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2010 Pinewood Site Improvement Projects
Pinewood, South Carolina

Volume 3
Report of Project 3 Element 2: Review, Enhancement and Optimization of Environmental Monitoring Systems

Prepared for:

Pinewood Site
Custodial Trust

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EXECUTIVE SUMMARY

Kestrel Horizons, LLC, as Trustee for the Pinewood Site Custodial Trust, awarded to AECOM three site improvement projects. Volume 3 of this report presents the findings and recommendations for Project 3, Element 2: Review, Enhancement and Optimization of Environmental Monitoring Systems.

AECOM performed a critical review of the environmental monitoring program, data analysis, and a monitoring system evaluation. Recommendations for the enhancement and optimization of the existing environmental monitoring systems at the Pinewood site were then formulated. The goal of the review is to find the best balance between long-term cost and protection of the environment. The optimization of the monitoring program provides a framework in which to classify all environmental samples. In order to utilize the optimization strategy, the following items are necessary: (1) Program objectives and specific short-term objectives; (2) Monitoring hypotheses (based on the Conceptual Site Model); and (3) Decision rules. Decision rules are formulated as if/then statements that specify the conditions under which a specific action will be undertaken or a decision will be made.

The conceptual site model first prepared in 2002 was reviewed with respect to current site conditions and the current monitoring program. This review indicated that portions of the groundwater monitoring program are no longer appropriate for the Pinewood Site (e.g., due to substantial off-site pumping and construction of the sand blanket drains [SBDs] below the First Flush Basin, etc). As a result of on-Site construction activities and built infrastructure and off-Site groundwater withdrawal, both the surface and subsurface hydraulic regime has been altered and the conceptual site model has changed. Based on these changes, the current monitoring program is no longer appropriate. Therefore, the monitoring optimization recommendations provided herein are based on Site-specific conditions and multiple lines of evidence independent of requirements in the RCRA Part B Permit. This optimization includes the installation of new monitoring wells for the following:

1. Detection monitoring downgradient of landfill sections I, II and II; and
2. The 12-month hydraulic evaluation to further evaluate the new groundwater flow conditions in and around the paleo-channel and better understand the effects of off-site groundwater withdrawal.

Some existing wells were eliminated from the long-term monitoring optimization (LTMO) based on their spatial locations relative to the updated conceptual site model.

Data analysis techniques were used to develop the LTMO. Chemistry data were segregated into the following categories for independent analysis: 1) storm water, 2) surface water, 3) leachate, 4) SBDs, 5) French drains, and 6) groundwater.

Results of this data analysis were used to identify site-specific tracers or key “indicator chemicals” that are recommended for incorporation into the LTMO Program (e.g., chloride and 1,4-dioxane). The physical and chemical properties along with the occurrence and distribution of chloride and 1,4-dioxane in leachate make them excellent indicator parameters to monitor for potential future releases of liquid leachate to the environment. Indicator chemical monitoring will reduce the overall analytical cost of the monitoring program.

Data analysis also identified numerous deficiencies in laboratory data quality and identified specific chemicals or elements that are recommended for elimination from the LTMO due to laboratory uncertainty (e.g., mercury). The following recommendations are based on this data analysis:

1. An audit of the analytical laboratory should be performed to rectify data quality deficiencies;
2. Periodic split sampling and analysis by an independent laboratory should be performed.
3. A facility-wide Quality Assurance Project Plan should be prepared to govern all future environmental sampling.
4. A facility-wide Sampling and Analysis Plan should also be prepared that describes each current LTM program, program objectives and decision rules.

Monitoring technologies were evaluated with the goal of identifying technologies that can provide rapid data reporting and/or have the potential to improve the cost effectiveness of the monitoring program without sacrificing the quality of the data or level of assurance. The monitoring technologies included point-source monitoring (e.g., groundwater or surface water), and site-wide geophysical monitoring techniques that can supplement the point source monitoring program. The following are recommended for use at the Site;

1. The VOC Headspace Monitor is recommended for implementation at Pond A and/or Pond B outfalls to monitor the surface water discharge for potential VOC release events from the site.
2. A one-time groundwater quality characterization is recommended for each specific aquifer unit beneath the site for an expanded list of metals and specific anions. This data will provide a baseline characterization of aquifer geochemistry that can be used in the future to evaluate potential changes to the unique properties of each aquifer unit.
3. Down-well sondes are recommended in proposed new wells installed in the TLS along the northern perimeter of landfill Section II. This area is recommended because it is now hydraulically downgradient of landfill Section II and the close proximity of Section II to the northern property boundary.
4. Pilot-scale geophysical and electrical studies are recommended along the perimeter of landfill Section I using the techniques described in Section 5.0 to assess the feasibility of identifying potential future leachate releases outside the landfill perimeter and to supplement the LTMO.

