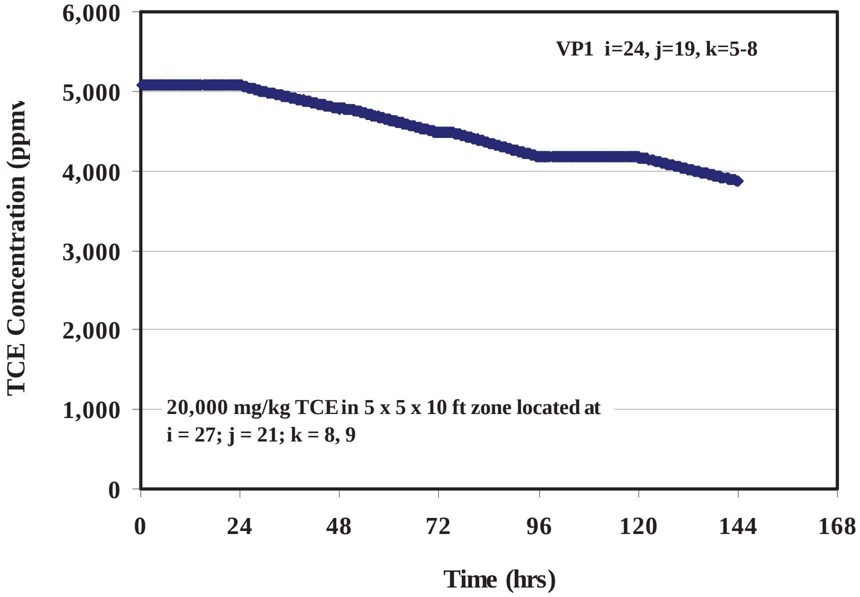
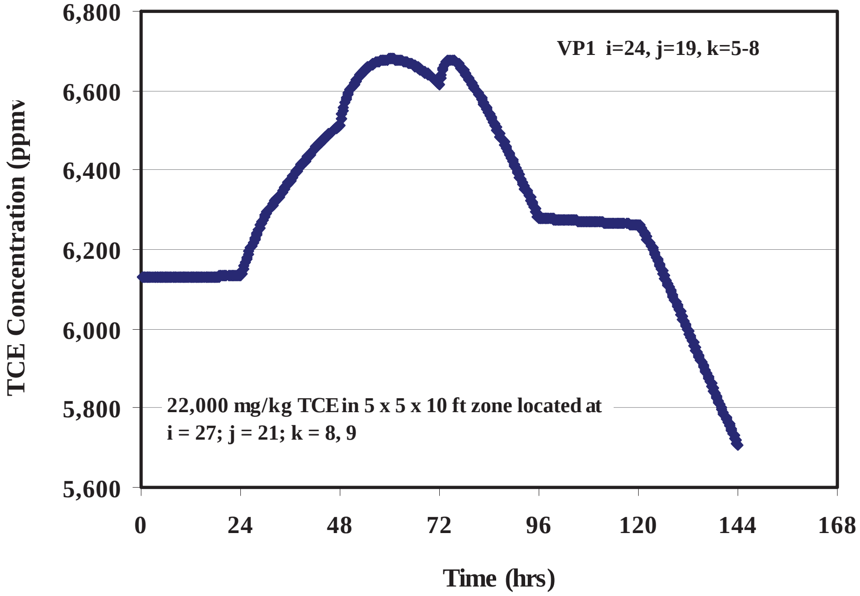
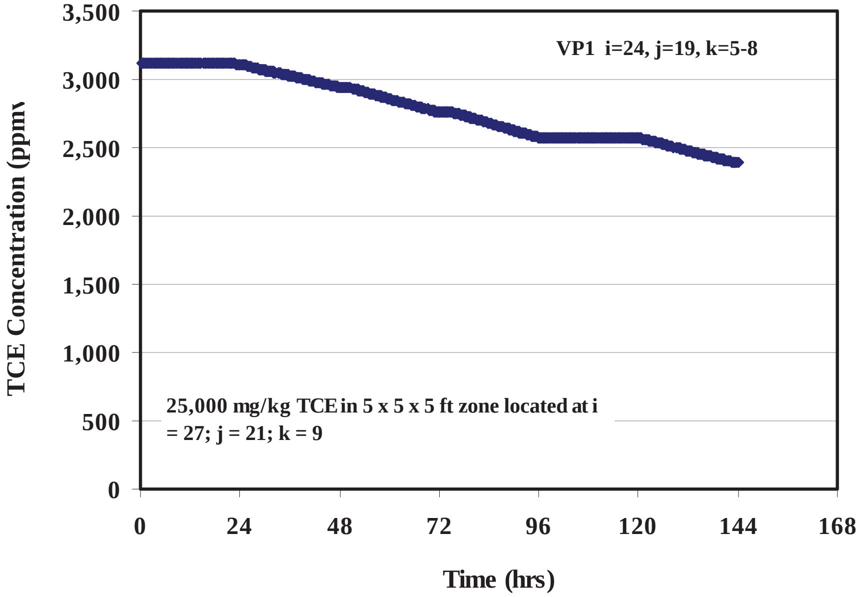
Source Area #7



U12-PV1
Source Area #8







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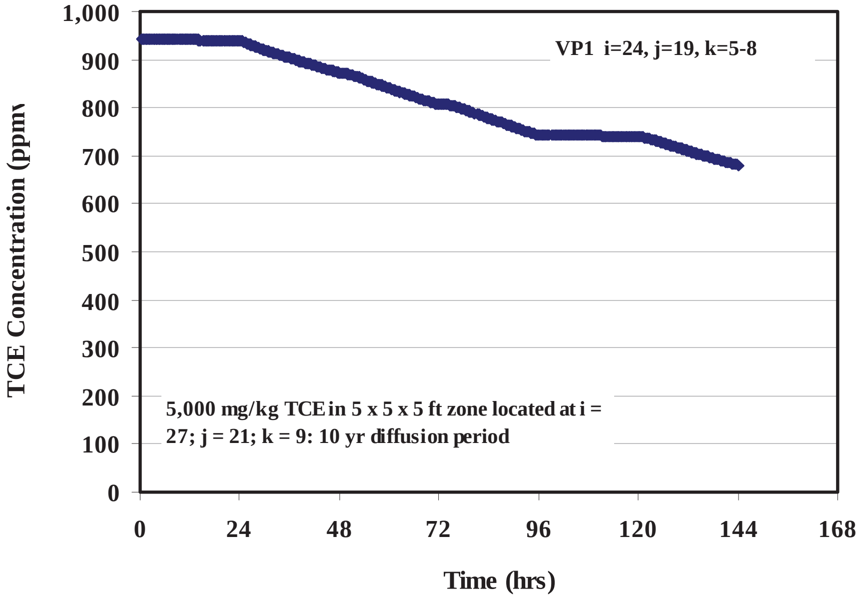
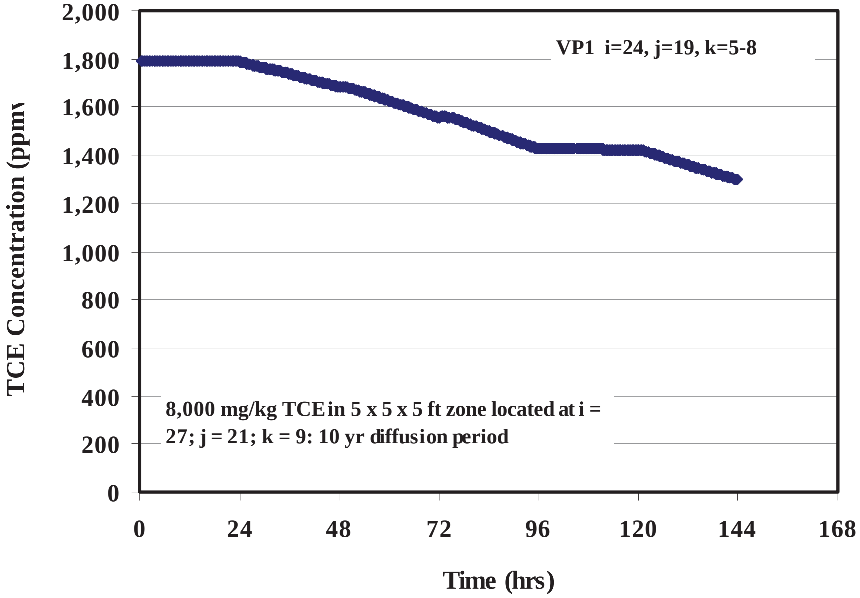
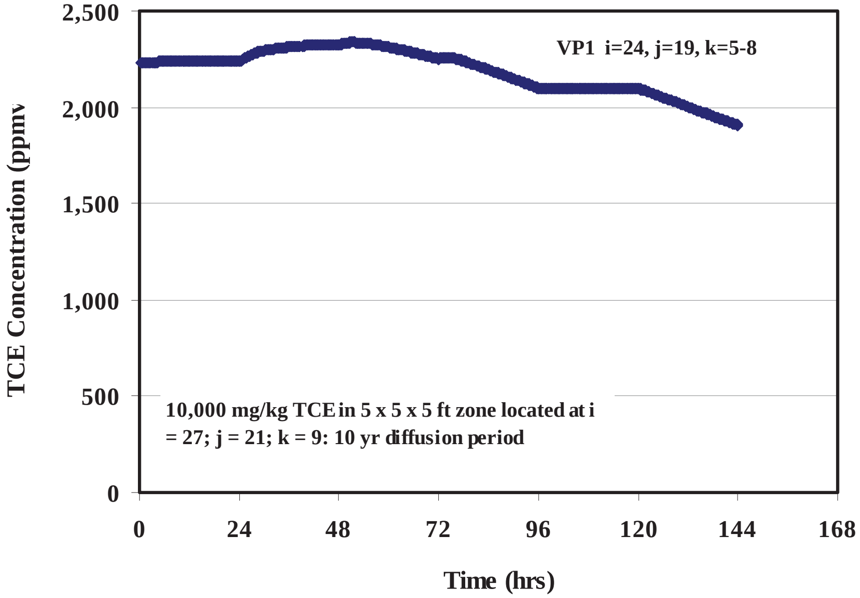
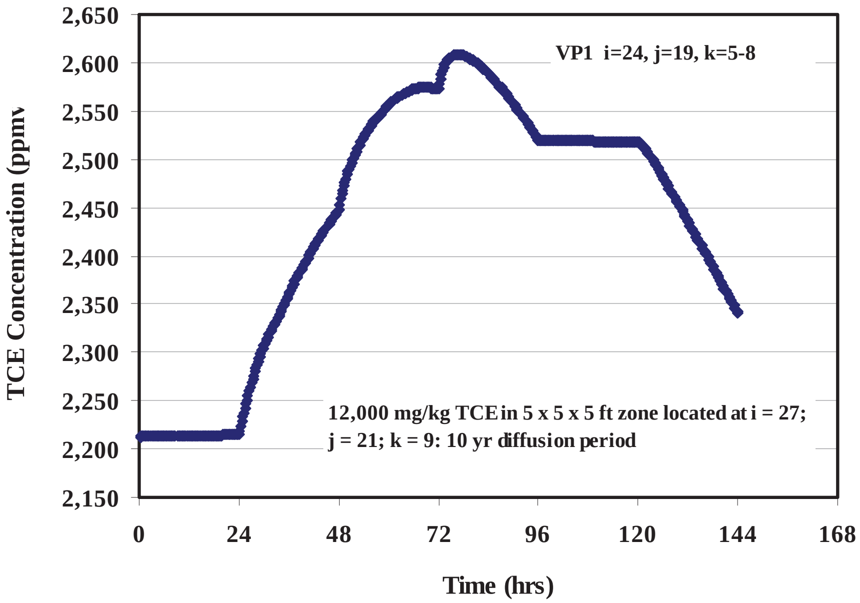
Source Area #8