Based on the results of the evaluations, AECOM developed an optimization strategy for management of all elements of the Pinewood Site environmental monitoring program. The system developed divides the monitoring into two broad categories: long-term programs and short-term programs. Long-term programs are defined as any monitoring required for a minimum of five years, at which time, review and optimization will again be undertaken. These long-term programs will provide a stable basis for all future monitoring. Short-term programs are those that are required for specific purposes but that will not last for five years.

The long-term programs can be further divided as follows: Long-term Monitoring, Detection Monitoring, and Operations Monitoring. Short-term programs can be divided as follows: Characterization Monitoring and Supplemental Monitoring.

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3-D	three-dimensional
µg/L	micrograms per liter
µmhos/cm	micro-mhos per centimeter
AECOM	AECOM Technical Services, Inc.
AGI	Advanced GeoSciences, Inc.
BTEX	benzene, toluene, ethyl-benzene and xylene
cis-1,2 DCE	cis-1,2 Dichloroethylene
cm/sec	centimeters per second
COCs	constituents of concerns
CSM	Conceptual Site Model
CVOCs	Chlorinated Volatile Organic Compounds
DC	direct current
DM	Detection Monitoring
DMP	Detection Monitoring Program
EJCDC	Engineers Joint Contract Documents Committee
EM	electromagnetic
ER	electrical resistivity
ESTCP	Environmental Security Technology Certification Program
FD	French drain
FFB	First Flush Basin
ft	feet
ft/day	feet per day
ft/ft	feet per foot
GEL	General Engineering Laboratory
g/mol	gram per mole
gpm	gallons per minute
HD	horizontal dipoles
IP	induced polarization
K’	vertical hydraulic conductivity
Koc	organic carbon partition coefficient
LTM	long-term monitoring
LTMO	long-term monitoring Optimization
m	meters
MCL	maximum contaminant level
mg/L	milligrams per liter
mhos/cm	mhos per centimeter
mS/m	millisiemens per meter
NPDES	National Pollutant Discharge Elimination System
nV	nanovolt
OCS	Opaline Claystone

O&M	operations and maintenance
OMP	Operations Monitoring Program
ORP	oxidation reduction potential
PSCT	Pinewood Site Custodial Trust
PLC	programmable logic control
PCE	tetrachloroethylene
POC	point of compliance
PSDL	Primary Sawdust Landing
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RPO	Remedial Process Optimization
SAP	Sampling and Analysis Plan
SBDs	sand blanket drains
SCADA	Supervisory Control and Data Acquisition
SSDL	Secondary Sawdust Landing
SVOC	semi-volatile organic compound
SWMU	Solid Waste Management Unit
TCE	trichloroethylene
TDS	total dissolved solids
TLS	Transitional Lang Syne
UBC	Upper Black Creek
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VD	vertical dipoles
VOC	volatile organic compound
WT	Water Table
WTMP	Water Table Monitoring Program

1.0 INTRODUCTION

The Pinewood Site Custodial Trust (PSCT) owns the former Safety-Kleen, Inc. hazardous waste storage, treatment, and landfill facility near Pinewood, South Carolina in Sumter County (Pinewood Site). Kestrel Horizons, LLC (Kestrel) is Trustee for the PSCT. Kestrel is responsible for overseeing consultants, contractors, and suppliers who provide services in study, design, construction, remediation, operation, maintenance, transportation, disposal, and monitoring for the Pinewood Site. The primary mission of the Trustee for the PSCT is to ensure the responsible use of Trust funds in carrying out the activities required to complete closure of the site and to care for and monitor the site over the next century, in accordance with the applicable laws, regulations, permits and agreements.

Kestrel identified three site improvement projects to aid in the understanding of the relationships of the Section I landfill and site infrastructure with the hydrogeology and how best to monitor environmental media for long term protection of the environment. These projects include the following:

- Project 1: Detailed Performance Evaluation of the Section I Cover System;
- Project 2: Section I Storm Water Management Evaluation;
- Project 3, Element 1: Three Dimensional Visualization Model of Site Design Features and Hydrogeologic Conceptual Site Model; and
- Project 3, Element 2: Review, Enhancement, and Optimization of Environmental Monitoring Systems.

This report summarizes Project 3, Element 2 and provides a critical review of the environmental monitoring program, data analysis, monitoring system evaluation and recommendations for the enhancement and optimization of the existing environmental monitoring systems at the Pinewood site. The goal of the review is to find the best balance between long-term cost and protection of the environment. The optimization of the monitoring program provides a framework in which to classify all environmental samples. Decision rules are used in developing logic for the monitoring programs. These rules are formulated as if/then statements that specify the conditions under which a specific action will be undertaken or a decision will be made.

1.1 PROJECT DESCRIPTION AND OBJECTIVES

This work supplements the previous site evaluation, Conceptual Site Model (CSM) update and development of the site-wide numerical groundwater flow and transport model prepared in 2002 (Earth Tech, 2002). The objectives of the 2002 evaluation were the following:

1. To evaluate the groundwater monitoring program for Section I landfill. This evaluation included the review of well construction records, lithologic logs, historical groundwater elevation data, and historical groundwater quality analytical data.
2. To develop a range of possible chemical release scenarios from Section I, and evaluate the potential nature and timing of those potential release scenarios to the hydrogeologic units beneath the landfill and how they would interact with the existing groundwater monitoring system.

Appendix A includes the *Groundwater Sampling and Analysis Plan (SAP) – Interim Status Monitoring* (October 2003), which is the original work plan developed for the site and describes the monitoring program based on the CSM at that time. This program has evolved since the work plan was issued due to construction activities, new infrastructure, and groundwater withdrawal using pumping wells installed outside the site property boundary. Currently, routine sampling and fixed laboratory analysis are conducted based on the current CSM as described below in Section 3.0. The primary objective of Project 3 Element 2 is to enhance and optimize the monitoring program using efficient and cost effective means without sacrificing the protection of human health and the environment, or compromising the existing monitoring system/program. To achieve this goal, AECOM Technical Services, Inc. (AECOM) performed the following:

1. Reviewed and evaluated the current environmental monitoring systems and how they relate to hydrologic features, infrastructure, events, and processes identified at the site through the CSM.
2. Evaluated landfill cell construction specifications.
3. Reviewed the CSM and groundwater flow model developed by Earth Tech in 2002.
4. Data analysis of the comprehensive database provided by Kestrel.
5. Identified sources of uncertainty, data gaps or data enhancement opportunities to refine the CSM.
6. Evaluated the occurrence and distribution of chemicals in the leachate generated in landfill Section I, II, and III to identify potential tracers or indicator chemicals for use in future monitoring programs.
7. Identified key monitoring parameters of the hydrologic systems.
8. Determined areas of unacceptable uncertainty in the monitoring and analytical testing program.
9. Suggested locations for new monitoring wells.
10. Suggested the use and optimum locations for new innovative monitoring devices that provide real-time data for Site Custodians to make management decisions.
11. Segregated monitoring programs for clarification, to assemble decision rules and to control future costs of the various programs.
12. Developed the optimum sampling frequencies and methodologies to lower costs, maximize efficiency, and reduce waste management requirements.

13. Identified opportunities for fiscal conservation through sampling and analyses optimization.

Results of the evaluation are provided herein.

1.2 LONG TERM MONITORING OPTIMIZATION

The United States Environmental Protection Agency (USEPA) (2004) defines monitoring as

> "… The collection and analysis of data (chemical, physical, and/or biological) over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics…directly related to the management objectives for the site in question."

Long-term monitoring optimization (LTMO) is conducted after some active, passive, or containment remedy has been selected and put in place, and is used to evaluate the degree to which the remedial measure achieves its objectives. Cap and containment with hydraulic control is the presumptive remedy in place at the Pinewood Landfill. Waste material is contained in engineered landfill cells within landfill Sections I, II, and III, landfill cells are capped, and landfill leachate levels are maintained below the base of the surficial Water Table Aquifer. Water levels in the surficial Water Table Aquifer are also controlled using French drain (FD) systems.

Optimization of long-term monitoring (LTM) programs need not be limited to the subsurface and can extend to the operation of the above-ground treatment processes or the management of materials generated during LTM programs and site operation and maintenance (O&M) (e.g., leachate and purge water management). Therefore, during this LTMO process, Remedial Process Optimization (RPO) criteria were evaluated and considered. RPO is an iterative, systematic planning tool to improve remedial system effectiveness and reduce cleanup time and cost. Although PRO is not criteria for LTMO, there are similarities in RPO and LTMO evaluations that apply to the Pinewood Site; therefore, the RPO criteria were considered during this evaluation relative to the management of fluids generated at the site. A typical RPO evaluation includes the following components:

1. Evaluate the accuracy of the CSM, and the appropriateness of cleanup goals.
2. Assess the potential of the remedial design and/or remedial action to meet cleanup goals.
3. Establish decision criteria, and create decision trees for cleanup goals, technology selection, and performance evaluation.
4. Optimize system operation, performance monitoring, and LTM.
5. Verify that field procedures and analytical protocols meet objectives.
6. Streamline and standardize data management.

It is assumed that after a site enters the LTM phase, site characterization is essentially complete, and the existing monitoring network can be adapted, as necessary, to achieve the objectives of the LTM program (Reed and others, 2000). Although the Pinewood Landfill Site has been studied extensively by numerous investigators over time, the CSM has recently changed due to off-site pumping by others, beyond the control of the Trust, and which has resulted in data gaps in the LTM program. These changes and how they affect the LTM program are documented herein.