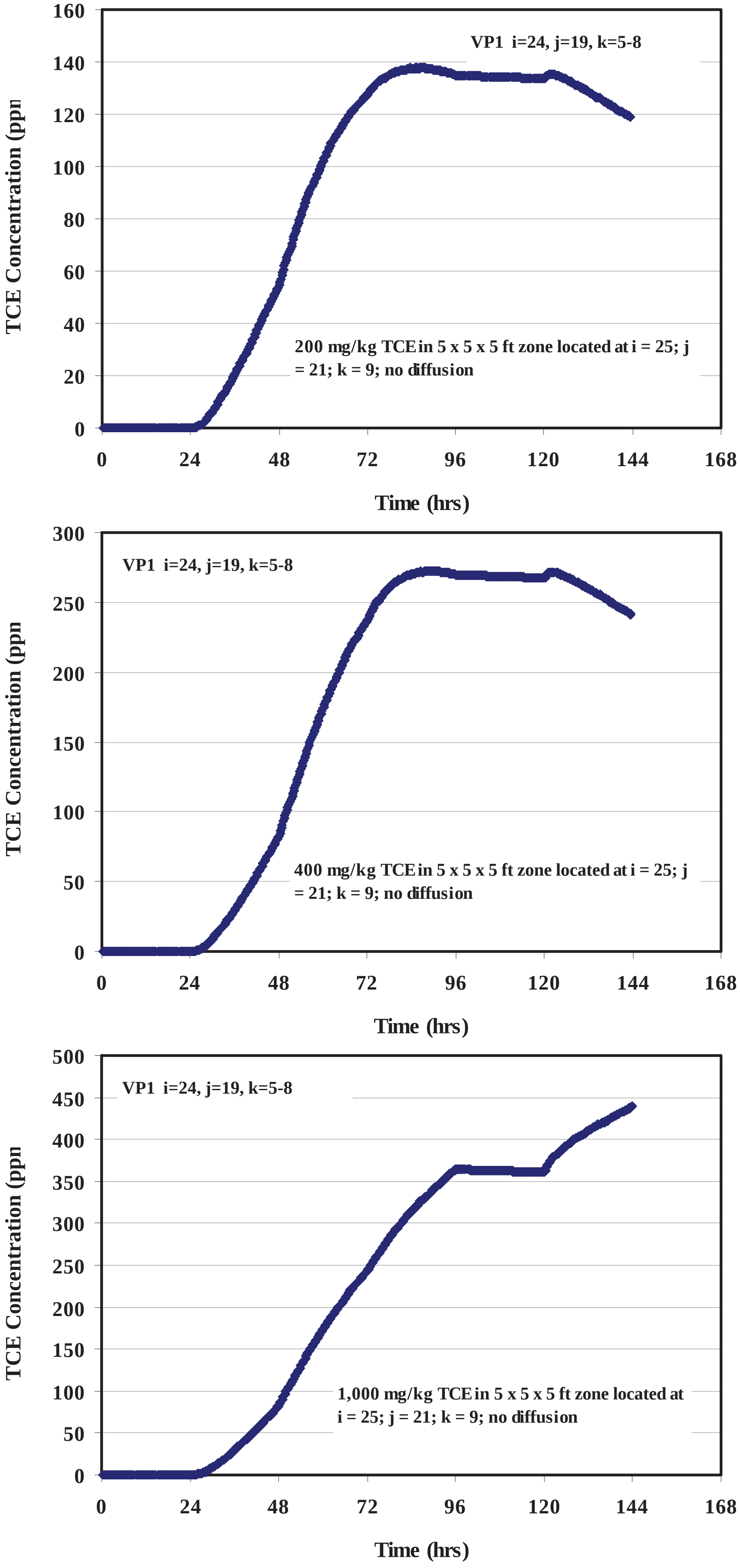




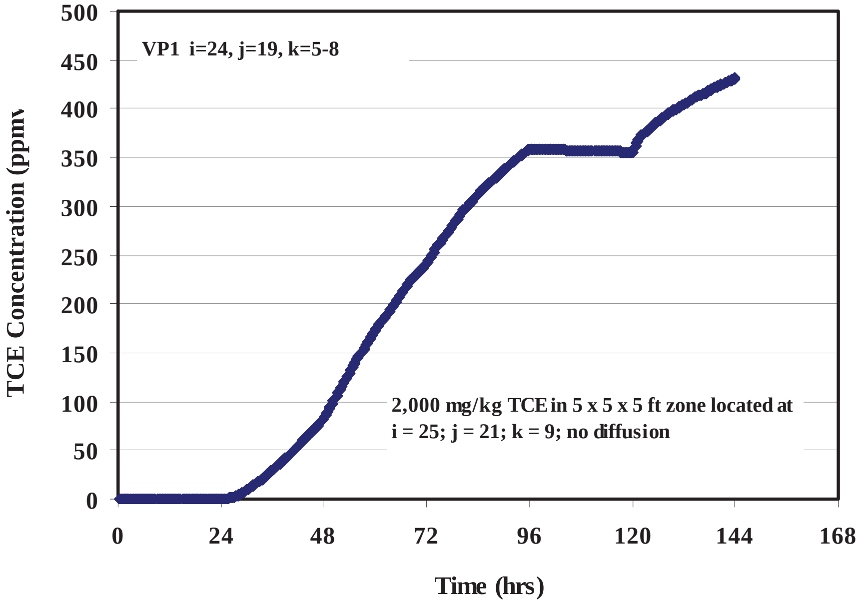
U12-PV1
Source Area #8

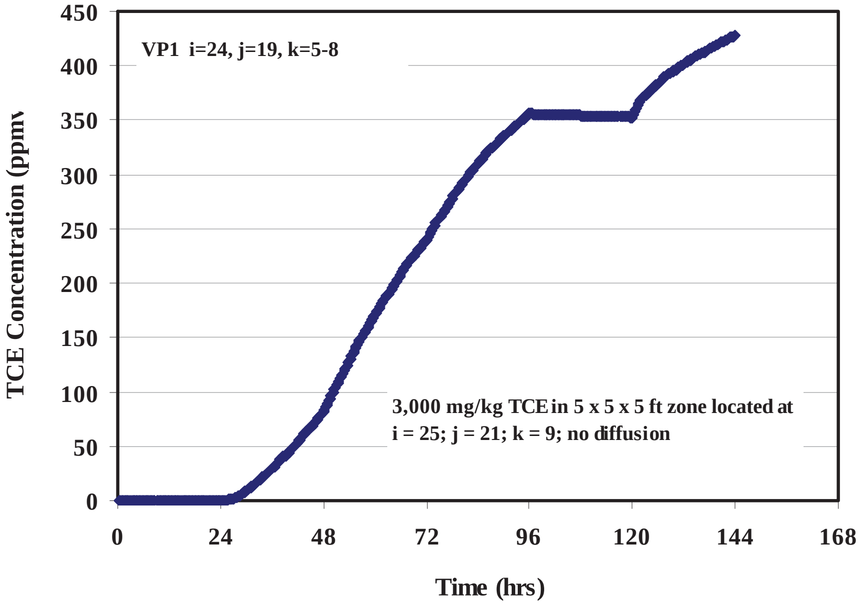


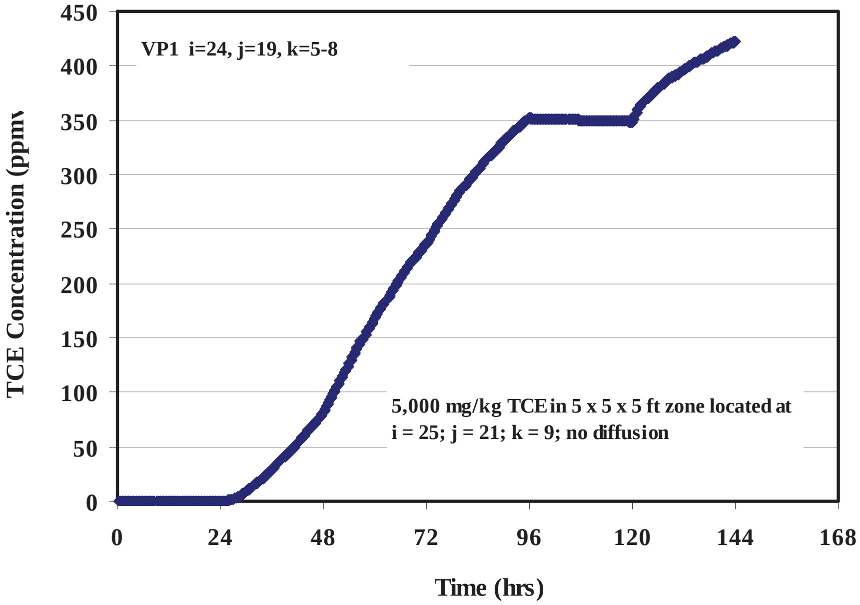
U12-PV1
Source Area #9



U12-PV1
Source Area #9







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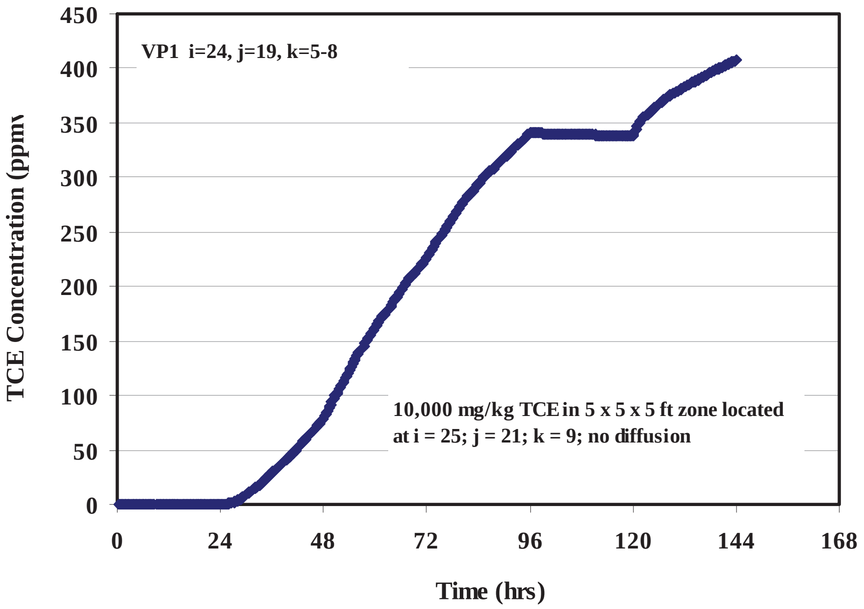
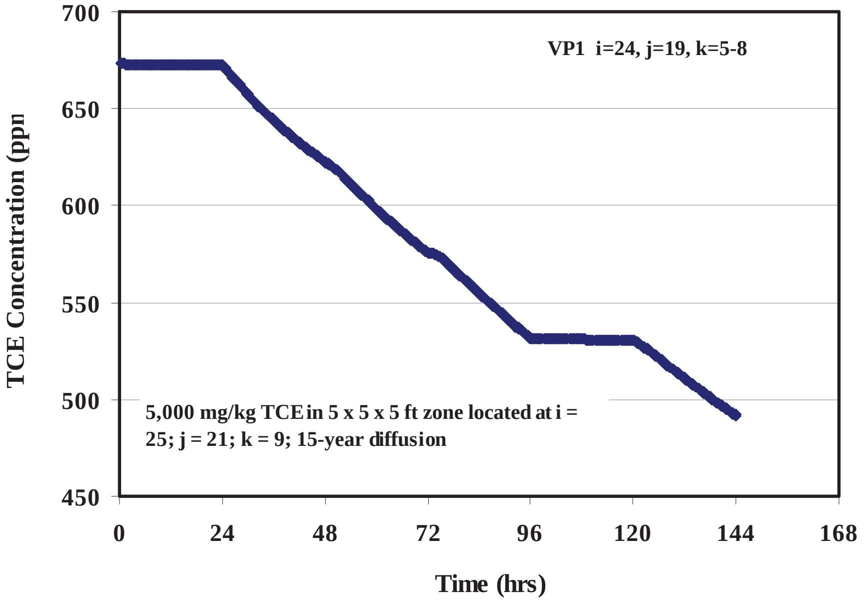
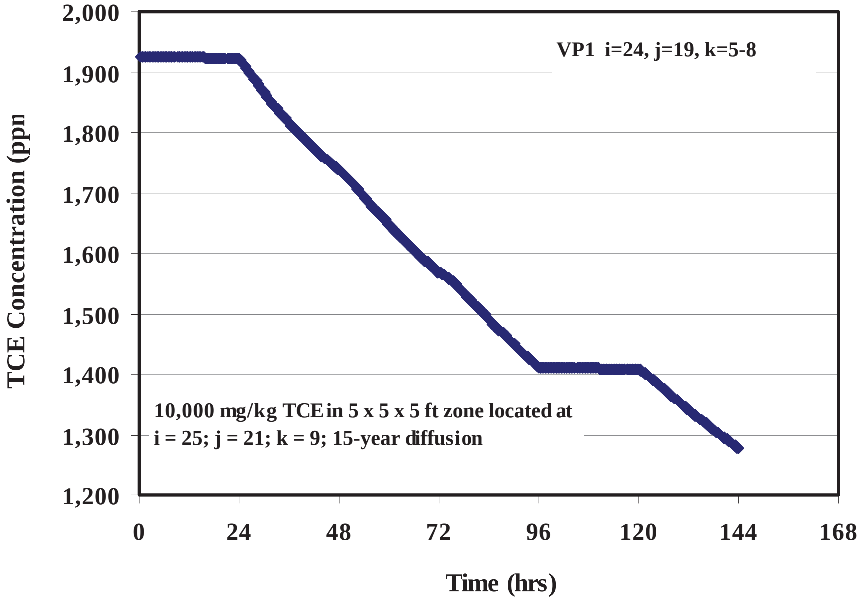
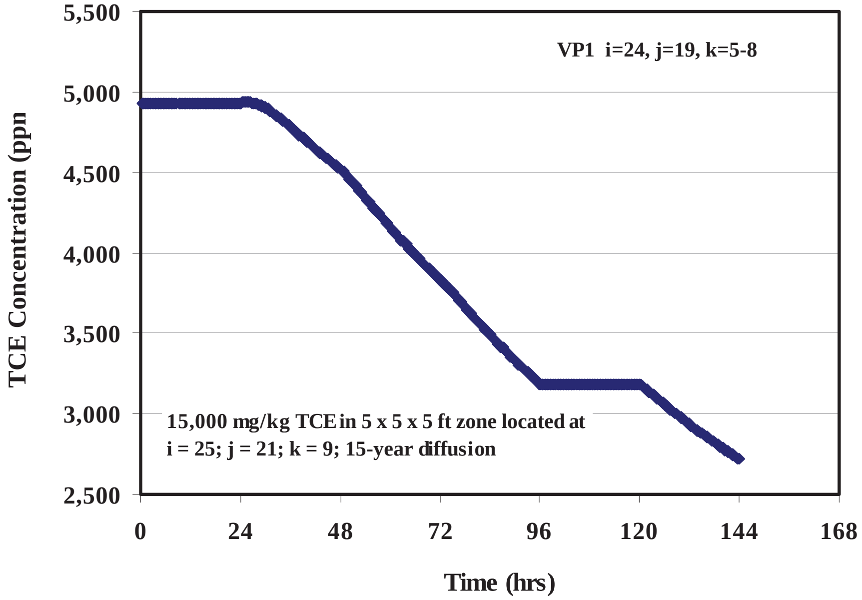
Source Area #9

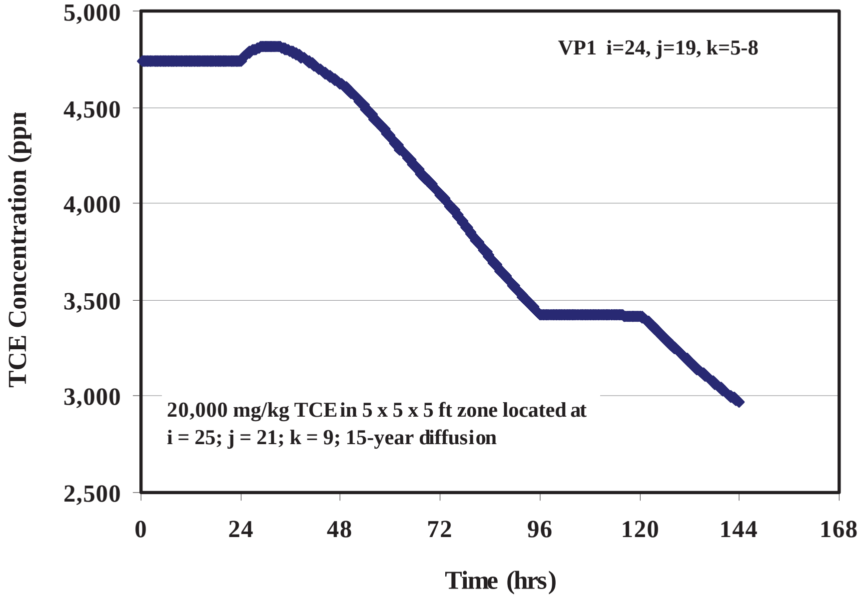


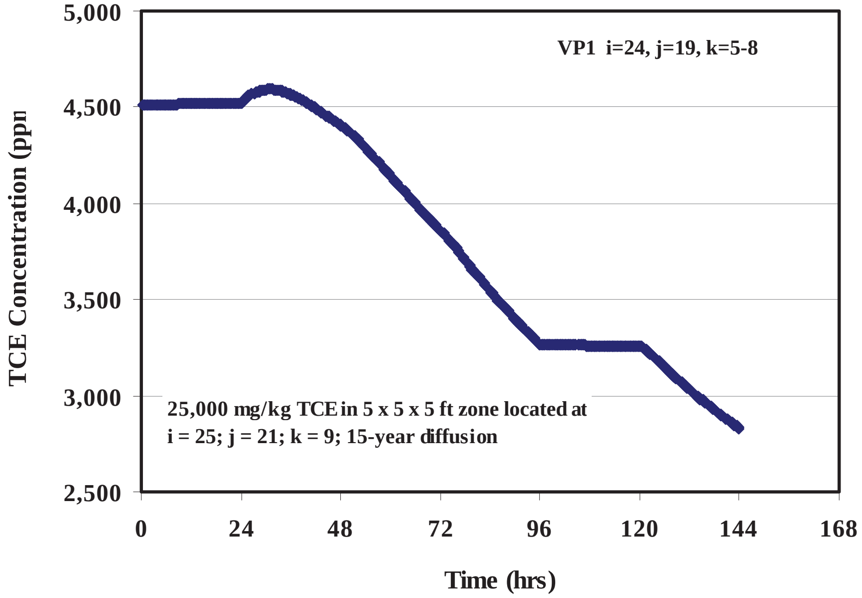




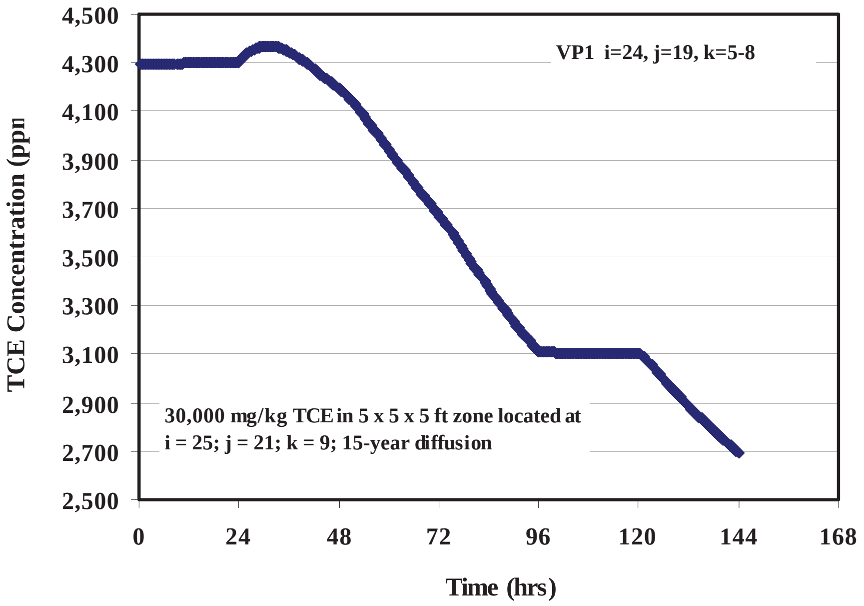
U12-PV1
Source Area #9

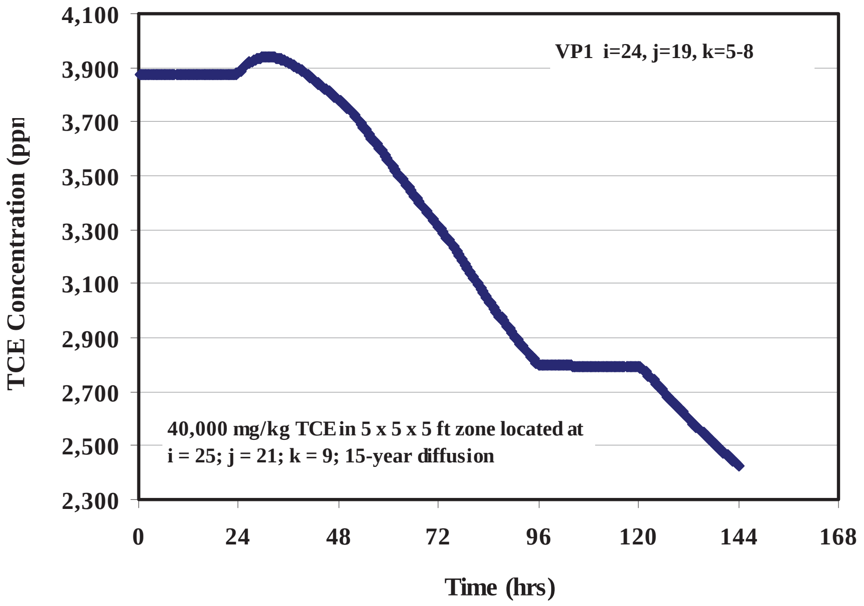


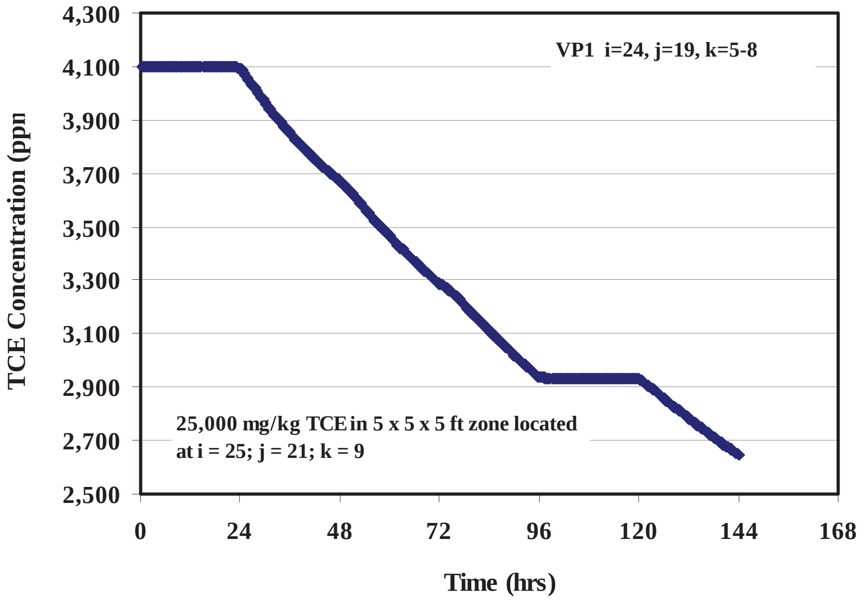




U12-PV1
Source Area #9







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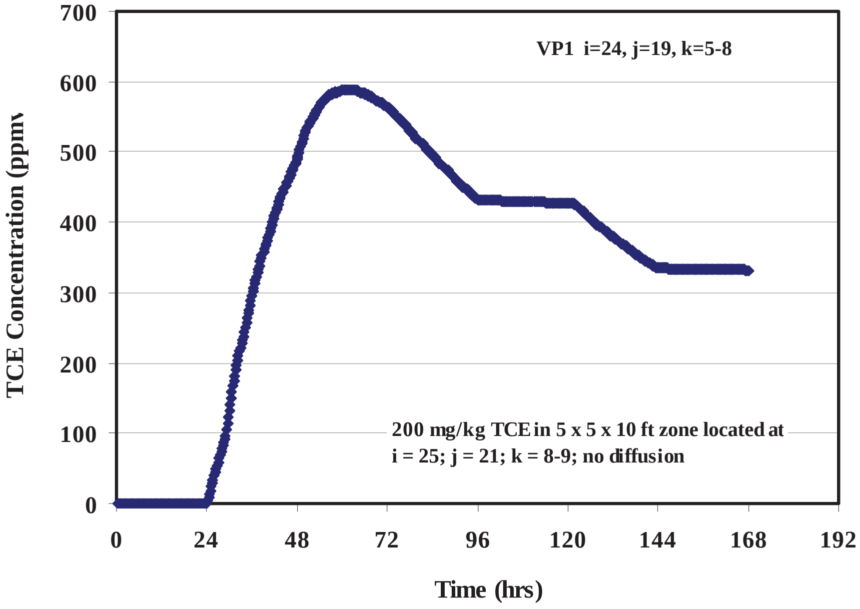
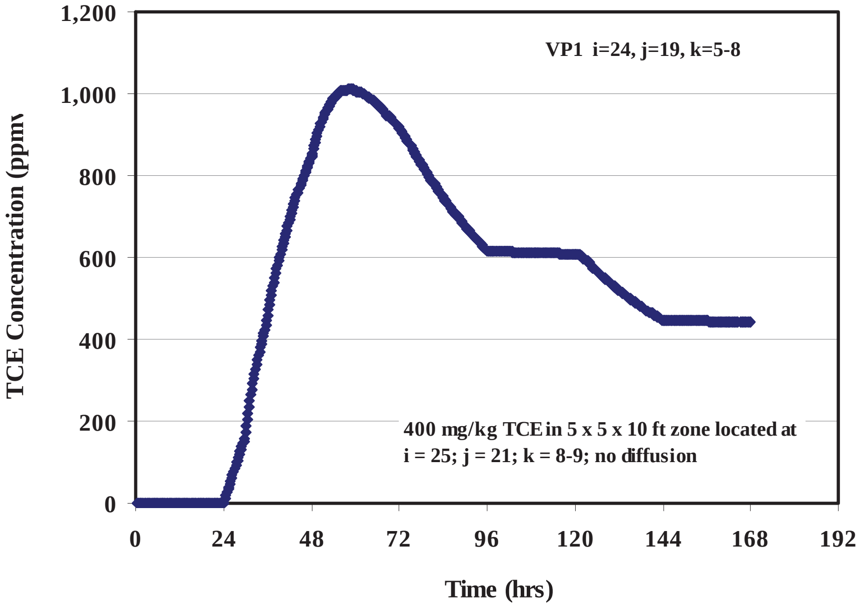
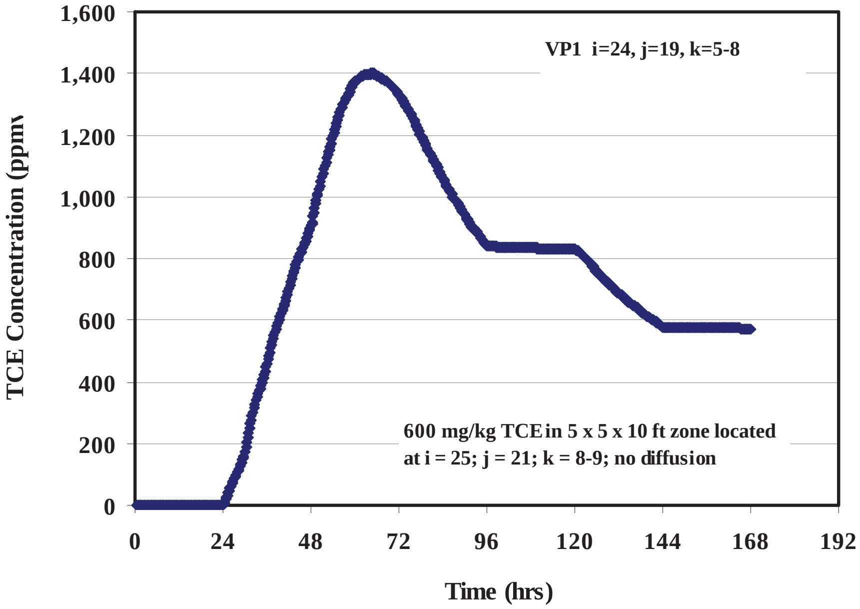
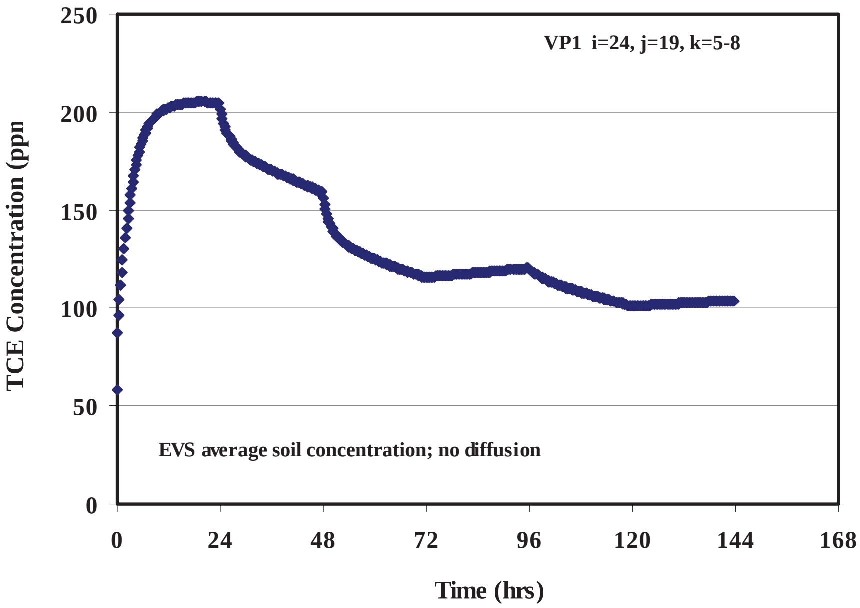
Source Area #9