The Pinewood Landfill Site LTM program is in its early stages and the LTM program to date has yielded: 1) incomplete information on the performance of the remedy; and 2) more information than is necessary to make decisions about the efficacy and operation of the remedy. LTMO offers an opportunity to improve the cost-effectiveness of the LTM effort by assuring that monitoring achieves its objectives with an appropriate level of effort. This LTMO has identified a change in the CSM and resulting inadequacies in the monitoring program, and provides recommended changes to protect against potential impacts to the public and the environment.

1.3 REPORT OUTLINE

The remainder of this document is organized as follows:

- **Section 2** presents Analysis of CSM information;
- **Section 3** provides a summary of monitoring programs;
- **Section 4** describes the screening and detailed analysis of the chemical data;
- **Section 5** provides an overview of the monitoring technology evaluation;
- **Section 6** discussed the specific monitoring program strategy and optimization;
- **Section 7** discusses optimized monitoring program recommendations; and
- **Section 8** lists the references utilized for this report.

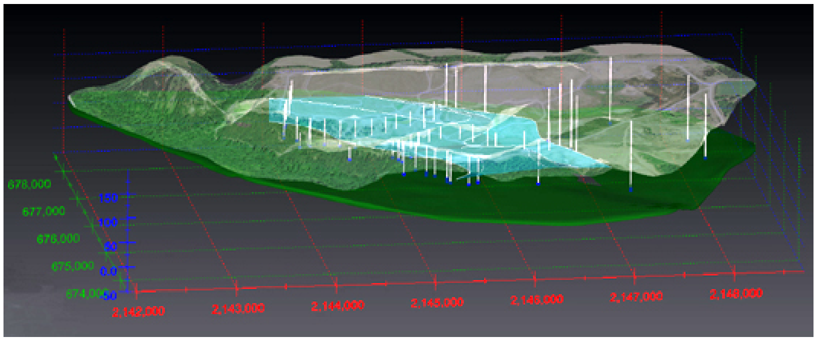
2.0 ANALYSIS OF CONCEPTUAL SITE MODEL

Containment structures such low-permeability bottom liners and caps and leachate-collection systems have been defined as related to stratigraphy, surface water and groundwater flow in the three-dimensional model of the site recently constructed by AECOM. The objective of these containment structures is to isolate wastes from the natural environment. The monitoring program must provide the data needed to judge how well this function is being performed. The CSM is a model of how the landfill structures and the natural environment relate and perform. The CSM provides a tool for predicting how potential releases might occur and the environmental media that could be impacted. The monitoring program must be designed to test these predictions. Where predictions are confirmed, confidence in the CSM is improved and where confirmation fails, data are provided to support informed revisions to the CSM.

The CSM was refined in 2002. Since then, a number of changes of on-site and off-site conditions have occurred. High-volume groundwater pumping (for water-supply purposes) now occurring to the northwest of the landfill property has impacted the groundwater flow directions within some of the aquifers. The aquifer recharge and discharge structures have also been altered. In order to best optimize the LTM program, AECOM made an evaluation of these recent changes and their impact to the CSM. The objective of this evaluation was to determine whether the LTM is still appropriate for the changed conditions. A description of the aquifer units, taken from the 2002 document, is provided below for reference. A summary of groundwater flow direction changes are also provided in this section.

The local hydrogeologic system is comprised of six aquifers separated by intervening confining beds. The descriptions of the hydrogeologic units proceed from the bottom upward. For consistency, the accepted nomenclature used in the site-specific reports will be used, rather than that used in related U.S. Geological Survey (USGS) reports.

A schematic cross-section illustrating the 2002 CSM is shown in top portion of Figure 2.0-1. A corresponding cross-section through the three-dimensional (3-D) visualization (Project 3 Element 1) is presented in the bottom of Figure 2.0-1. Vertical hydraulic gradients for January 2010 and July 2010 are summarized in Tables 2.0-1 and 2.0-2, respectively.



2.1 UPPER BLACK CREEK AQUIFER

The Upper Black Creek (UBC) Aquifer is thought to have been deposited in a deltaic environment. Previous investigations divided it into UBC-A and UBC-B. The UBC-B is thought to correspond to the Pee Dee Formation (USGS). The UBC-A has been interpreted as part of the confining zone between the Sawdust Landing and Pee Dee Aquifers. The UBC-B is a more massive sand than the UBC-A. This unit is 30 to 35 ft thick and consists primarily of well-sorted sands. The water levels in the UBC-B are much higher than are those of the UBC-A and therefore, under non-pumping conditions, the vertical flow potential is upward.

A confining unit separates the UBC-A and UBC-B units and it consists of silty clay and clay. This bed is continuous, of variable thickness, and reaches 10 ft thick. Hydraulic conductivity data are not readily available but are expected to be approximately 0.028 to 0.0028 ft/day.

The UBC-A probably consists of multiple discontinuous sands though some reports have identified two distinct sand units within the UBC-A. These sands are UBC-A1 and UBC-A2 and are not continuous across the site. However, regional literature views the UBC-A as one unit. The UBC-A is continuous across the site with thickness ranging from 5 to 20 feet (ft). The UBC-A has been partially eroded at the Transitional Lang Syne (TLS) channel (aka paleo-channel). Hydraulic conductivity (K) for this unit ranges from 0.1 to 5 feet per day (ft/day).

2.2 CONFINING BED BETWEEN UBC-A AND RHEMS

A confining bed (clay unit) separates the UBC-A and the overlying Primary Sawdust Landing (PSDL) Member of the Rhems Formation. This clay is absent beneath the eastern portion of the Facility. The clay is the upper sequence of the UBC (Cretaceous age), and is massive (K ranges between 0.00028 and 0.028 ft/day, estimated) and varies in thickness. Two laboratory tests resulted in conductivities of 1.16 x 10^{-7} and 8.22 x 10^{-8} centimeters per second (cm/sec; 0.00033 and 0.00023 ft/day).

2.3 RHEMS: SAWDUST LANDING MEMBER

The Sawdust Landing Member (Paleocene) of the Rhems Formation includes two depositional cycles resulting in two aquifer systems. These are an upper sequence of discontinuous interbedded sand to sandy clay (Secondary Sequence) and a lower sequence of coarser, more continuous sand (Primary Sequence). Both units contain multiple sands that are not continuous across the site.

2.3.1 Primary Sawdust Landing

The PSDL consists of medium to coarse sand. An approximately 600 ft wide area has been eroded by the TLS channel, under Section III of the eastern portion of Pinewood Landfill. The PSDL generally ranges from 4 to 25 ft thick. Groundwater flow is to the southwest, where it probably discharges into the Wateree River/Lake Marion. Vertical flow is downward into the UBC-A. The TLS channel acts as a sink and gradients flatten in this area. The horizontal gradient is 0.0049 feet/foot (ft/ft) and the mean K from slug tests is 0.0034 ft/day, and 1 to 10 ft/day from aquifer performance testing. Groundwater flow velocities range from 0.049 to 0.49 ft/day.

2.3.2 Confining Unit Between the Primary Sawdust Landing and the Secondary Sawdust Landing

This unit consists of silty clay to clayey silt. Vertical hydraulic conductivity (K′) ranges from 10^{-6} to 10^{-8} cm/sec (0.0028 to 0.000028 ft/day). These sediments are believed to have been derived from lower delta plain near shore marine shelf deposits.

2.3.3 Secondary Sawdust Landing

The Secondary Sawdust Landing (SSDL) is a heterogeneous unit with silts, clays and sands, resulting from tidal and fluvial influences from prograding deltaic sediments and tidal features. An area about 1200 ft wide has been eroded by the TLS channel (under Section III). Elsewhere, the SSDL ranges from 2 to 20 ft thick, thickening northwestward, and dipping east-northeast. It may outcrop beneath Lake Marion. Reported hydraulic conductivities are 0.057 ft/day from slug tests and 0.01 to 1 ft/day from aquifer performance tests. Higher conductivity values were in the southeastern part of the site and lower values in central and western parts. Groundwater flow velocities range from 0.0012 to 0.024 ft/day. Local gradients are primarily downward. Water levels are lower in the TLS channel than in other areas of the site.

2.4 CONFINING UNIT BETWEEN THE RHEMS AND THE TRANSITIONAL LANG SYNE

This confining unit consists primarily of silty clay. The unit ranges from 2 ft thick beneath the western portion of the site to 19 ft thick near the center of the site. This unit is missing at the TLS channel. The hydraulic gradients are generally downward. In the area south of Section II, this unit is a thick clay. The K′ ranges from 1.2×10^{-4} to 0.26 ft/day.

2.5 TRANSITIONAL LANG SYNE

The TLS underlies most of the facility. It is absent in a few small areas. The TLS dips to the southeast and may outcrop along the boundary of Lake Marion. The TLS is generally thin (2 to 10 ft) except in the TLS channel deposit (10 to 20 ft thick) that underlies a portion of the landfill facility. This sand channel has eroded the SSDL, PSDL, and part of the UBC-A. It consists of reworked TLS and Sawdust Landing sands that are coarser than the parent materials with little or no fines. This channel acts as a sink, with lower water levels than elsewhere on the site.

The TLS is not a productive aquifer and the geometric mean of the K data from all of the slug test data is 0.0037 ft/day. However, it is likely that the channel deposits are much more permeable than the aquifer as a whole. The calibrated hydraulic conductivities from previous modeling projects ranged from 0.037 to 0.1 ft/day.