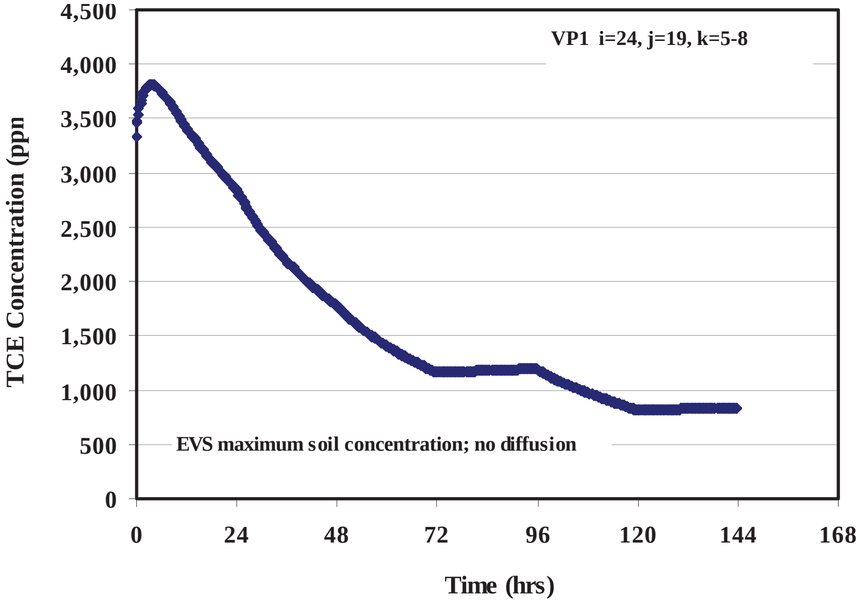






U12-PV1
Source Area #10





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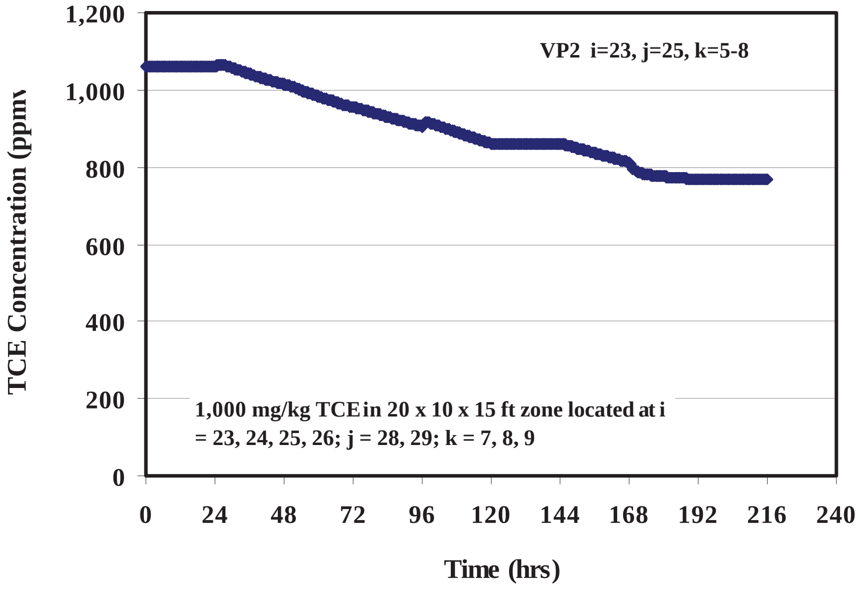
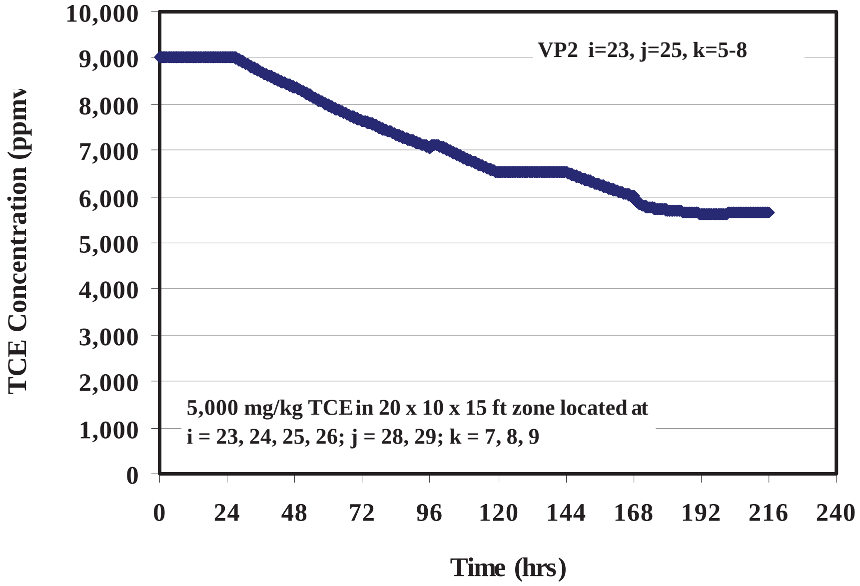
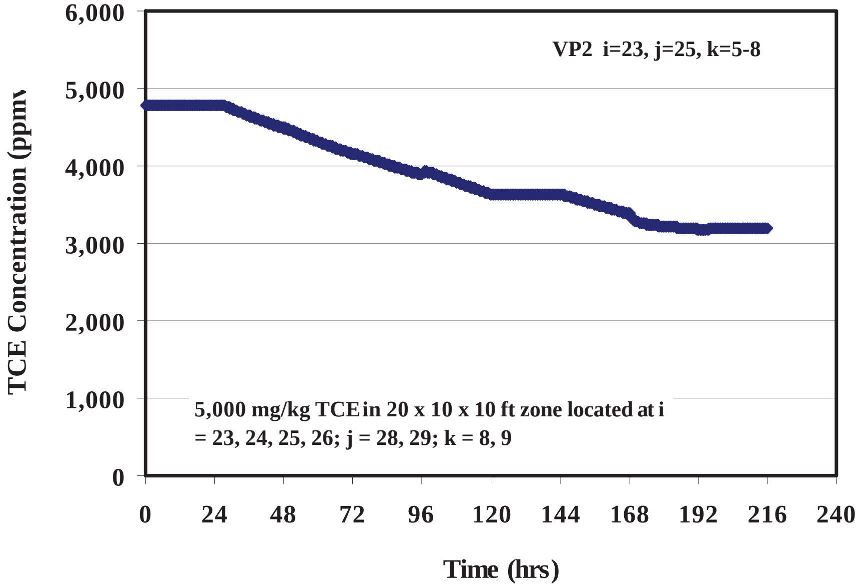
Source Area #1







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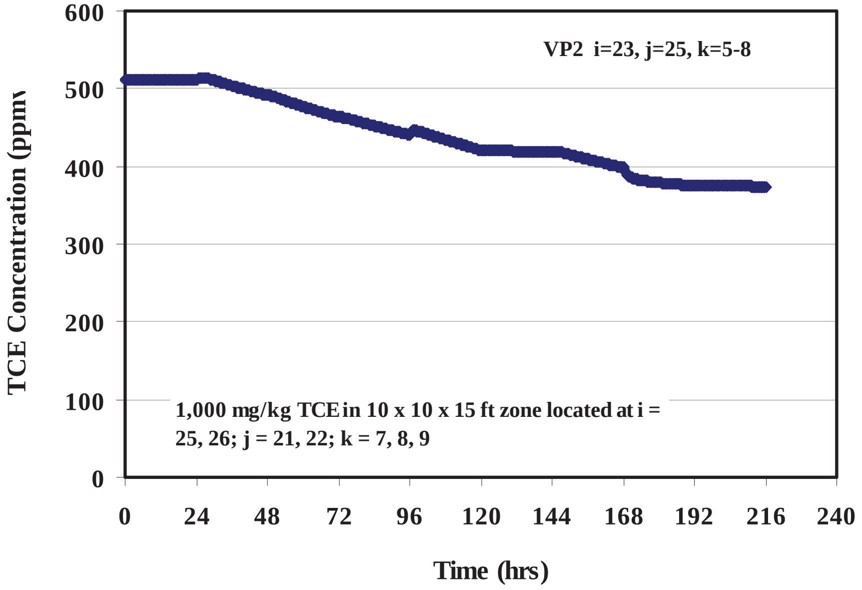

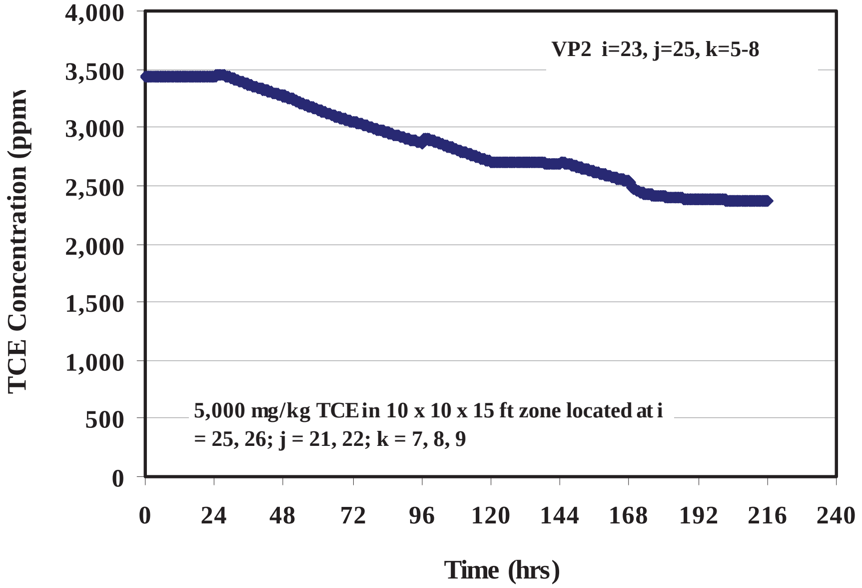

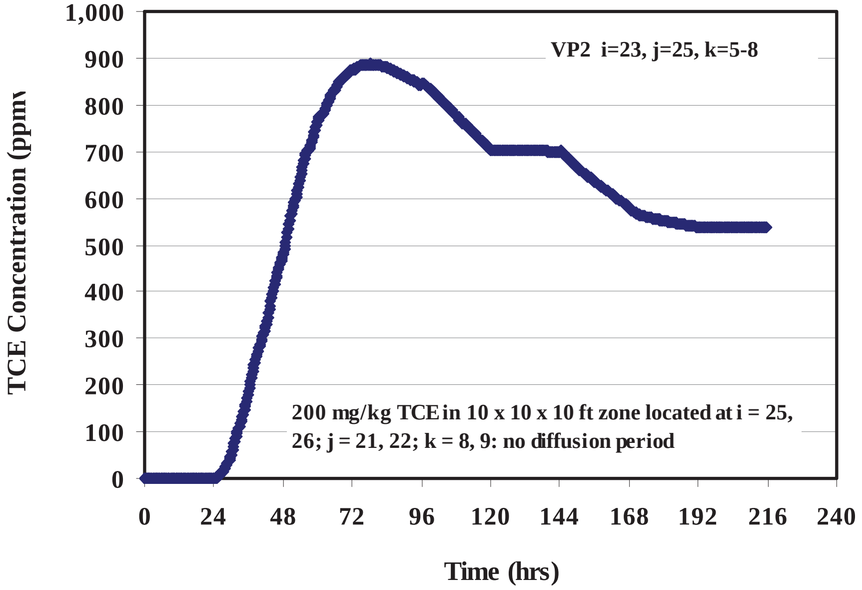

U12-PV2
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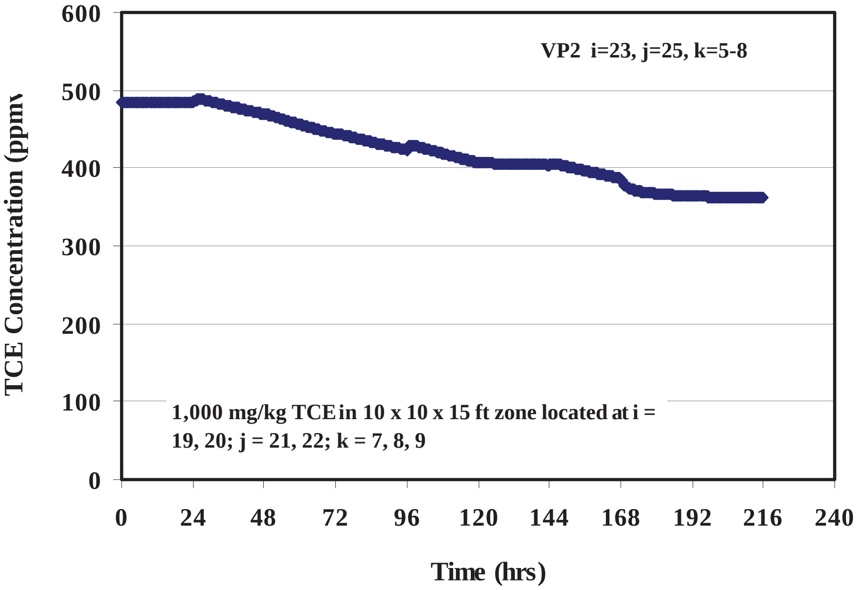

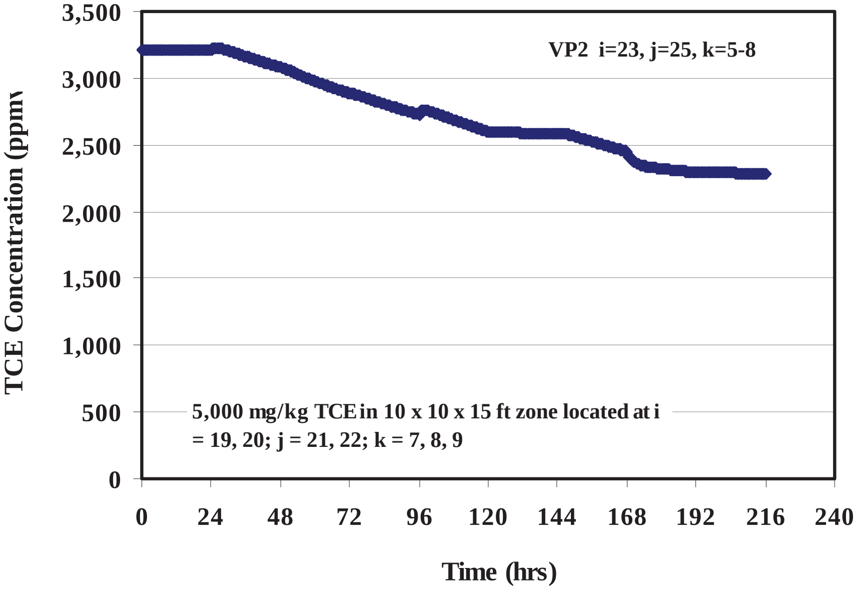

U12-PV2
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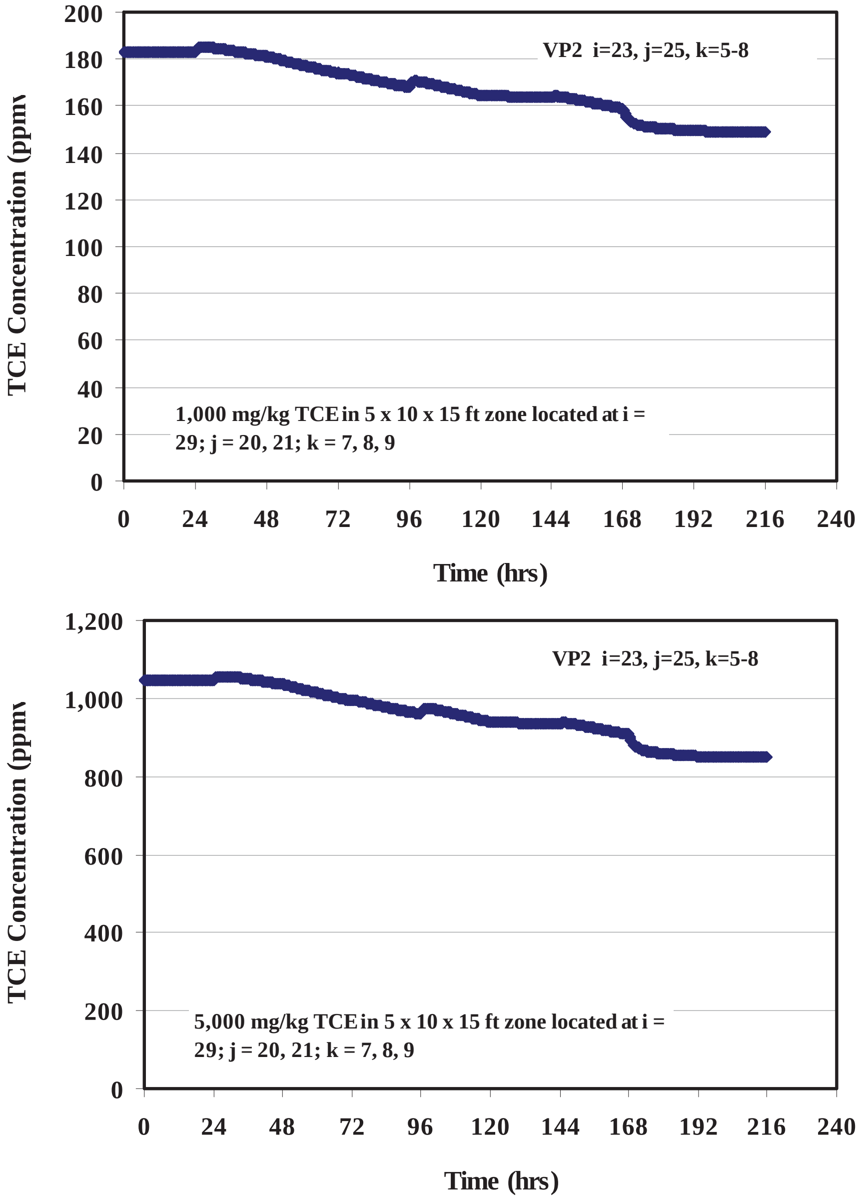

U12-PV2
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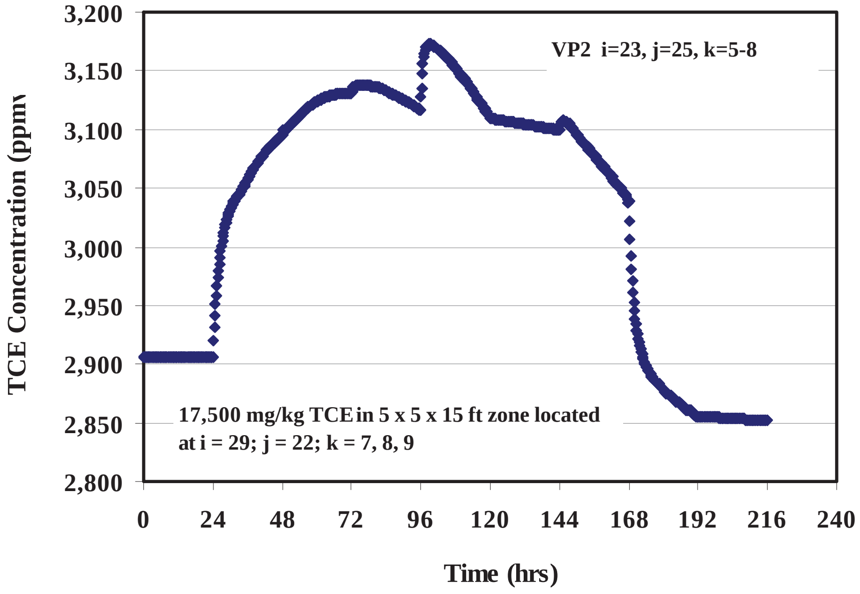