2.6 OPALINE CLAYSTONE

The Opaline Claystone (OCS) acts as a confining bed overlying the TLS. The OCS is generally continuous across the site. The unit reaches a maximum thickness of as much as 120 ft east of the site, and is missing in some stream and pond areas to the west and the upper OCS has been removed in the valley between Sections I and II [during construction of the First Flush Basin (FFB)]. The OCS consists primarily of a massive Opaline Claystone. The groundwater flow in this unit is primarily through joints and fractures due to secondary permeability. A Basal Clay unit consisting of black, semi-consolidated, massive clay is often present at the base of the OCS (Basal Clay). Near Section III and in the southern part of Section I, a red sand facies is present. Here, the OCS is cross-bedded with thin discontinuous sand units. The gradients across the OCS are downward. The claystone has a typical hydraulic conductivity 0.011 ft/day, but may be as low as 1.4 x 10^{-5} ft/day.

2.7 QUATERNARY

Sediments comprising the Surficial Aquifer lie unconformably over the OCS. The unit consists primarily of fluvial gravels, clean sands and mottled clays. The unit ranges from zero to approximately 40 ft thick. Much of this unit was removed from the site during mining of the OCS and for excavation of the landfill sections. This aquifer occurs under water table (WT) conditions with hydraulic conductivities ranging from 0.025 to 30 ft/day. The average K is 2.6 ft/day.

2.8 OVERVIEW OF AQUIFER AND CONFINING BED CHARACTERISTICS

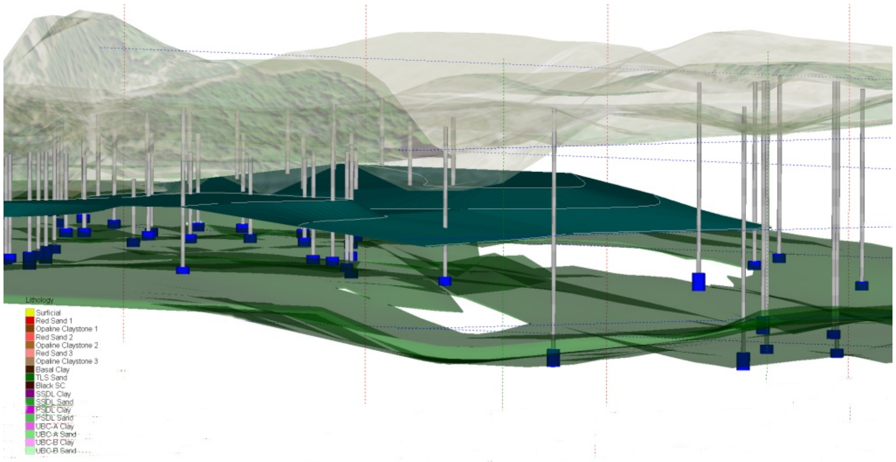
The major hydrogeologic units beneath the site and their characteristics are summarized on the following table:

Hydrogeologic Unit	Occurrence	Thickness (ft)	Hydraulic Conductivity (ft/day)	General Flow Direction
Surficial	Water Table	0 to 40 ft to the east thin to missing on site.	2.6 (average)	Toward local surface water bodies.

Hydrogeologic Unit	Occurrence	Thickness (ft)	Hydraulic Conductivity (ft/day)	General Flow Direction
Opaline Claystone	Confined/Unconfined	Up to 120 ft east of the site, missing (by erosion) near stream channels and ponds to the west.	0.011 to 1.4 x 10^{-3} (possibly as low as 1.4 x 10^{-5} ft/day)	Downward
Transitional Lang Syne	Confined	2 to 20 ft on site,10-20 ft thick in paleo channel, dipping to the southeast. Missing east of the site.	0.0037 to 0.1	West toward Lake Marion or toward channel deposit.
Secondary Sawdust Landing	Confined	0 to 20 ft thick on site, dipping to the east, missing in channel deposit.	0.01 to 1.0	West toward Lake Marion or toward channel deposit.
Primary Sawdust Landing	Confined	0 to 25 ft thick on site, dipping to the northeast, missing in channel deposit.	1 to 10 (aquifer tests) Lower values obtained from slug tests	Southwest toward Lake Marion or toward channel deposit.
Upper Black Creek – A	Confined	5 to 20	0.1 to 5	Northwest
Upper Black Creek – B	Confined	30 to 35	145	North to northwest.

The OCS is a porous but low-permeability unit that can absorb contaminants that might migrate into it and greatly enhance the ability of the landfill structures to isolate wastes. All landfill sections are constructed within the OCS for this reason. Potential contaminants migrating from the landfill would have to penetrate this formation before the TLS aquifer is reached. However, there are sand lenses within the Opaline Claystone, which can transmit small quantities of groundwater. These lenses will be discussed further below.