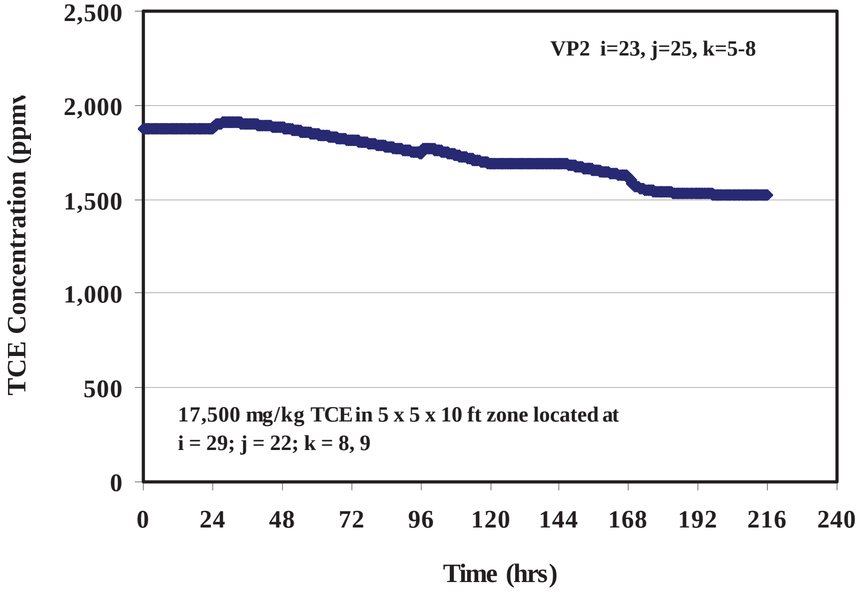

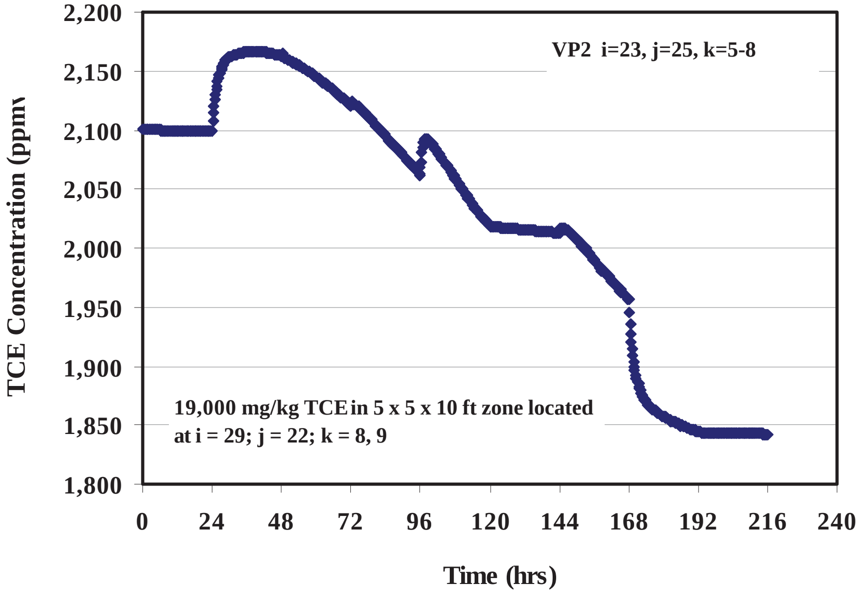

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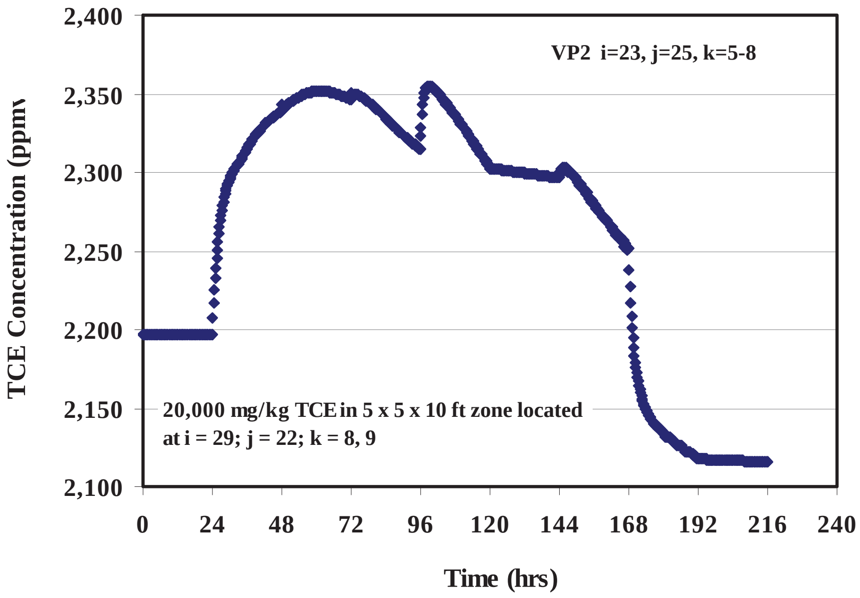

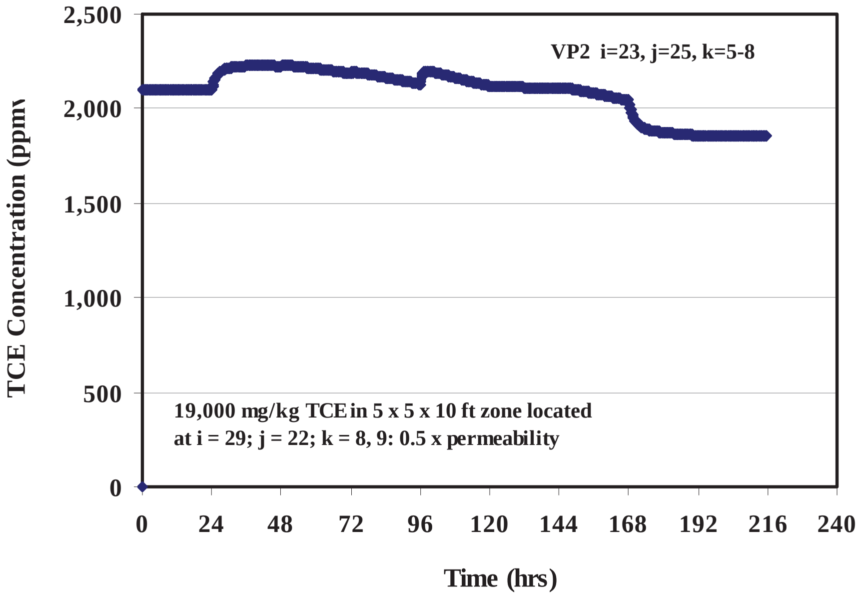

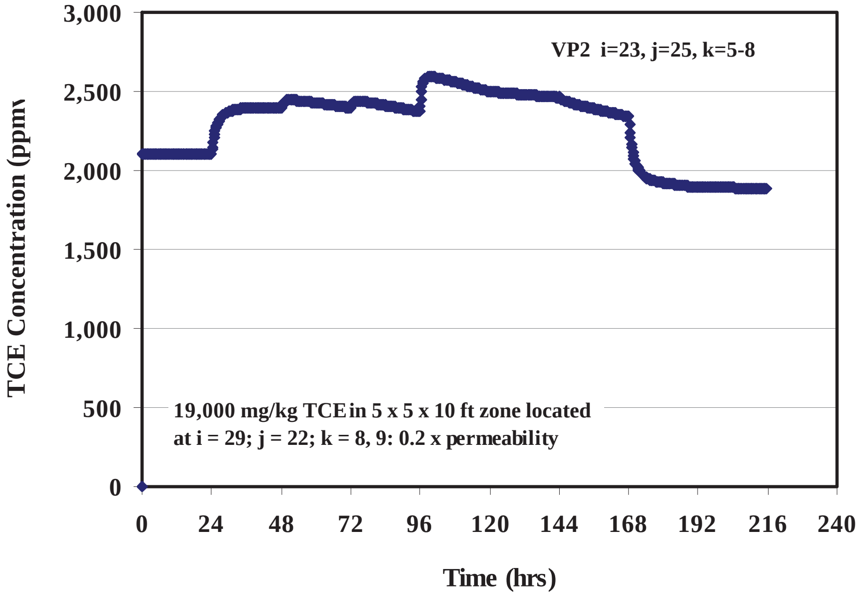

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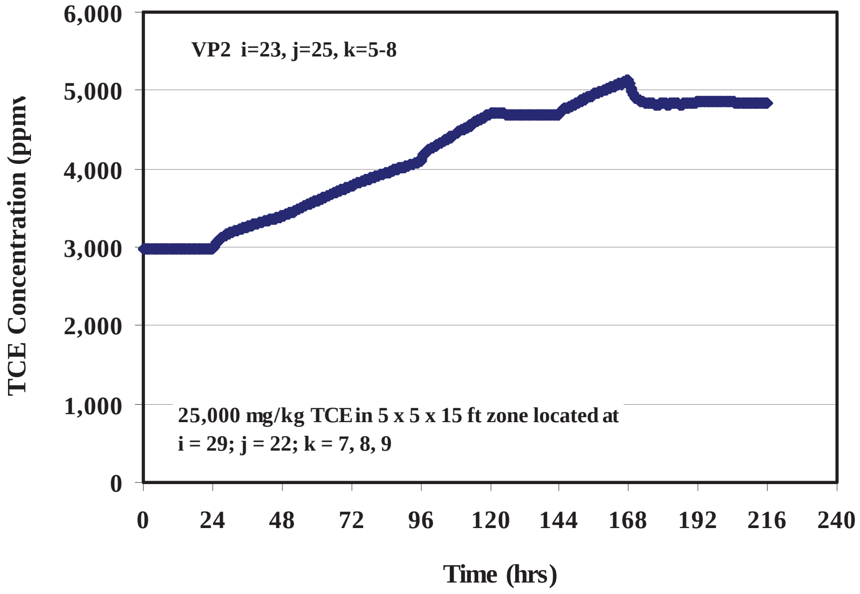

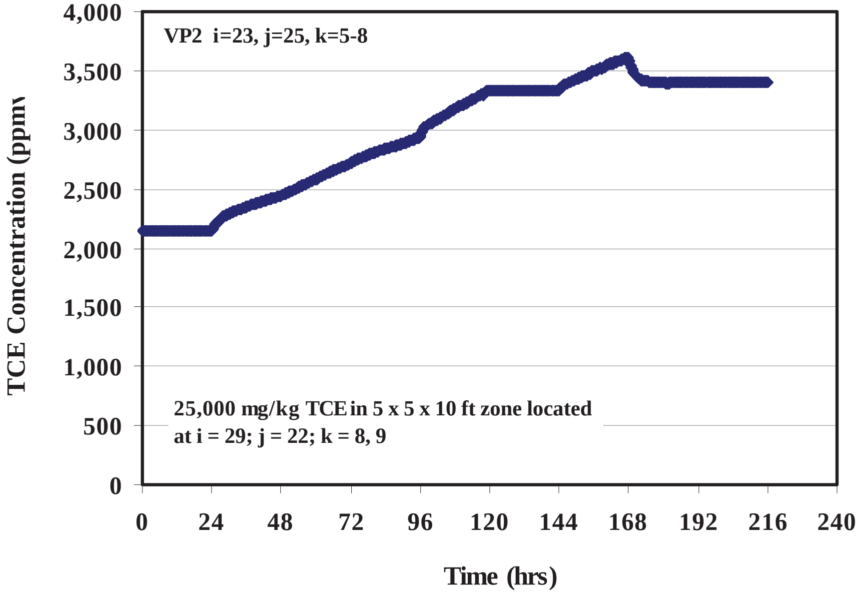

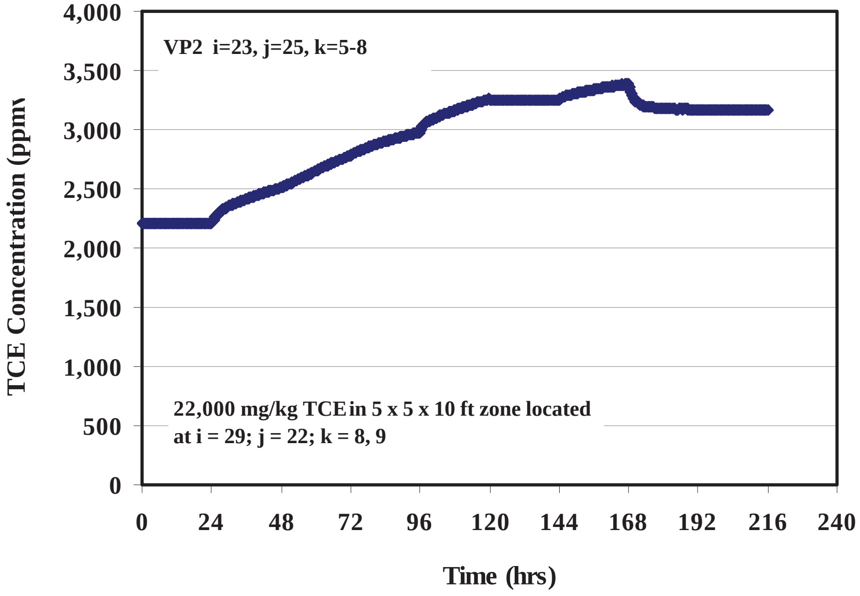

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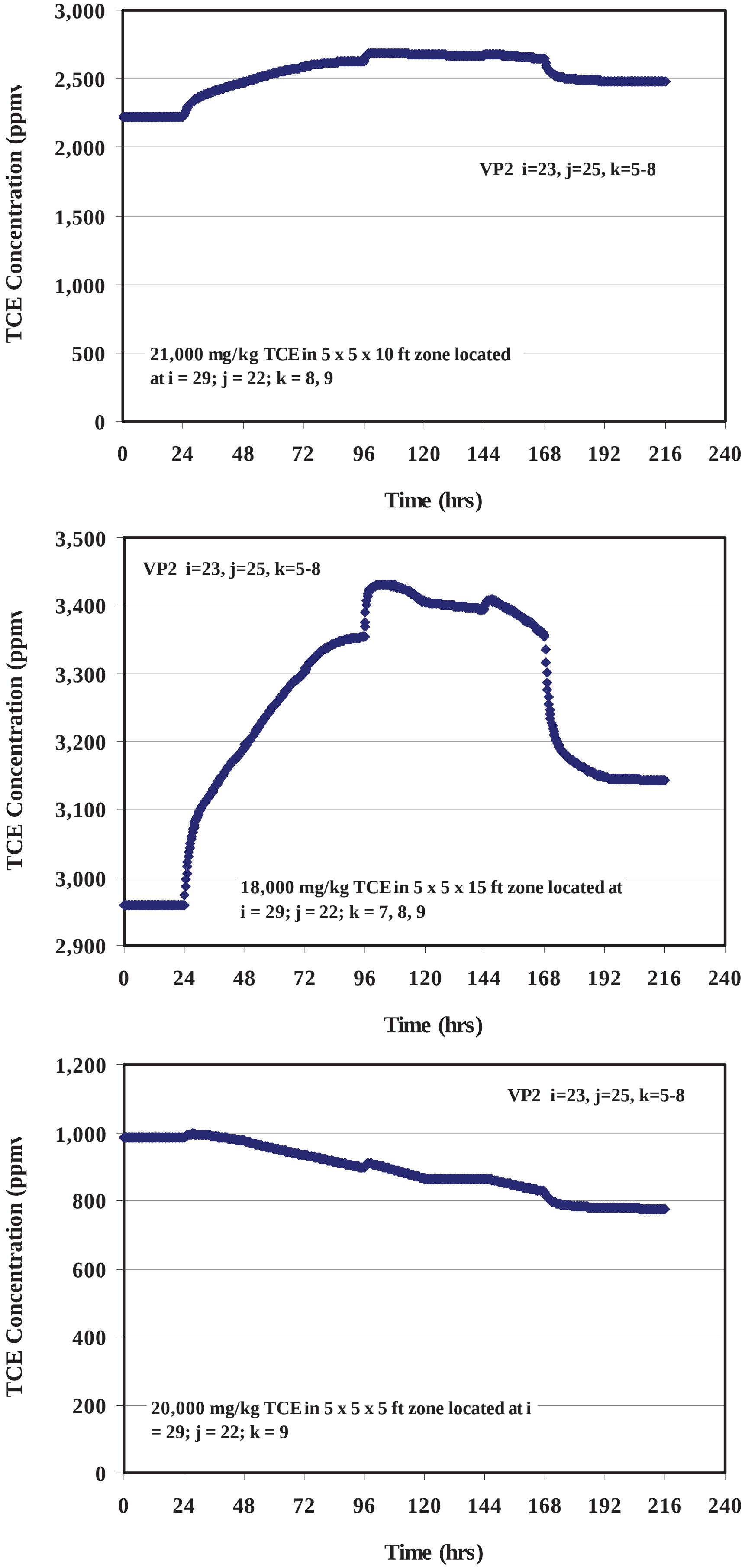

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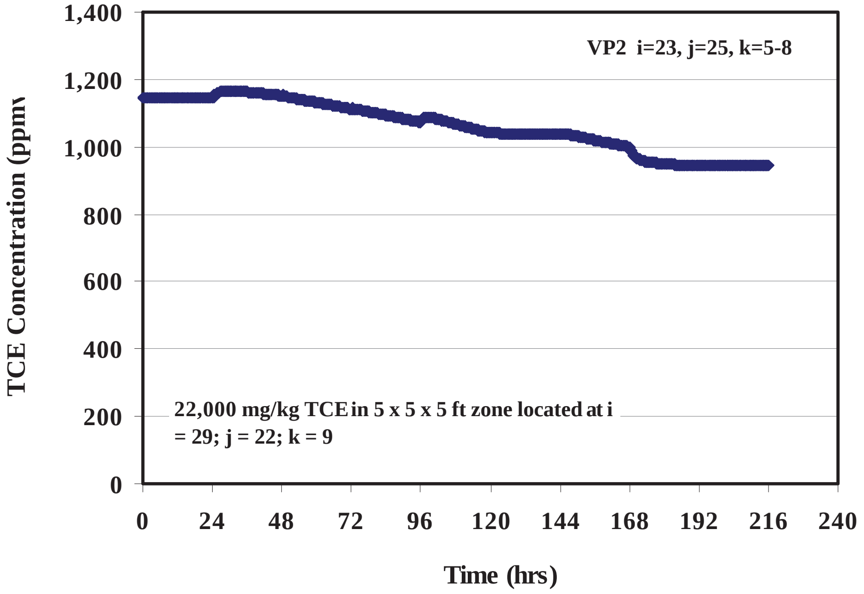

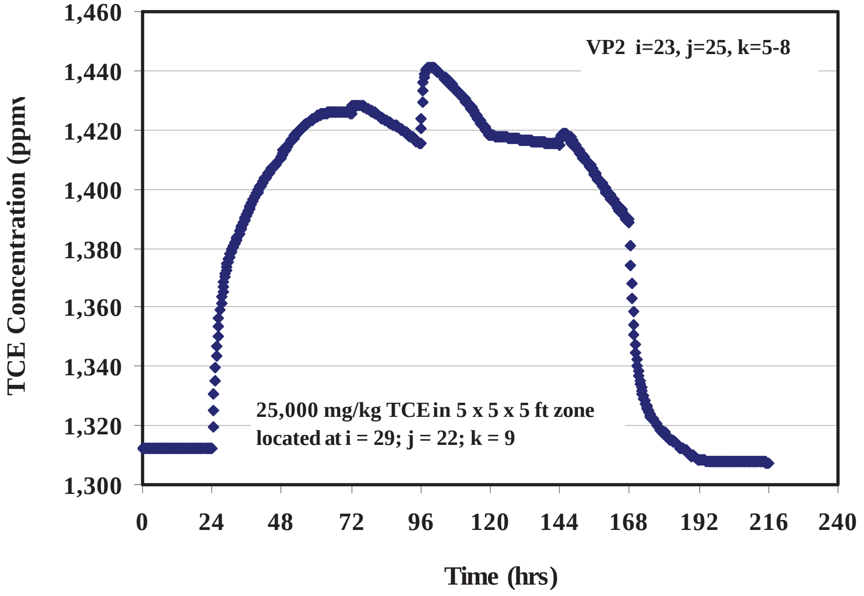

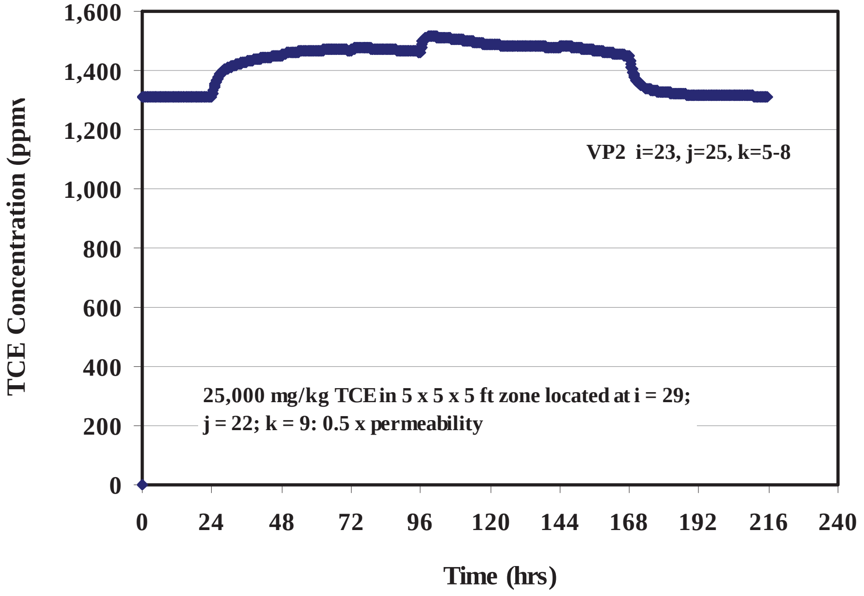

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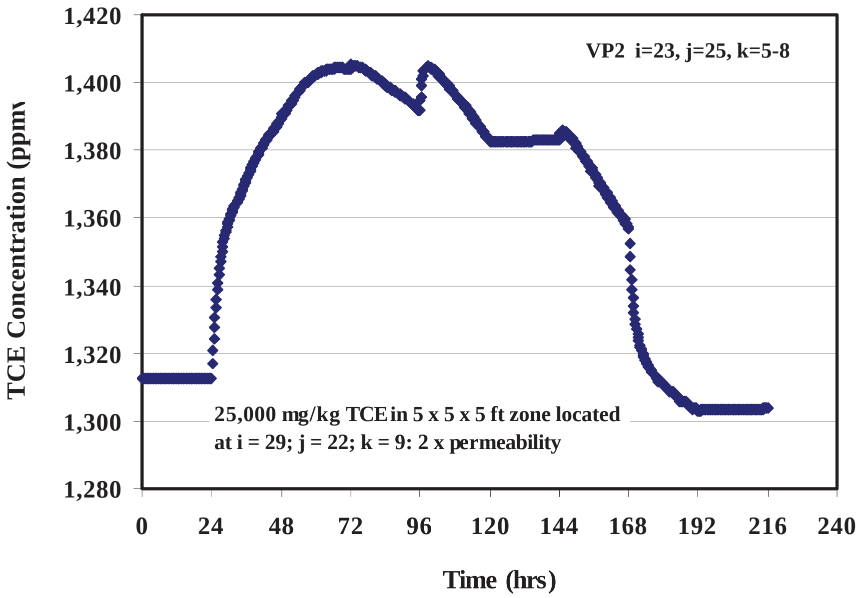