The previous CSM describes recharge and discharge characteristics and structure. The primary discharge point is to Lake Marion, for most of the aquifers. The UBC does not directly discharge to the lake in the vicinity of the site. Other drainages also serve as discharge areas, particularly for the shallow aquifers. Unnamed streams are located on site, to the north and south of the site. In addition, ponds are located to the north of the site. These features are discharge areas for the shallow aquifer. A series of FDs have been installed to the base of the Water Table Aquifer around the landfill sections. These drains also act as discharge area for this aquifer



To contrast with later discussions of current conditions, the following groundwater flow discussion is based on the CSM as of 2002. Groundwater flow within the Water Table Aquifer and the thin sand lenses that cut through the OCS was generally toward Lake Marion. However, within the OCS itself, it is unlikely that groundwater is interconnected from location to location because of the low discontinuity of the sand lenses and the low permeability of the unit. Within the TLS and SSDL, groundwater over much of the site flowed toward Lake Marion. However, divides running approximately north and south existed within these two aquifers under Section I and Section II. Therefore, to the east of the divide, groundwater flow was to the east. Flow within the PSDL and UBC-A was entirely toward the lake and no divides existed. To the east of Section III, buried, sand-channel deposits are present (part of the TLS). This channel deposit extends into the UBC-A. Within the TLS channel, water levels were slightly lower than in the divide area present in the TLS and SSDL and thus caused the easterly flow within these aquifers. Water from the TLS, SSDL, PSDL and UBC-A mingle within the channel deposits, reverse direction, and flowed back toward Lake Marion within the PSDL and UBC-A.

The distribution of recharge and configuration of on-site discharge structures have changed since the CSM and numerical model were prepared in 2002. These changes are as follows: (1) all of Section III has been capped, (2) the FFB and sand blanket drains (SBDs) have been constructed (interim corrective measures), and (3) the configuration of the discharge structures has been altered (Pond A has been added). Pond B has also been constructed on the northwest side of Section II. Because it is located far from the original source it does not alter groundwater flow in the area of interest. The North and South Aeration Basins have also been constructed but these ponds are lined and do not recharge groundwater.

The impacts of the changes described above are apparent on the Water Table Aquifer. Historic data from monitoring well WT020, which was in the FFB and abandoned in October, 2004, show that water levels ranged from elevation 112.74 ft to 115.57 ft over a three-year period. Engineering drawings indicate that the SBDs indicate are constructed at elevations of less than 100 ft. Therefore, the water level in this area is below 100 ft, possibly as deep as 92 ft (the elevation of the deepest drain) in some areas. This information shows that draw down of over 15 ft, possibly as much as 20 ft, is created by the SBDs. The drainage leading from the FFB, flowing toward Lake Marion, was also deepened. These two construction efforts have lowered the WT and created flow directions toward the basin and the drainage. This change in the WT surface is evident in Figures 2.8-1 and 2.8-2, which is shows the WT contour maps for November 2002 and October 2009, respectively.

As of this past year, groundwater flow within the PSDL and UBC-A aquifers has been reversed year round as a result of off-site pumping. Figures 2.8-3 through 2.8-10 illustrate this potentiometric surfaces in October 2009 and July 2010 for the TLS, SSDL, PSDL, and UBC-A aquifers. It is thought that the nearby pumping wells are screened in the UBC-A and possibly the PSDL, but well logs are not available. Though operational records are not available it is thought that the pumping occurs in the winter. Up until recently, groundwater flow within the UBC-A and PSDL aquifers was reversed (to the east—away from the Lake) only during the winter months and that the normal flow to the west was restored during summer. Based on water level measurements from 2010, this trend no longer occurs. Flow is reversed to the west all year. This reversal may be caused by residual draw down from several years of pumping or increased water usage up-gradient.

2.9 SITE DRAINAGE AND SURFACE WATER

FDs were installed by the previous owners/operators to lower groundwater tables or levels during the construction of Sections I, II, and III of the landfill and to divert off-site groundwater around the landfill site. There is one perimeter FD beginning at a location near the old tank farm and extending along the eastern edge of the property toward the entrance road/guard gate and then along the northern edge of the site along the North Road and ending near the intersection of North Road and West Road. There is a breakpoint on this perimeter FD located near the entrance road/guard gate at which the groundwater collected in the FD flows by gravity and discharges either into Pond A or Pond B and then to the head waters of Lake Marion. In one direction from the breakpoint, the groundwater in the FD flows along the east edge of the site and then into hard piping near the old tank farm and eventually flows or discharges (at the water surface elevation) into Pond A. In the other direction from the breakpoint, the groundwater in the FD flows for a short distance along the east edge of the site, along the north edge of the site following the North Road, and then into hard piping near the intersection of North Road and West Road and eventually flows or discharges (at the water surface elevation) into Pond B (AECOM, February 2011; Figure 4.7-1).

There is an additional FD that extends along a portion of the east and west sides and along the south end of Section I of the landfill. This FD was also installed to lower groundwater table during the construction of Section I. Groundwater collected in this FD flows by gravity from into hard piping along the west edge of Section I and eventually flows or discharges (at the water surface elevation) into Pond A in close proximity to the discharge from the perimeter FD into Pond A (AECOM, February 2011; Figure 4.7-1).