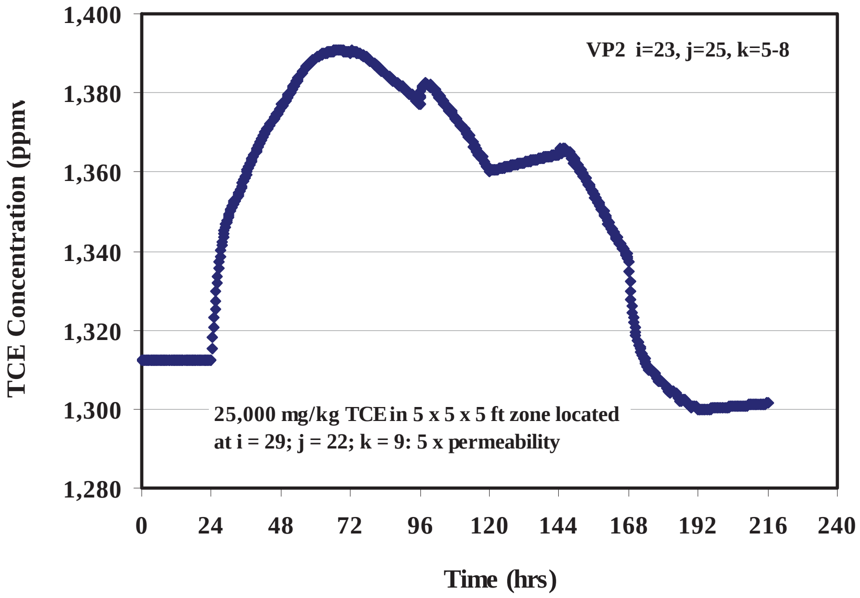

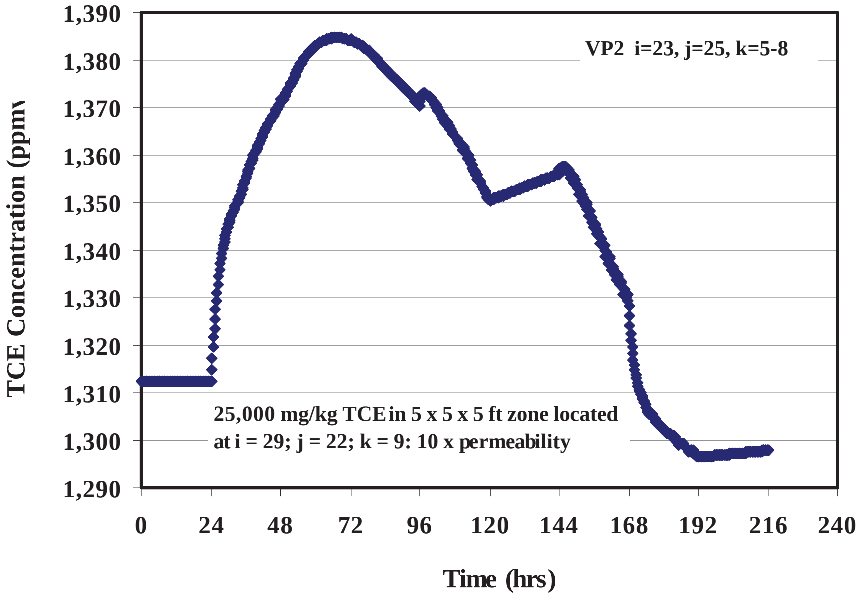

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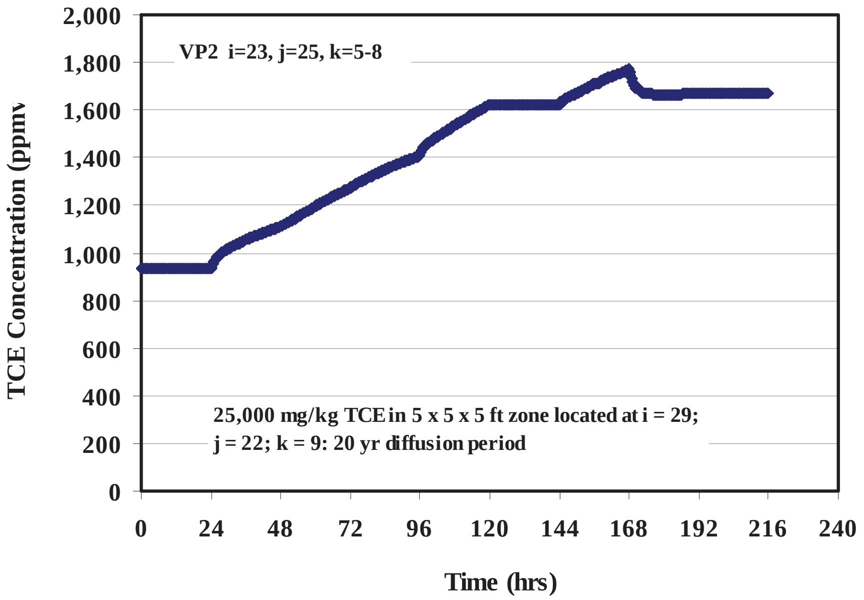

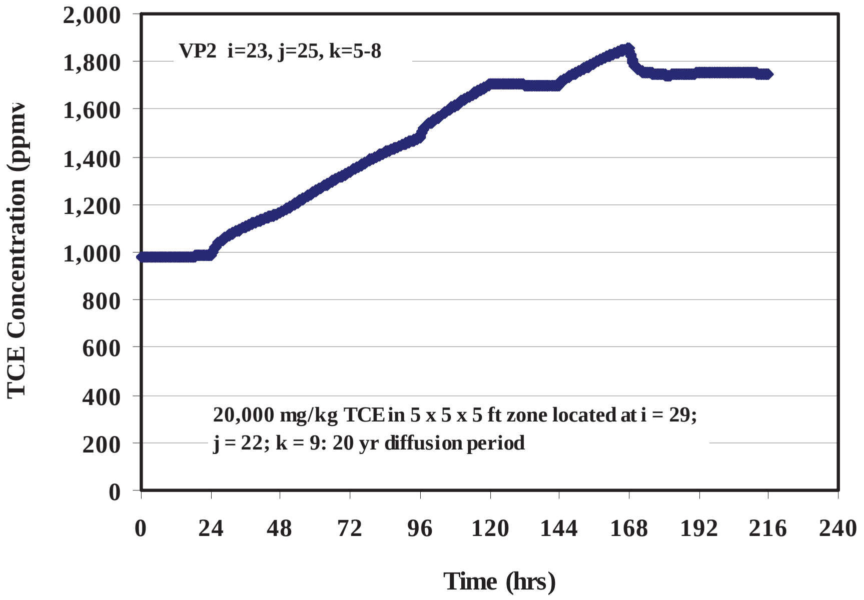

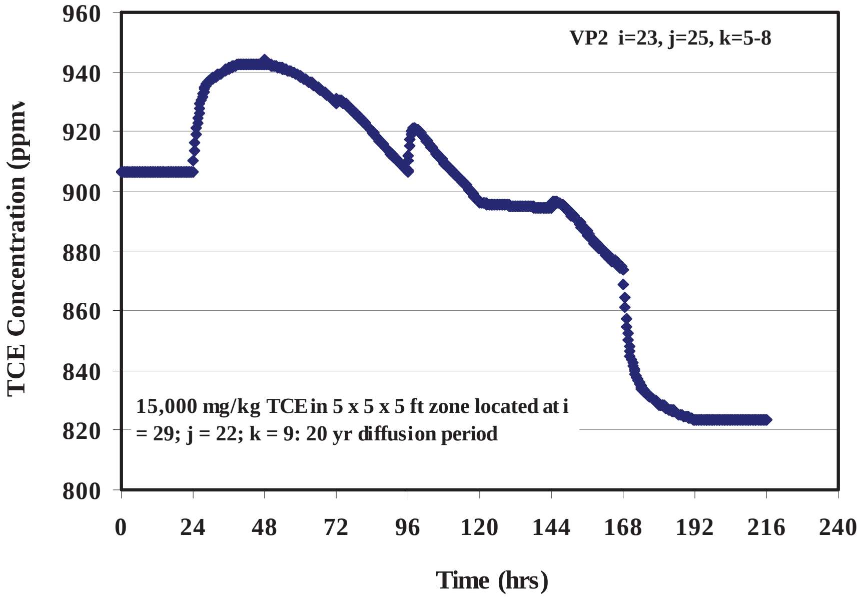

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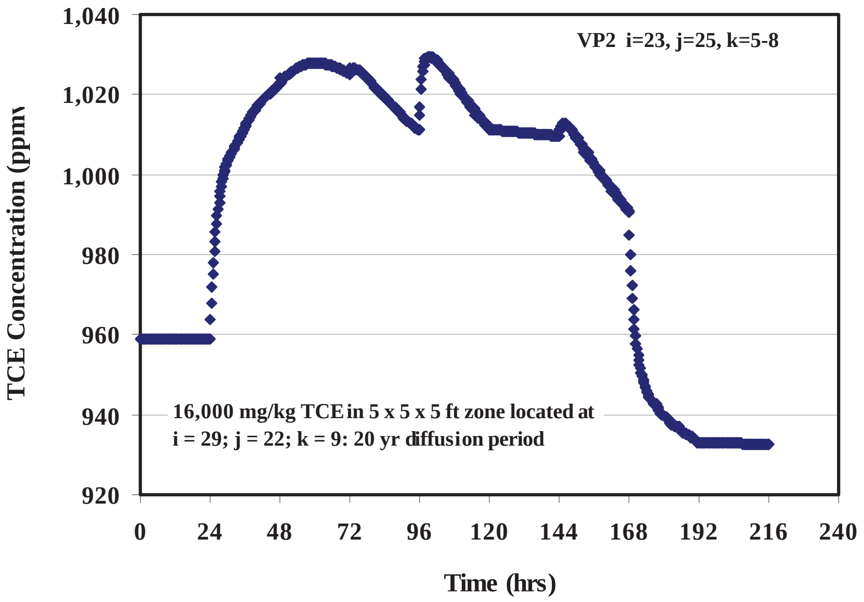

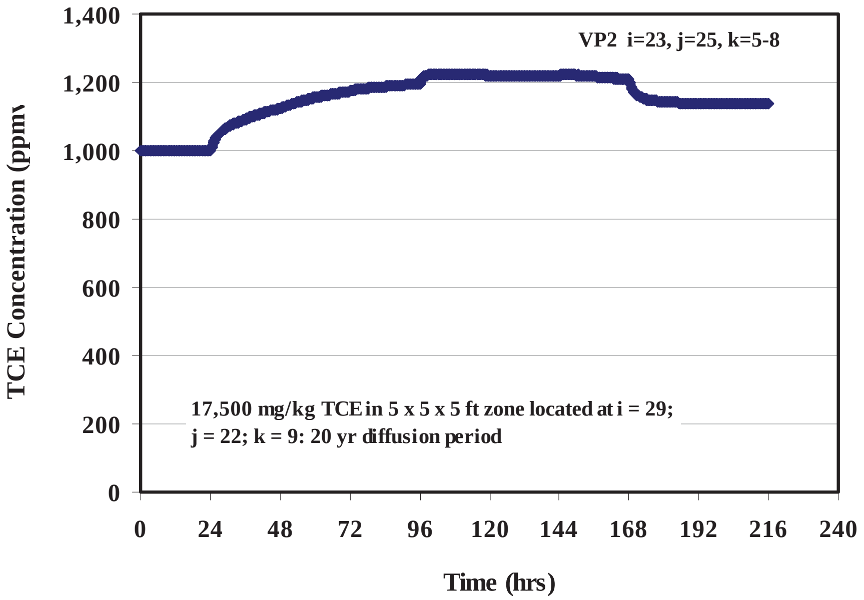

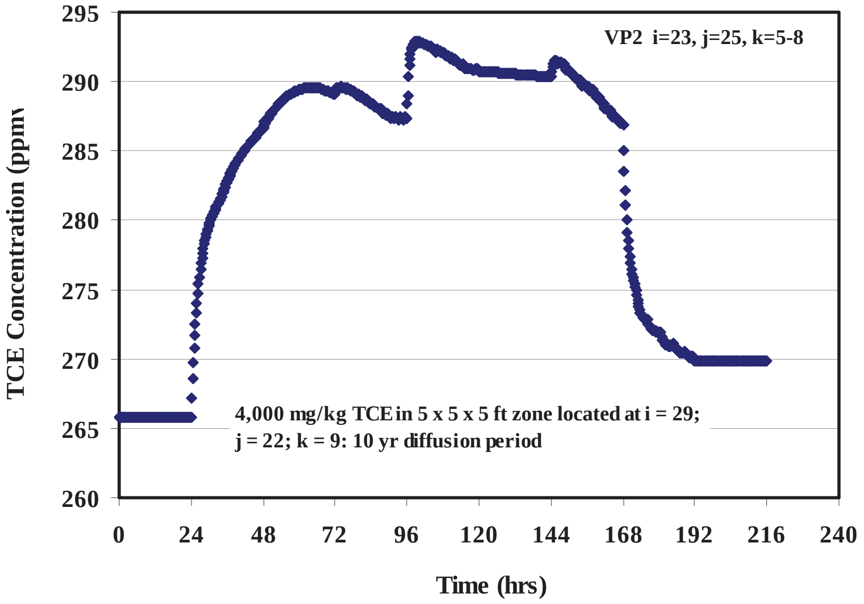

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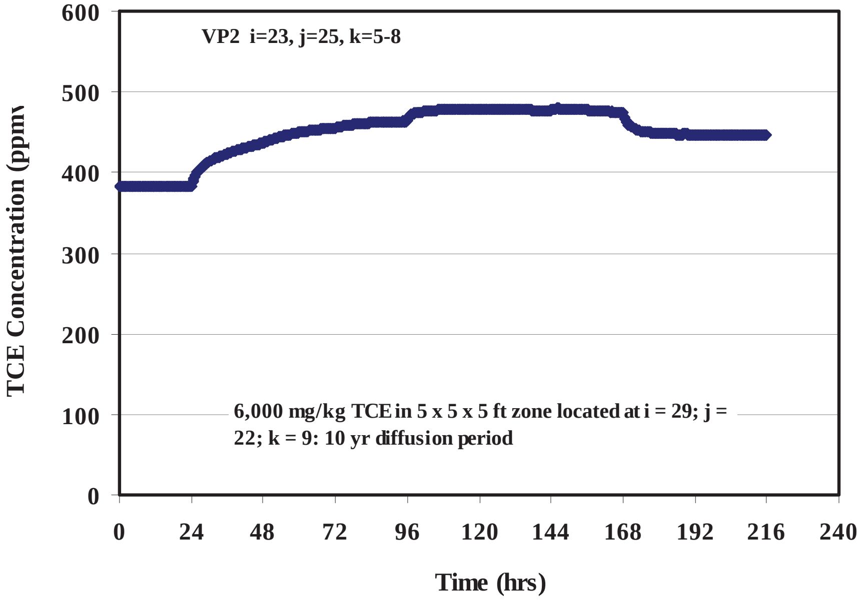

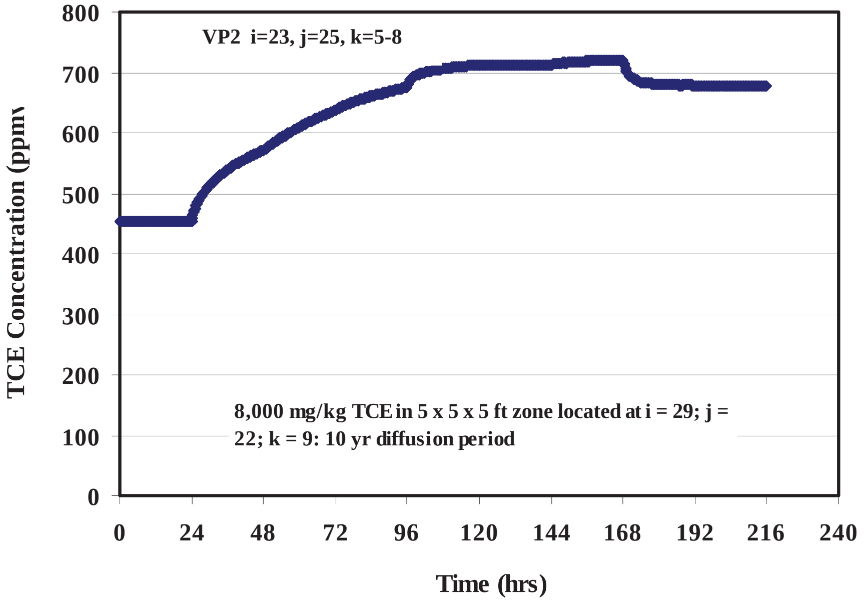

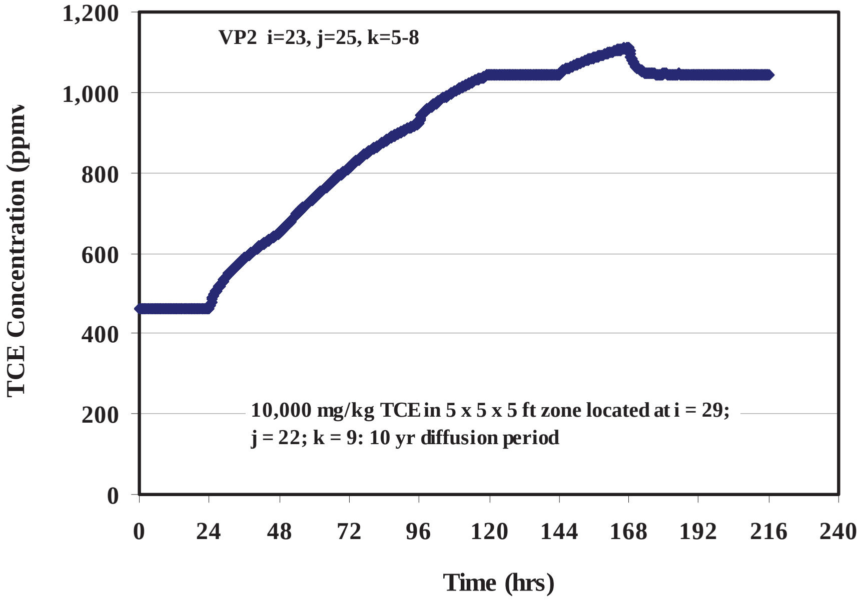

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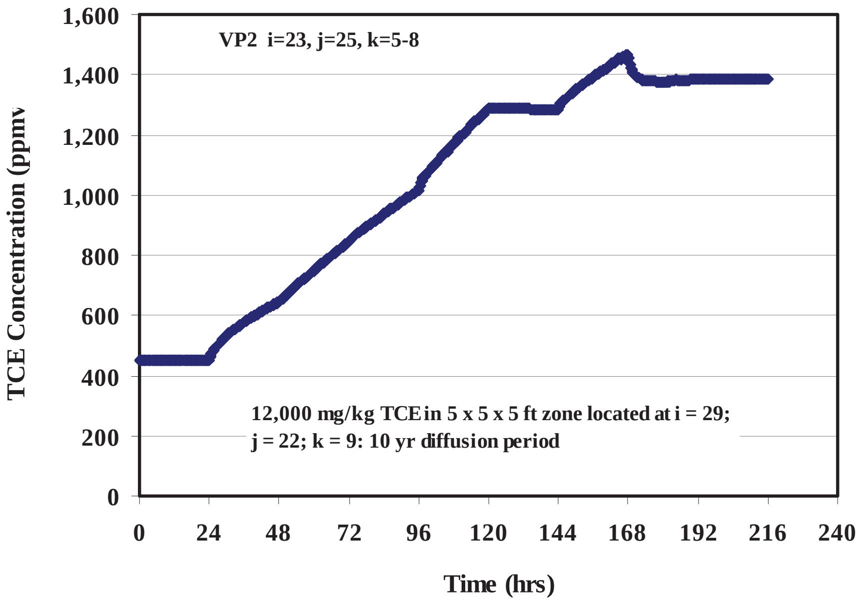

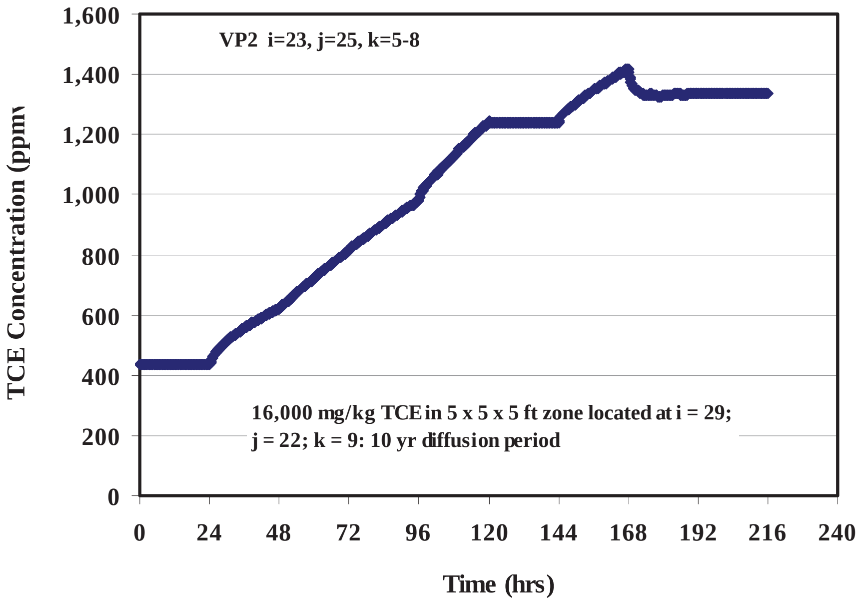

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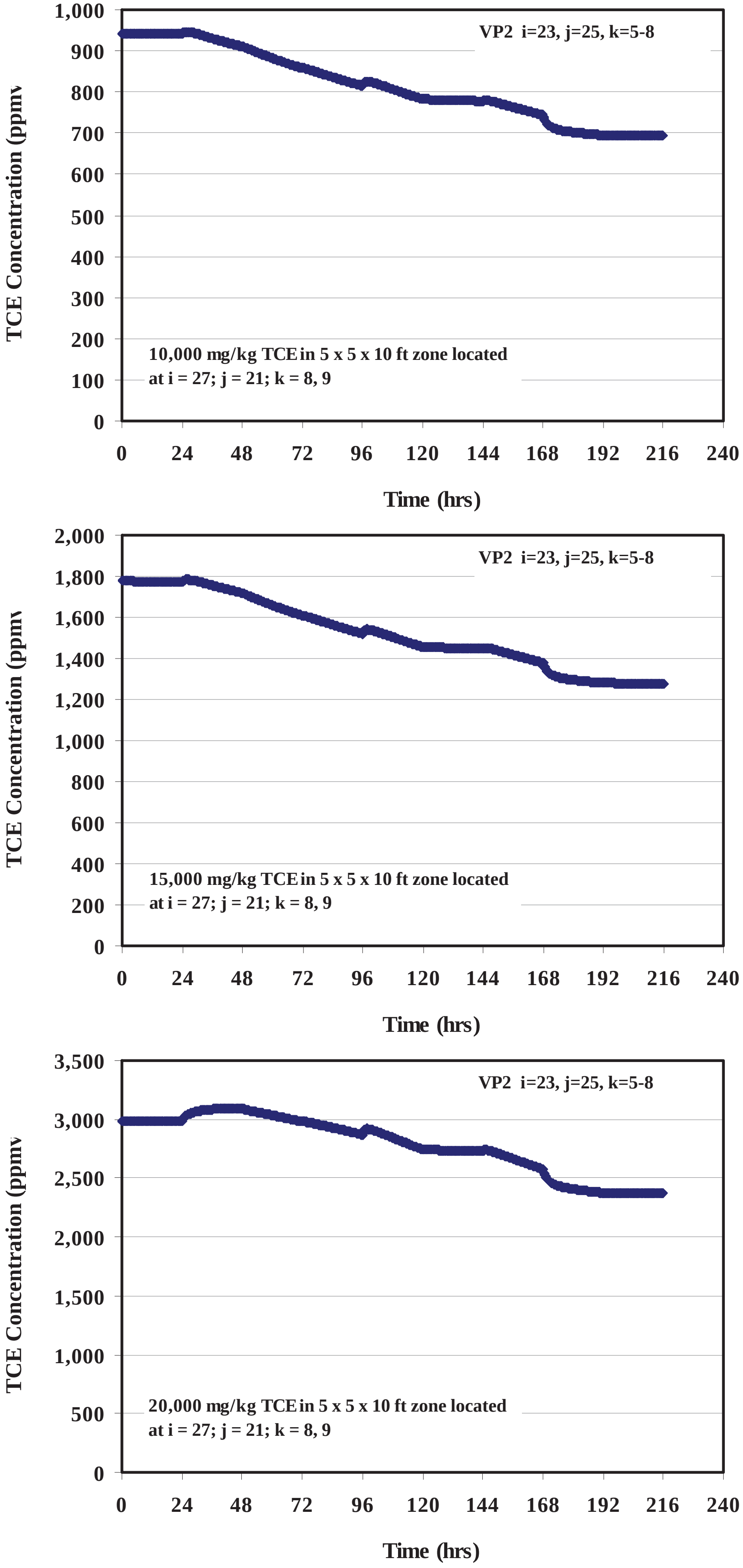
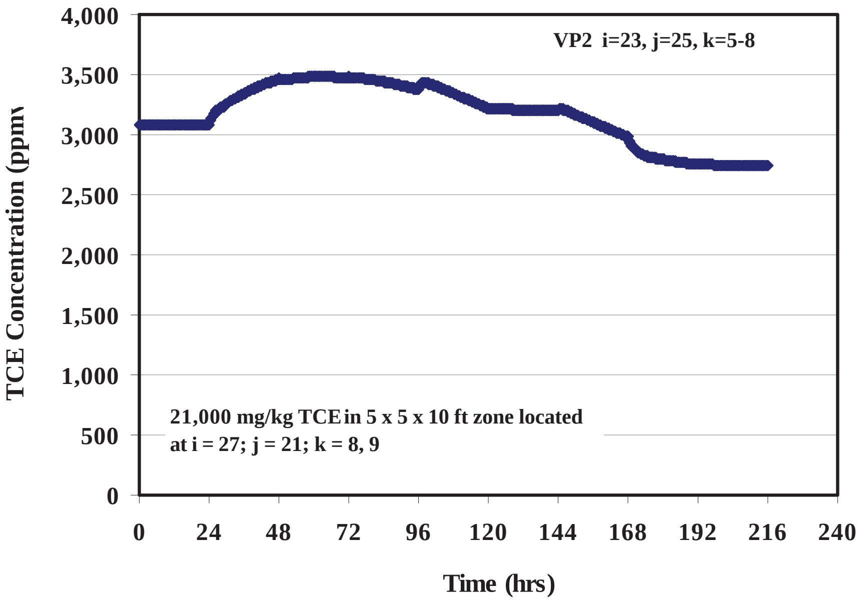
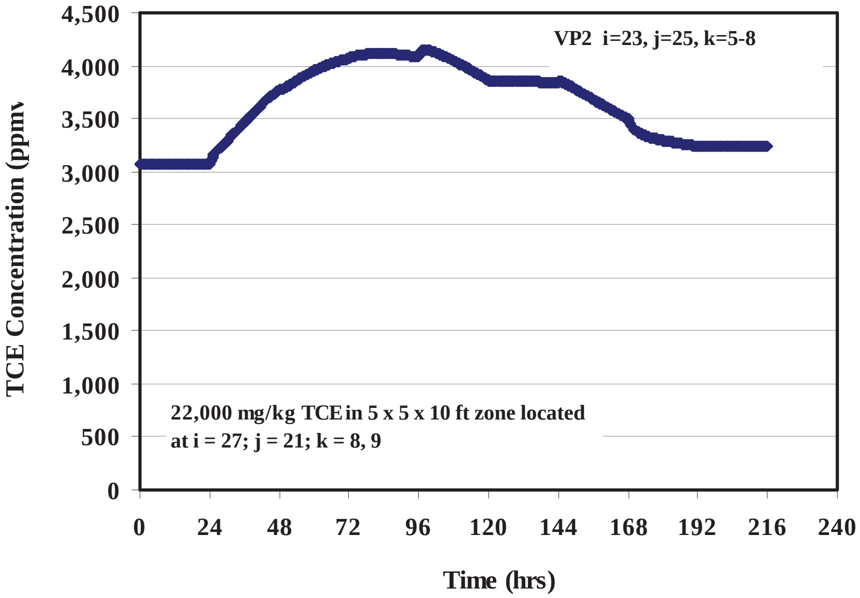
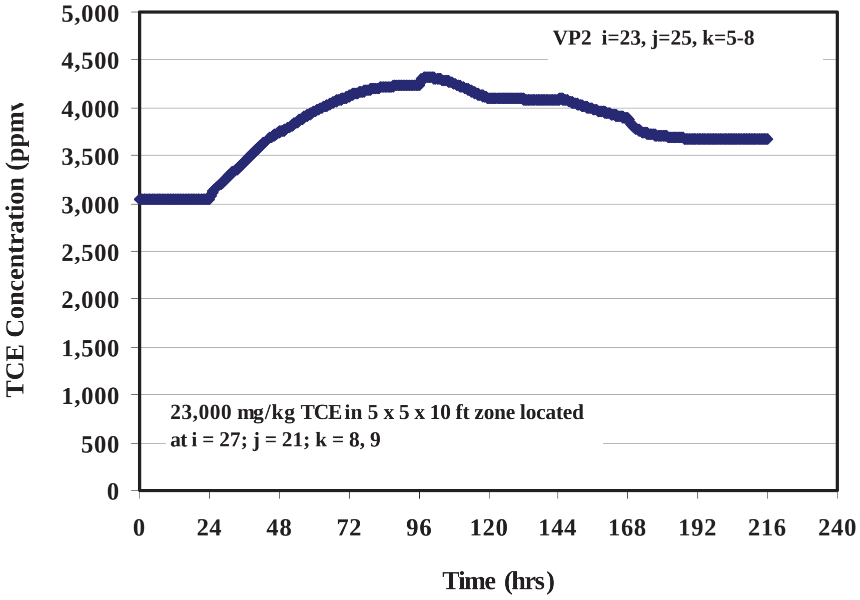
Source Area #8



U12-PV2
Source Area #8







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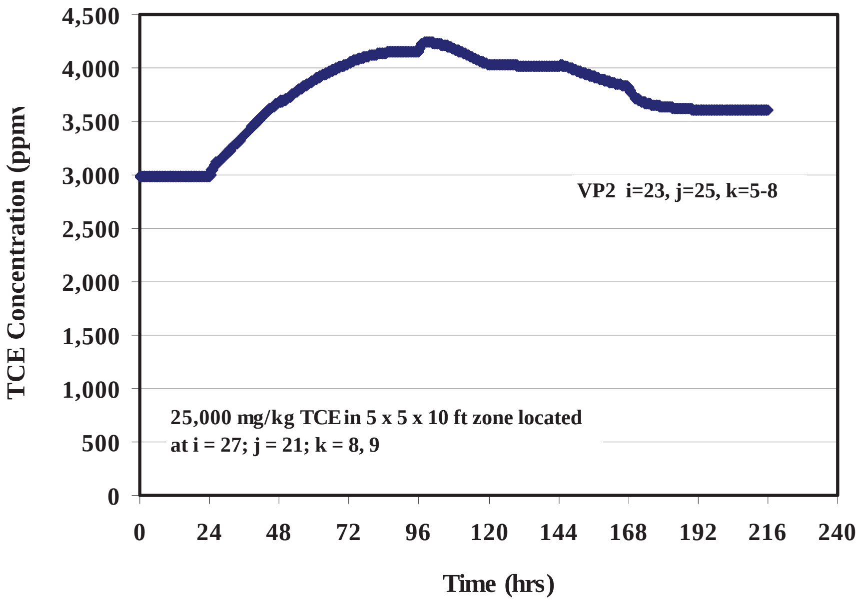

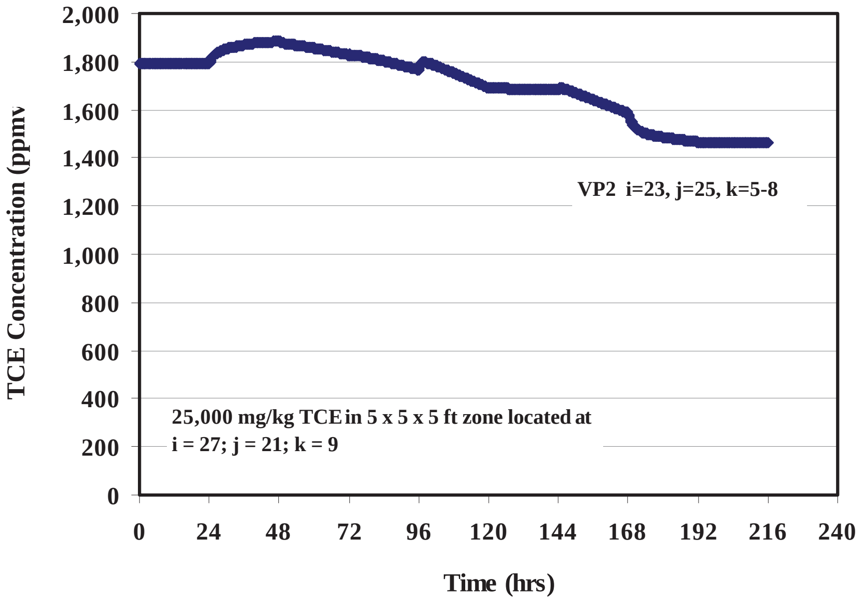

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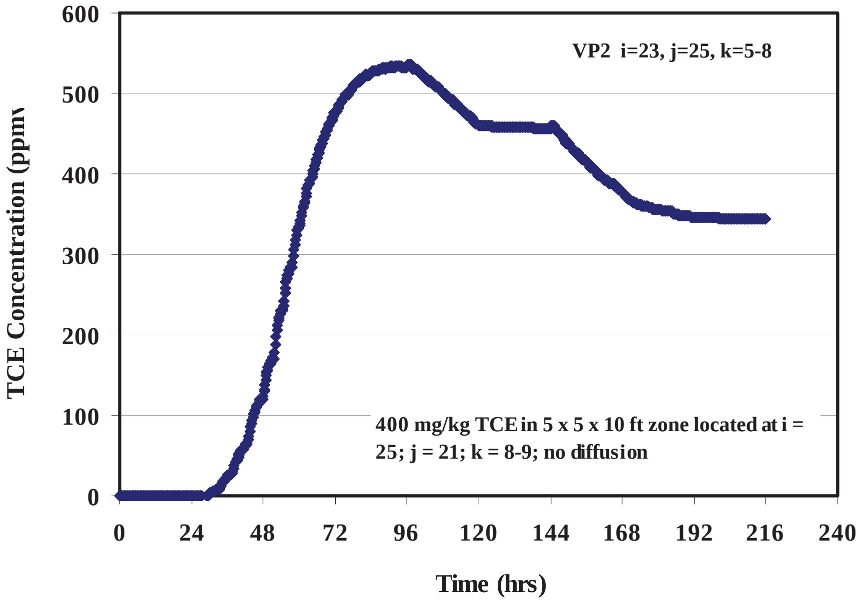
Source Area #9



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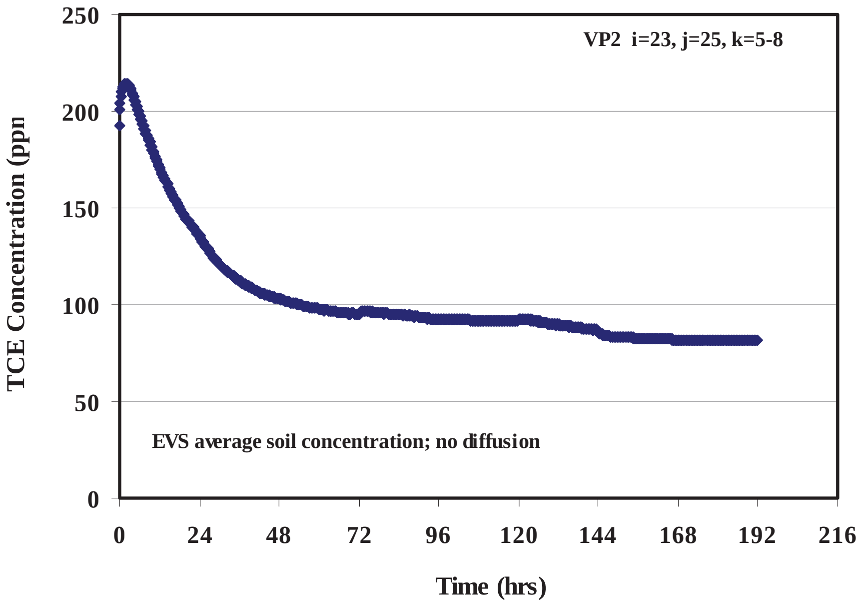
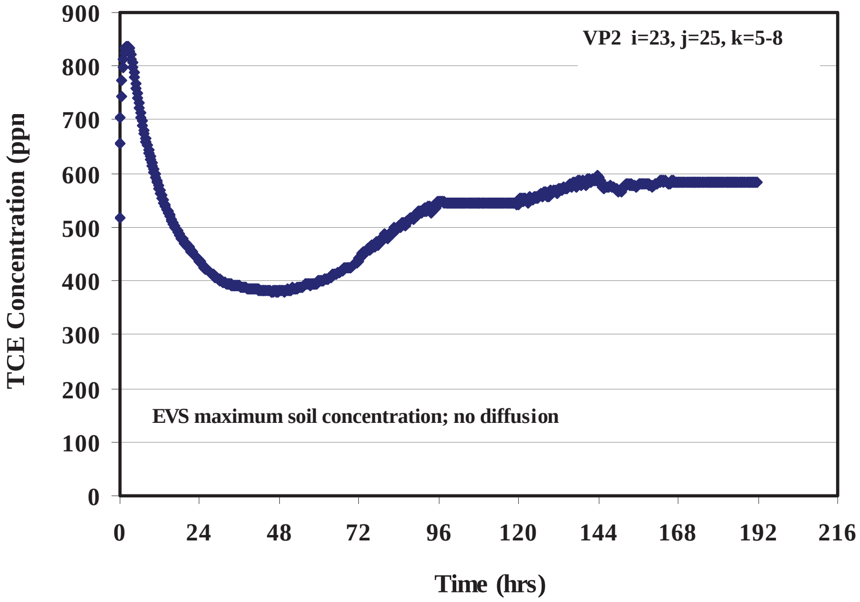
Source Area #10





U12-PV3
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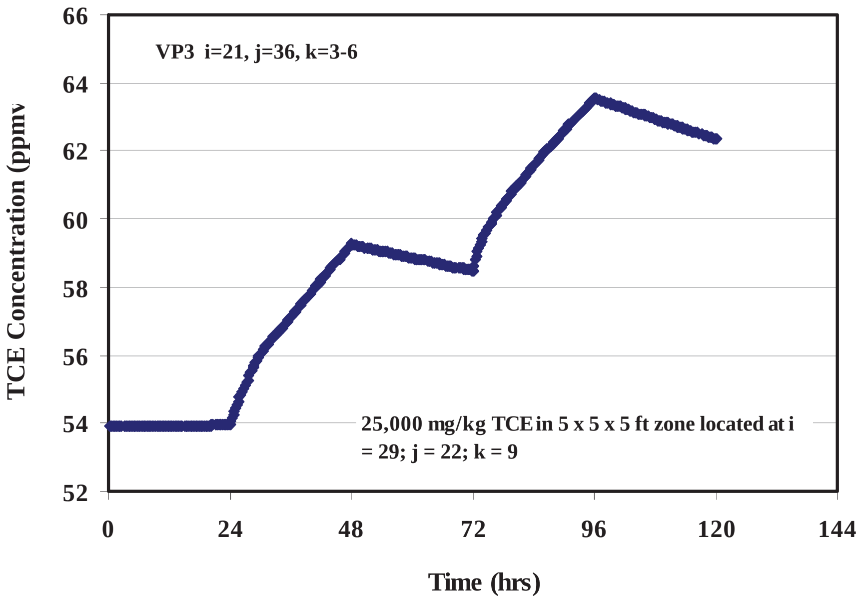
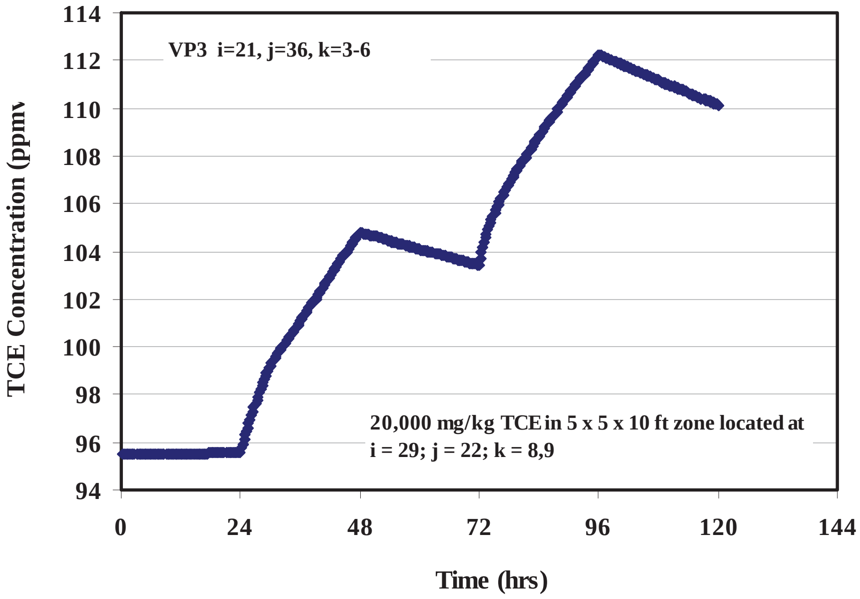
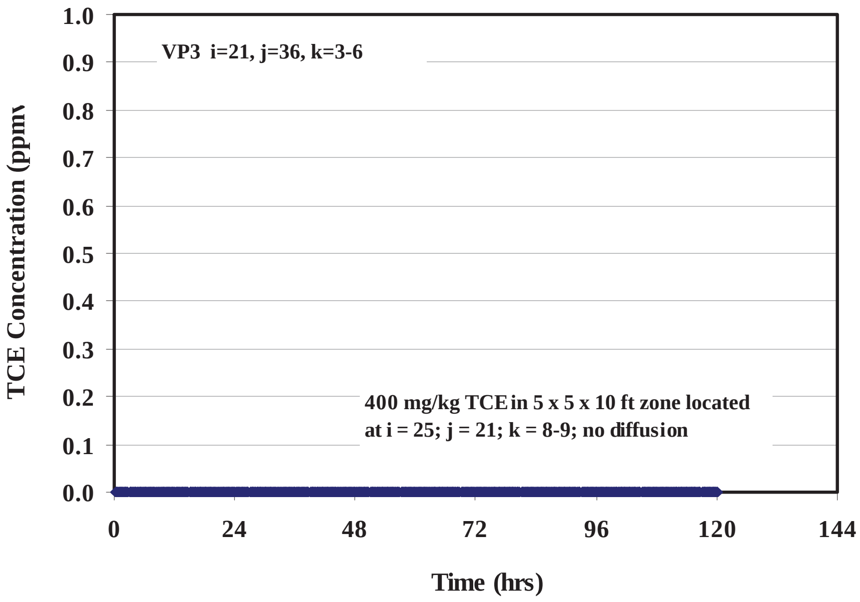
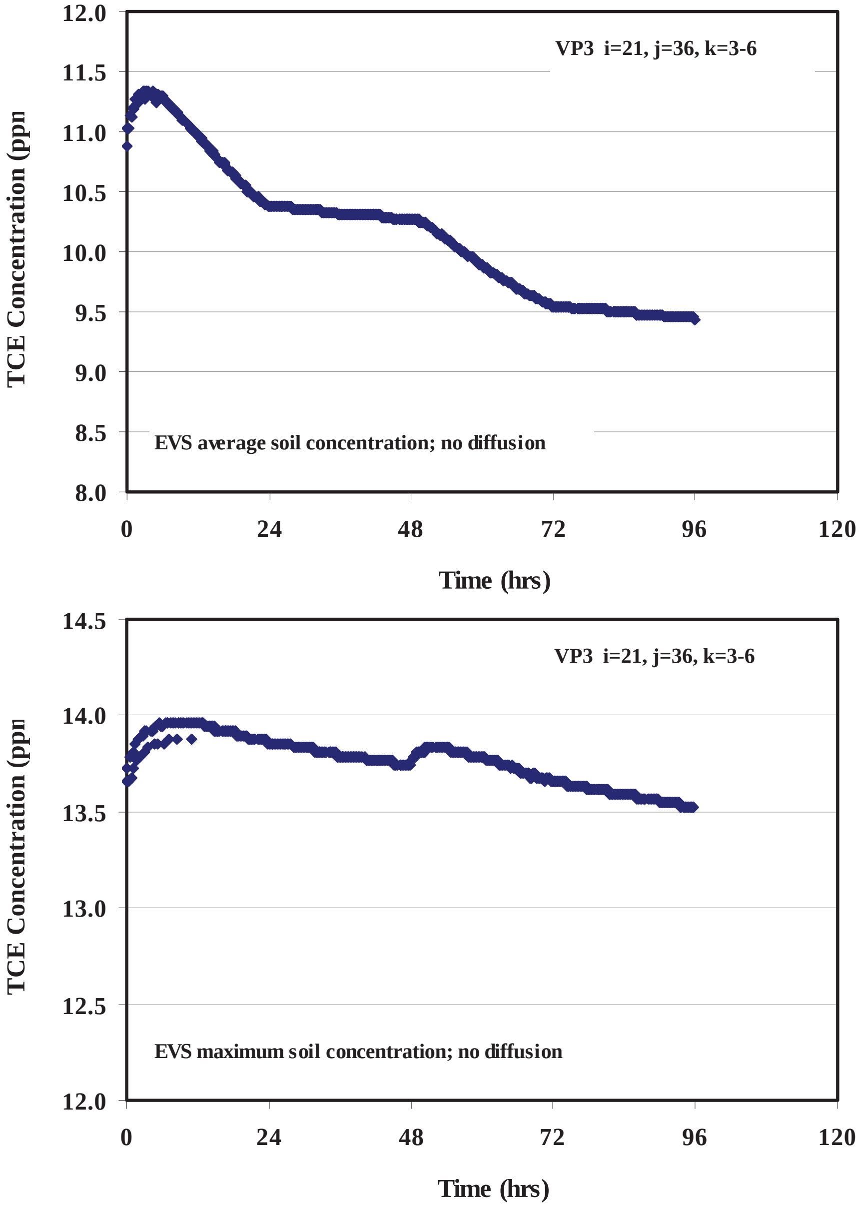




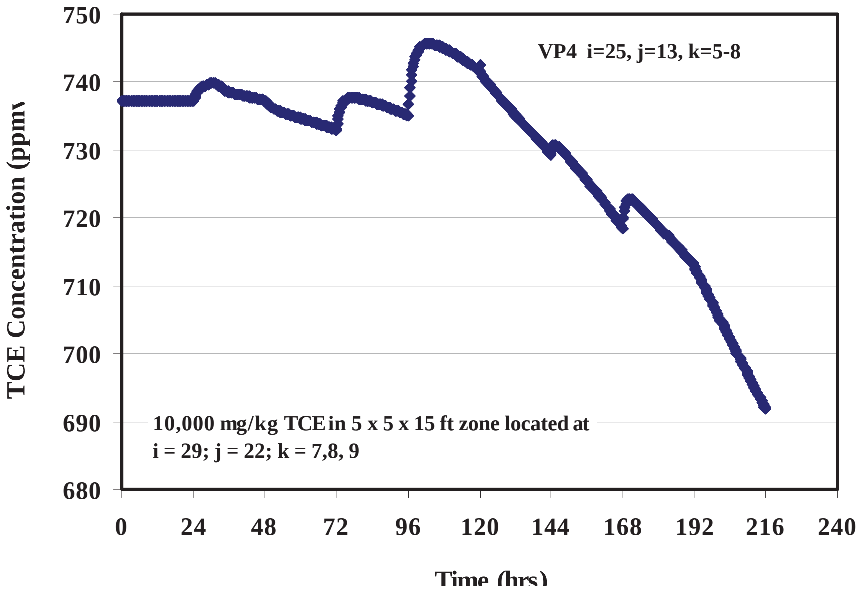
U12-PV3
Source Area #9

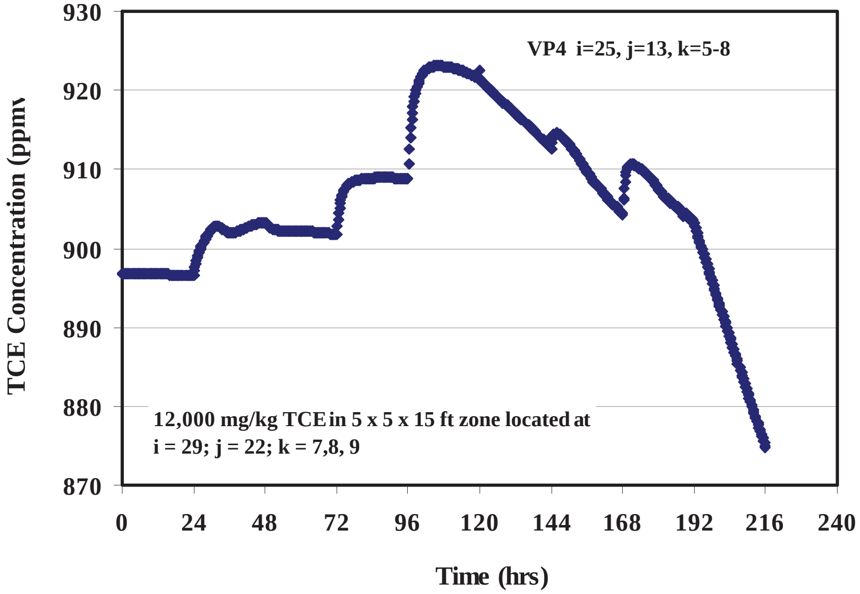


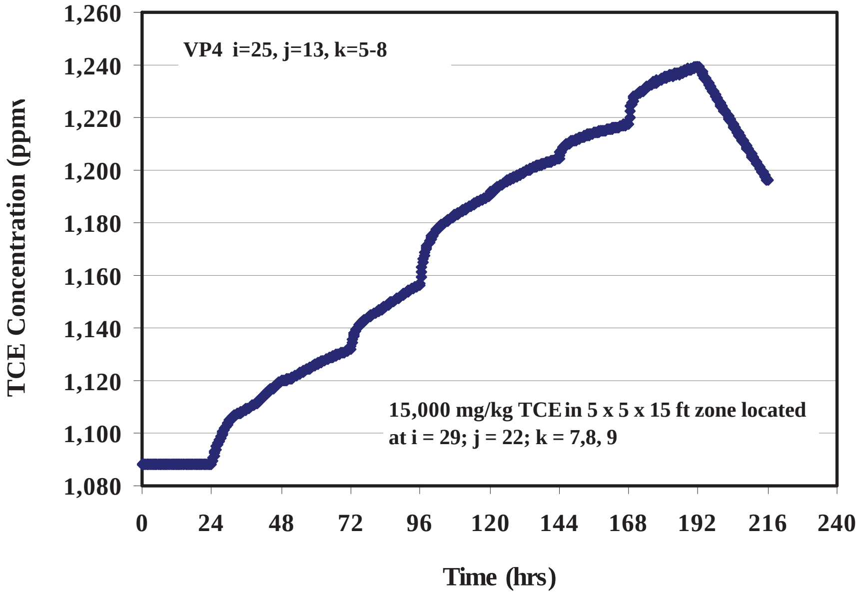
U12-PV3
Source Area #10



U12-PV4
Source Area #7







U12-PV4
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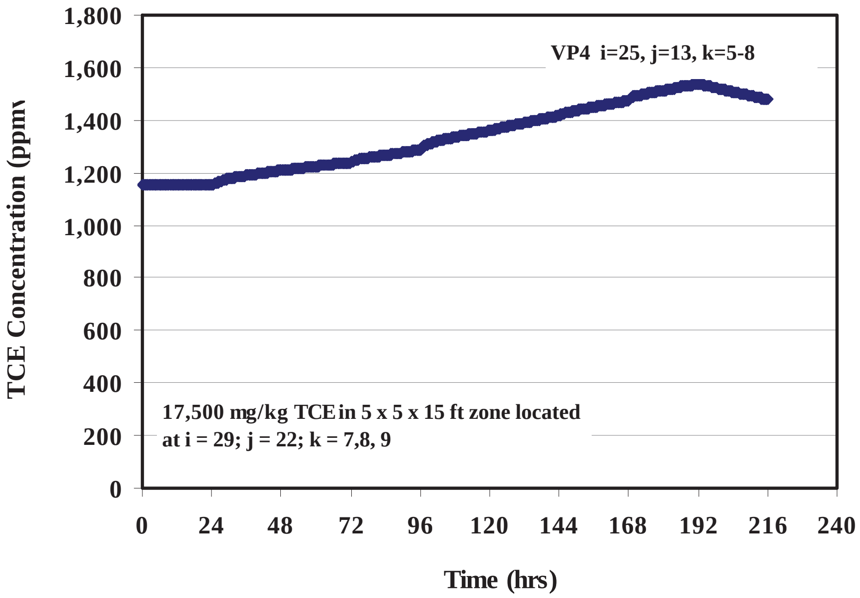
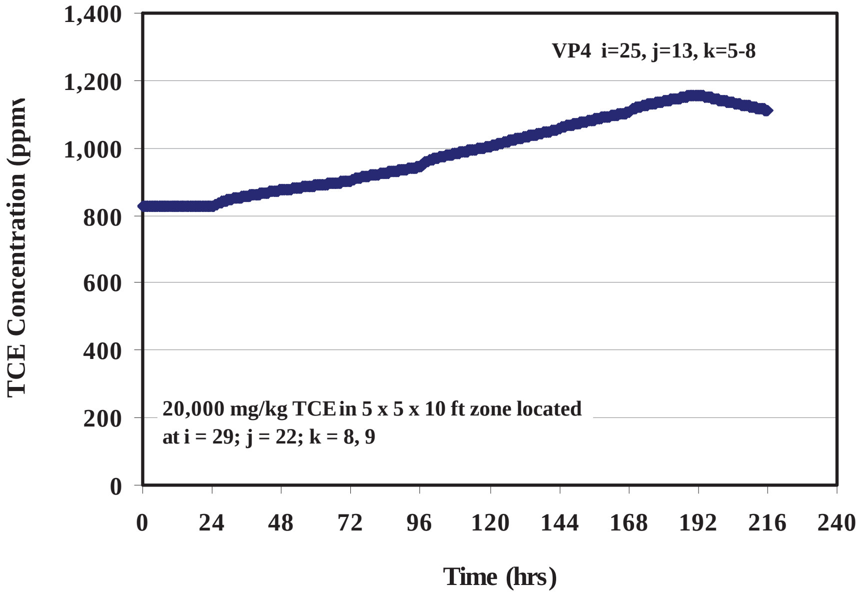
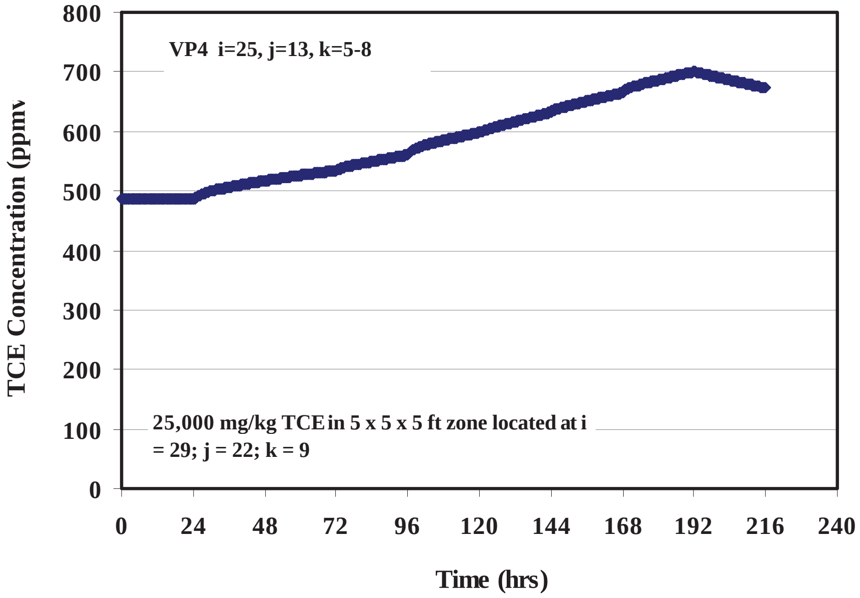
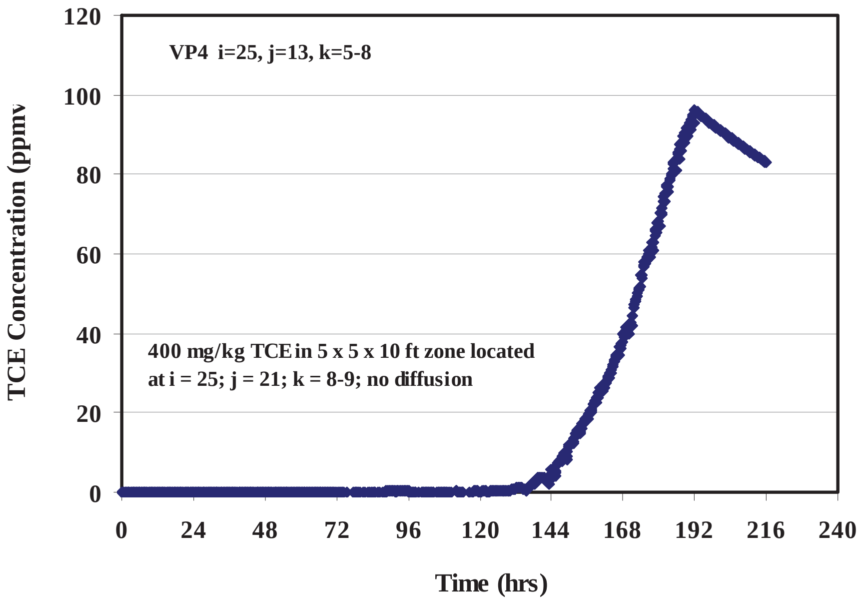


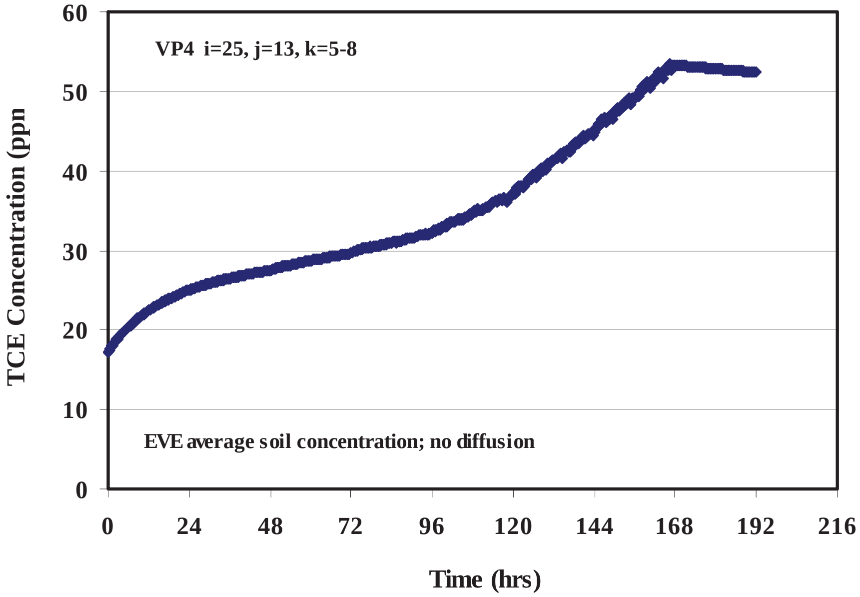


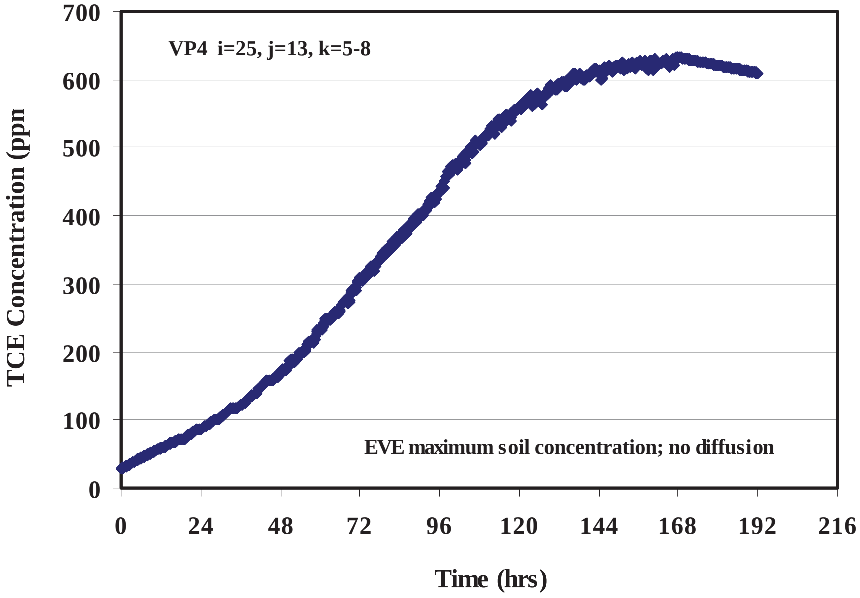


U12-PV4
Source Area #9

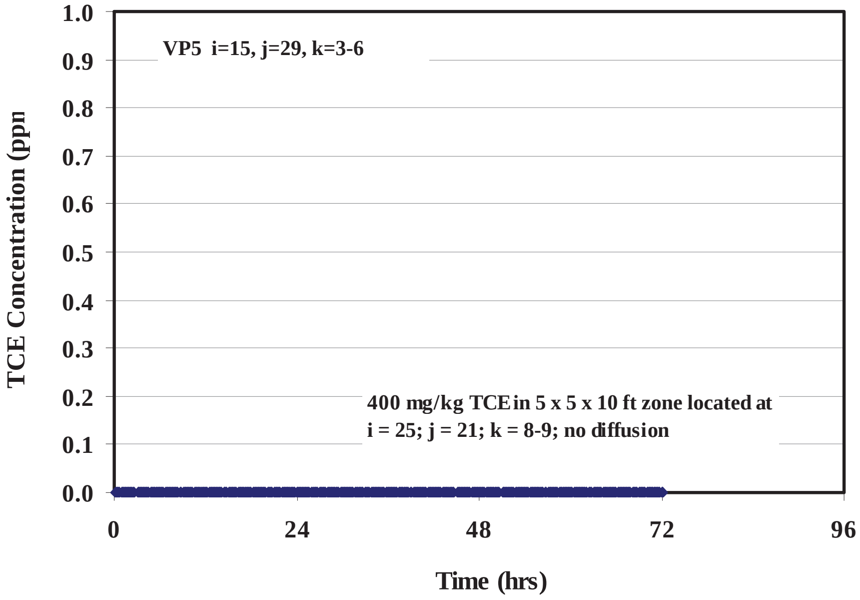


U12-PV4
Source Area #10

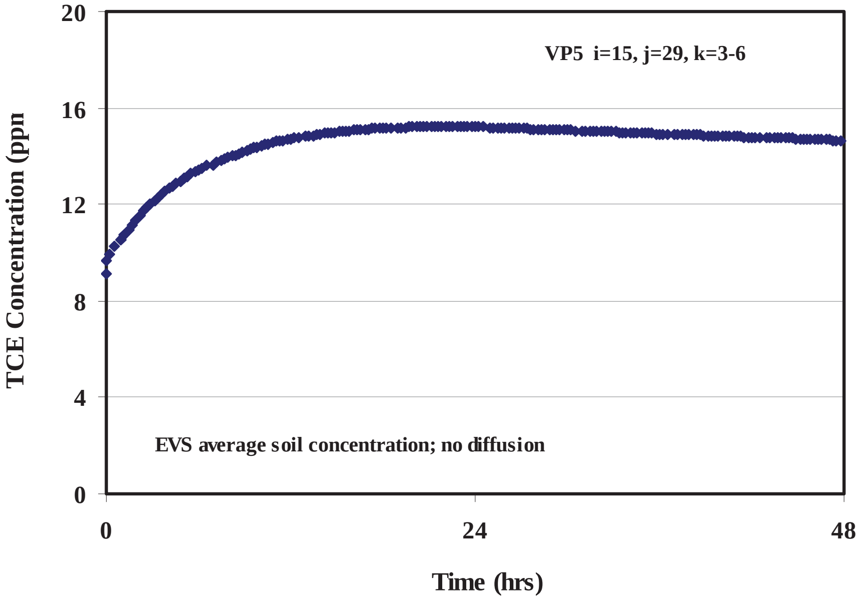


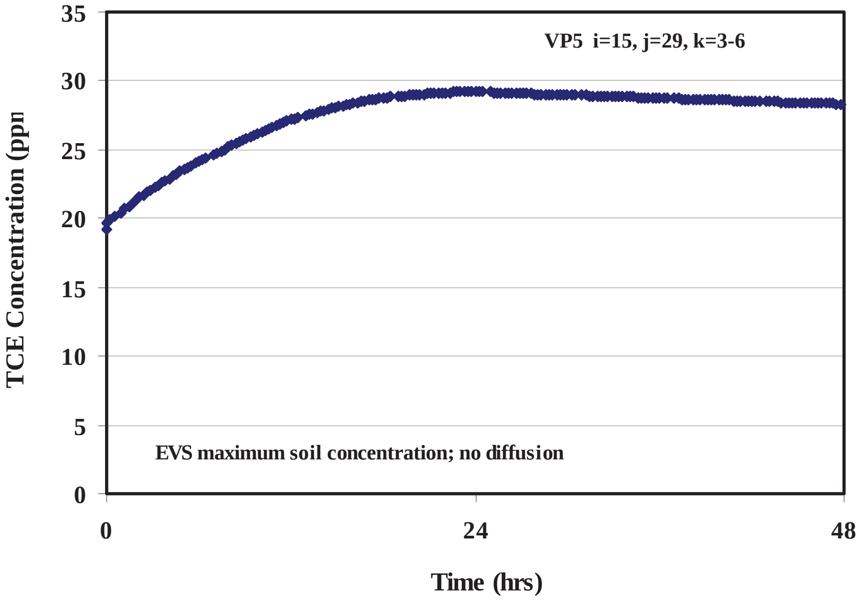


U12-PV5
Source Area #9

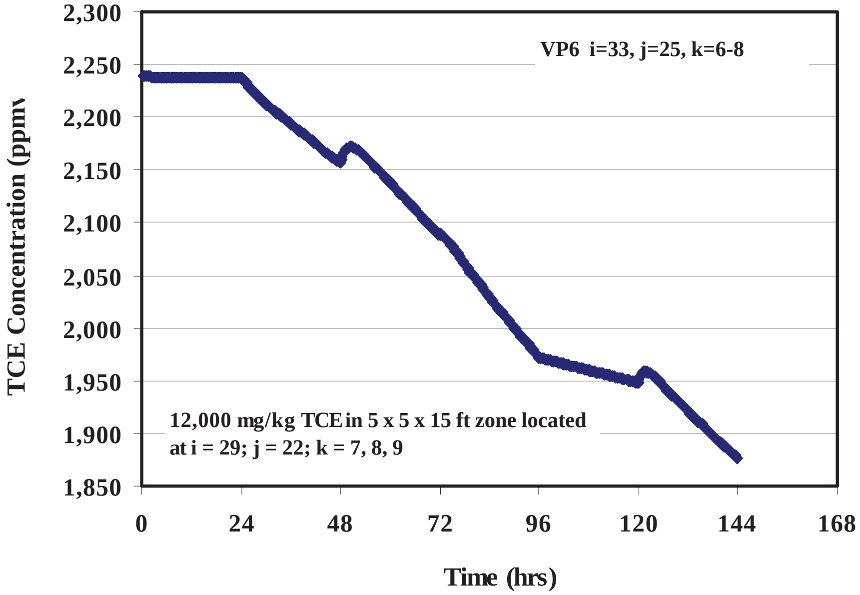


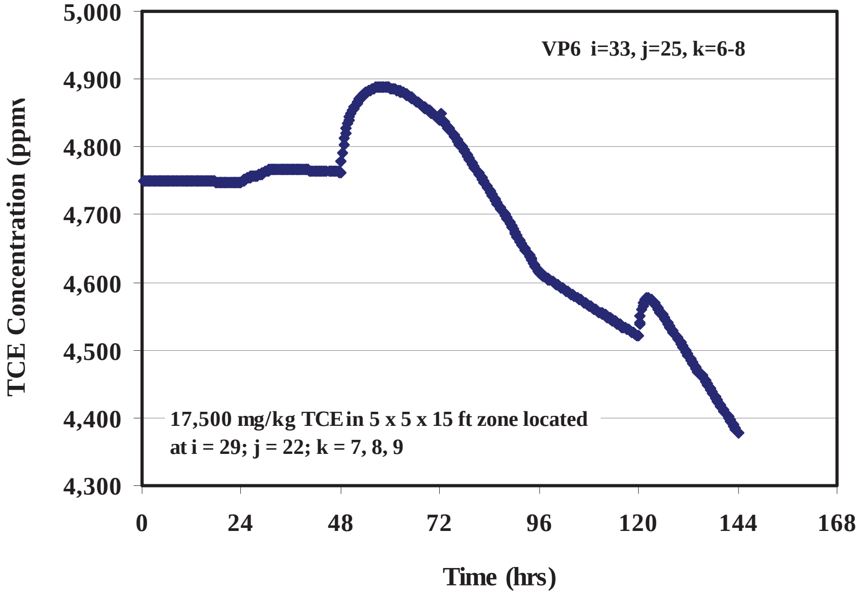
U12-PV5
Source Area #10

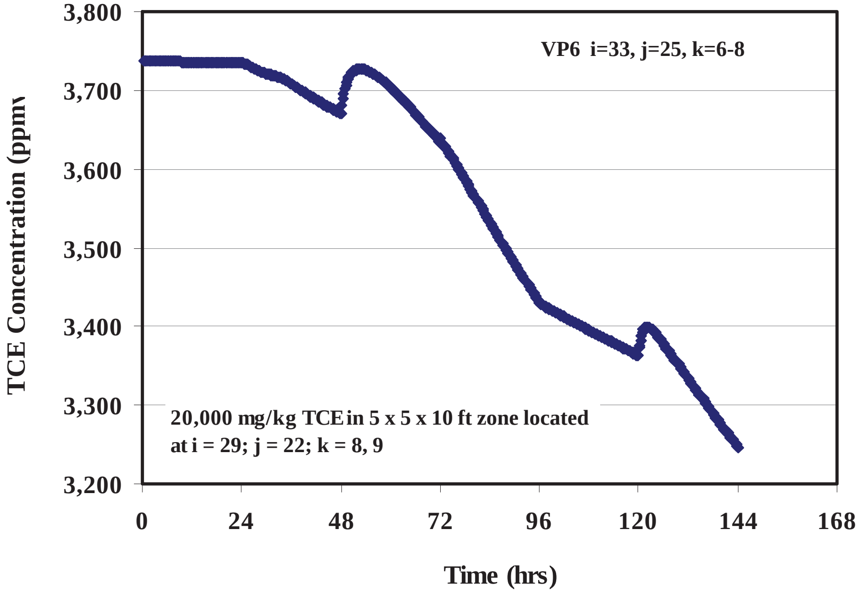




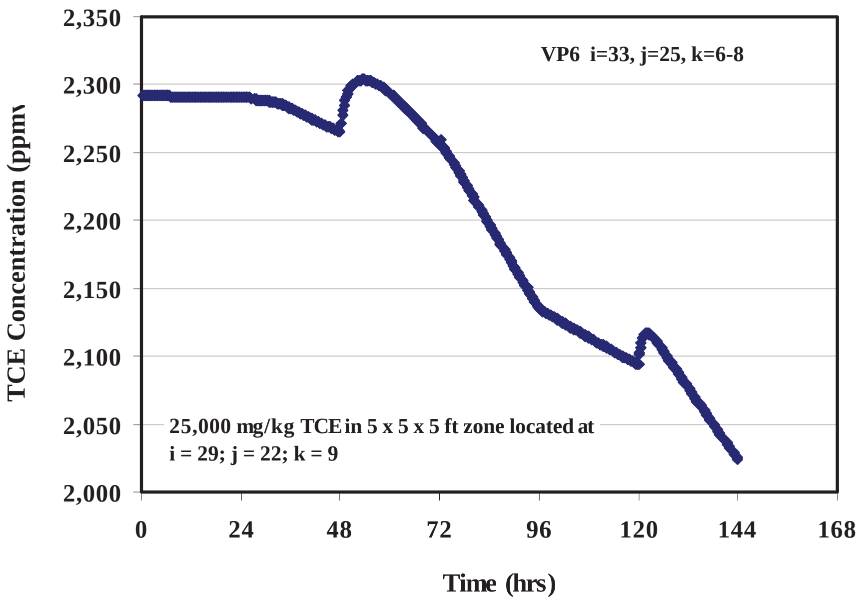
U12-PV6
Source Area #7



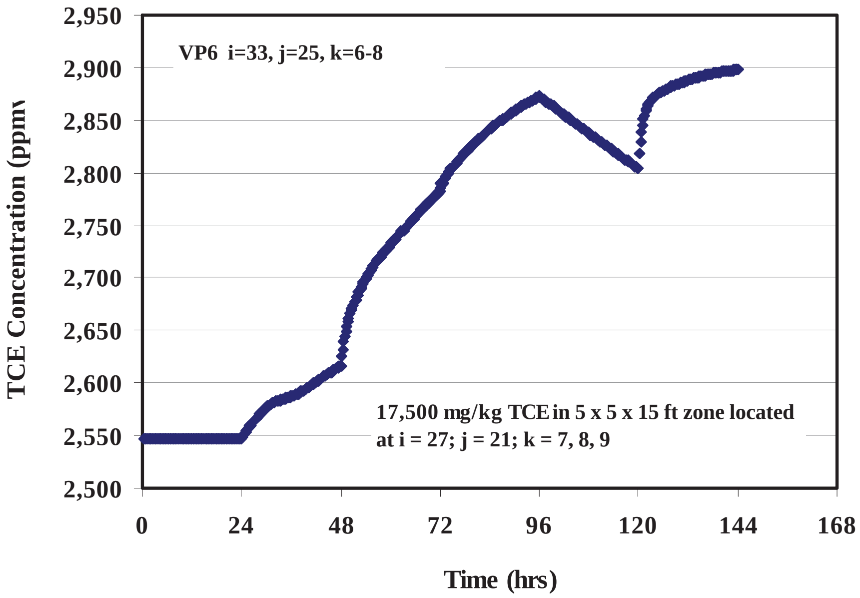


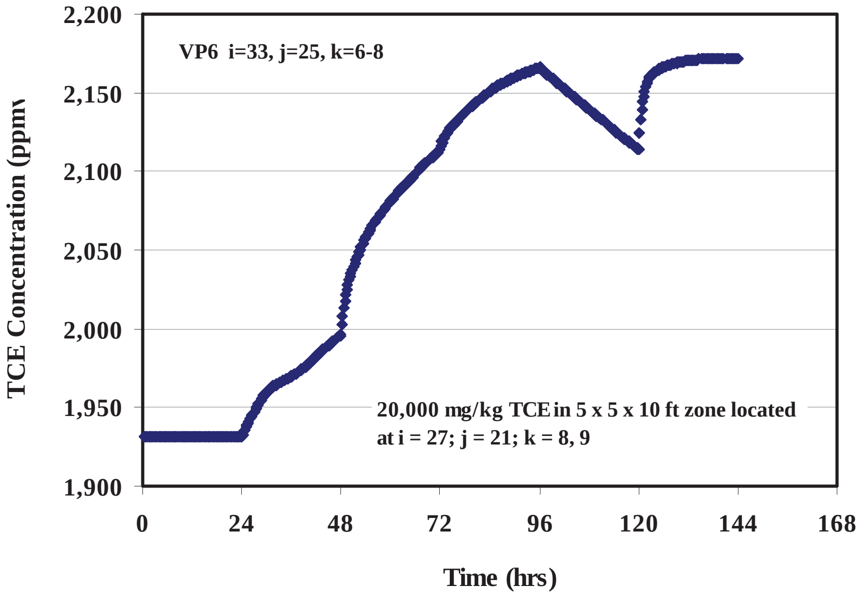


U12-PV6
Source Area #7

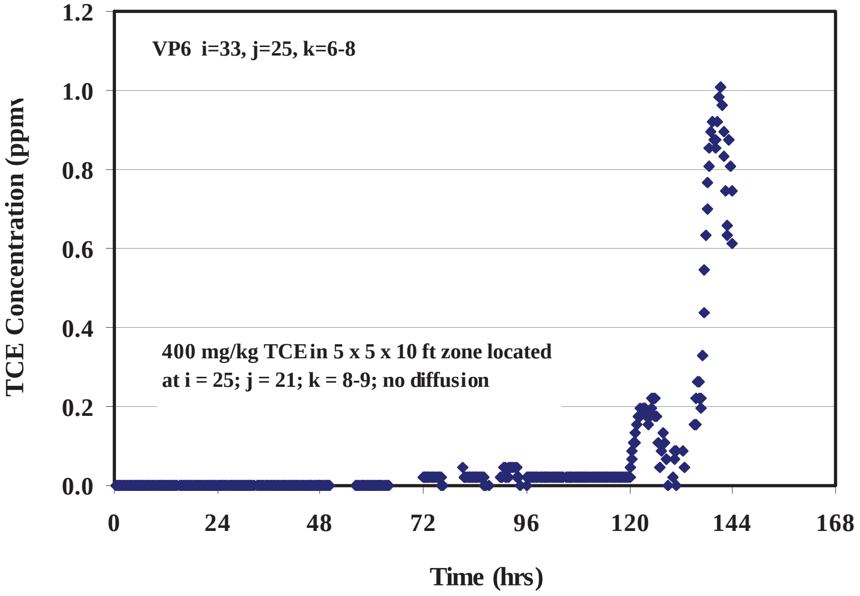


U12-PV6
Source Area #8

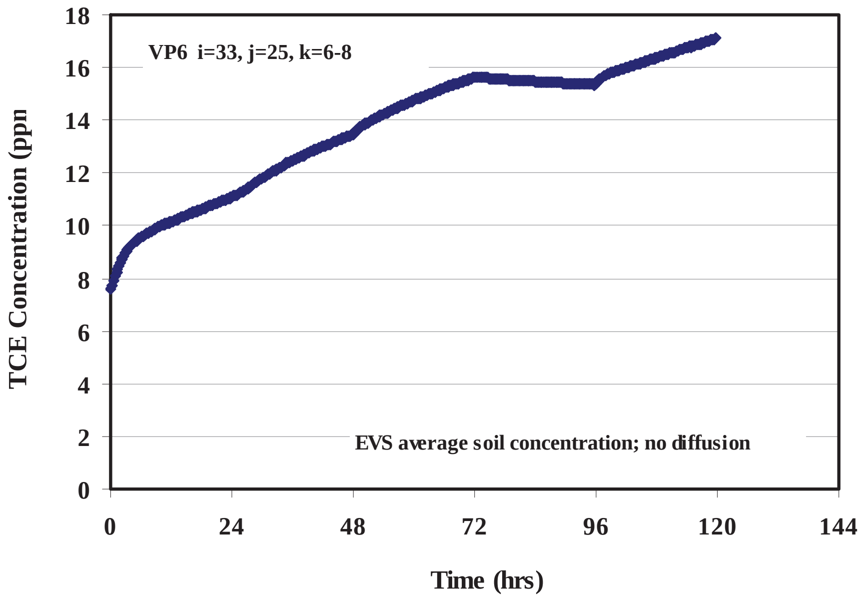


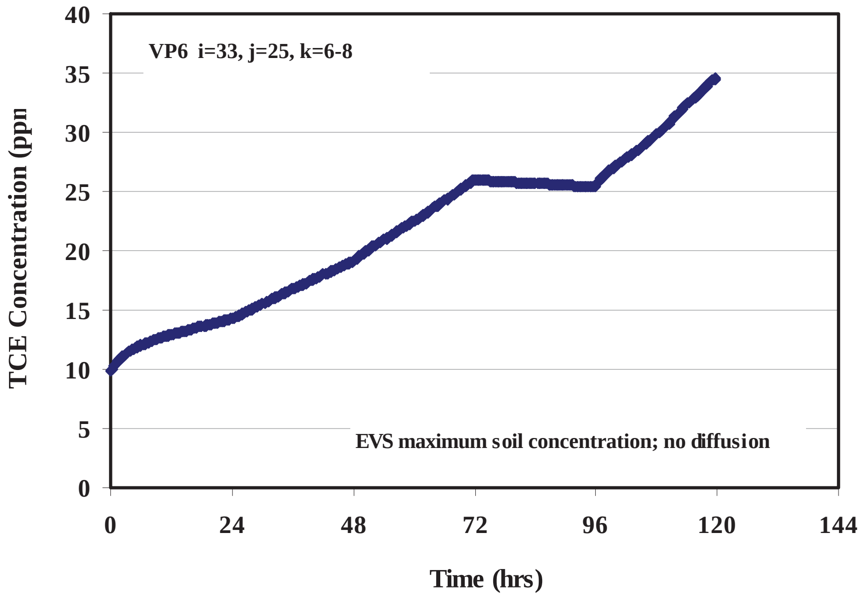


U12-PV6
Source Area #9

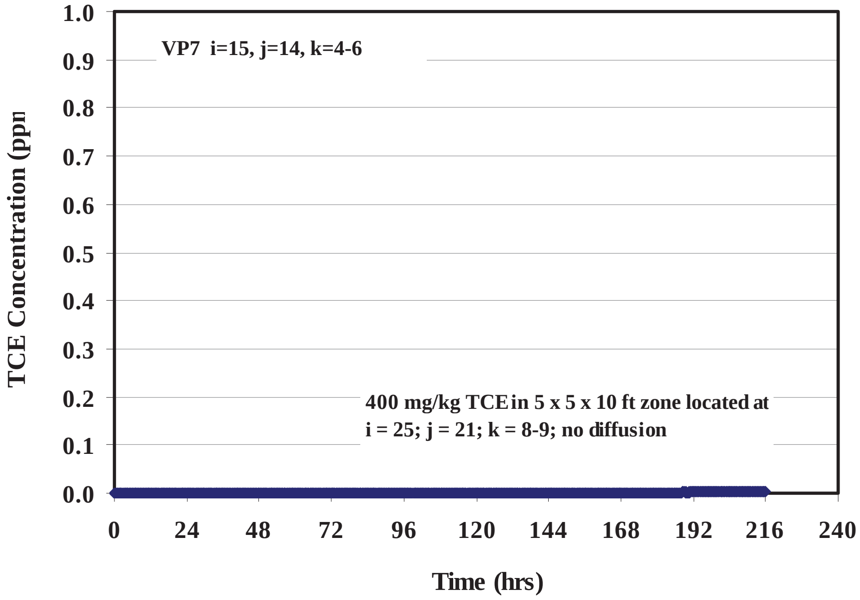


U12-PV6
Source Area #10





U12-PV7
Source Area #9



U12-PV7
Source Area #10