Significant improvements have been made to the Pinewood Site by the Trustees to improve surface water drainage. A Surface water discharges from the site include the following:

- Groundwater collected in the perimeter FD and the Section I FD;
- Groundwater collected in the Sand Blanket Drain installed to address shallow impacted groundwater from the vicinity of a former Solid Waste Management Unit (SWMU)
- Storm water runoff from Sections I, II, and III of the landfill site after rainfall events.

As previously described, groundwater collected in the perimeter and Section I FDs flows via underground piping into surface water ponds A or B. Storm water collected on site flows through a series of ditches, pipes, and/or culverts off the covers of Sections I, II, and III of the landfill and other drainage basins around the landfill directly into surface water Pond A or Pond B or into the FFB. The FFB discharges to Pond A through a deeply incised influent channel. Additionally, the groundwater from the Sand Blanket drain constructed beneath the FFB is collected and pumped to one of two aeration basins (termed North and South Aeration Basins) for air stripping of any VOCs (if needed) prior to being directed to the influent channel that leads to Pond A. The combined flow of groundwater and storm water from Pond A and from Pond B is then discharged via outfall weirs into an un-named tributary of Lake Marion in accordance with effluent limitations and other requirements of National Pollutant Discharge Elimination System (NPDES) Permit No. SC0042170 (AECOM, February 2011; Figure 4.8-1).

Based on the above analysis, the following conclusions can be drawn:

- The flow directions within the shallow, Water Table Aquifer and the OCS have not been impacted by off-site pumping.
- Draw down within the Water Table Aquifer from the SBDs appears to be occurring.
- Draw down resulting from off-site pumping may be occurring within the TLS and the SSDL aquifers.
- Flow directions within the PSDL and UBC-A aquifers are reversed year round.
- Storm water runoff and shallow groundwater intercepted by the FDs is directed into Lake Marion via discharges from Ponds A and B.

These conclusions indicate that portions of the LTM are no longer appropriate for the CSM.

3.0 MONITORING PROGRAM

The *Groundwater SAP Interim Status Monitoring* (October 15, 2003) describes the protocol for the sampling and analysis of groundwater from Point of Compliance (POC) wells at the site. Two separate groundwater monitoring programs are currently performed: 1) the Surficial WT Monitoring Program (WTMP), which includes monitoring wells screened in the WT and OCS water bearing zones, as well as other monitoring points including SBDs, surface water in Pond A, and storm water manholes; and 2) the Detection Monitoring Program (DMP), which includes monitoring wells screened in the deeper water bearing zones including the OCS, TLS, SSDL, PSDL, UBC-A and UBC-B aquifers.

The comprehensive monitoring programs were evaluated based on the database provided to AECOM in 2010 by Kestrel. Data in the database for the individual sampling events has varied over time with no reference fields to identify the rationale for the changes in sampling over time. An extensive review of the individual sampling events during 2009 and 2010 were compared to requirements in the *Groundwater SAP* (October 17, 2003).

The site is subdivided into two monitoring categories; 1) shallow zones, consisting of groundwater above the OCS (WT Zone) and within the sand lenses in the upper portion of the OCS (OCS sand lens wells); and 2) deeper zones, consisting of groundwater that occurs in units below the OCS.

3.1 2010 WATER TABLE MONITORING PROGRAM

The *Groundwater SAP Interim Status Monitoring* (October 15, 2003) includes the following guidance for WT monitoring:

1. Five WT monitoring wells should be analyzed quarterly for analysis of the Appendix IX list of analytes;
2. OCS monitoring wells should be analyzed quarterly for analysis of volatile organic compounds (VOCs), eight Resource Conservation and Recovery Act (RCRA) metals (Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium and Silver), chloride, and field parameters (pH, specific conductivity, temperature, field turbidity, and groundwater elevation); and
3. Monitoring wells in the OCS should initially be analyzed for four consecutive quarters, to establish background data, before scheduling.

The General Engineering Laboratory (GEL) Interim Corrective Measures (Formerly 3008h Order 87-27-R) Quarterly Water Table Reports provided by Kestrel for calendar years 2009 and 2010 were reviewed for the LTMO. The quarterly reports include results for other water quality samples described below that are not included in the 2003 *Groundwater SAP Interim Status Monitoring* (October 15, 2003).

A total of 32 water quality samples were collected during 2010 quarterly WTMP events. The WTMP monitoring network at the site currently consists of:

1. Five (5) WT wells used for water level monitoring only;
2. Five (5) WT wells used for water level and groundwater quality analysis;
3. Ten (10) OCS sand lens wells used for water level and groundwater quality monitoring;
4. Two (2) SBDs constructed in the FFB are sampled for groundwater quality analysis;
5. Two (2) outfalls from the Perimeter FD system are sampled for groundwater quality analysis;
6. Five (5) manholes in the Section I FD are sampled for groundwater quality analysis;
7. One (1) outfall of the Section I FD are sampled for groundwater quality analysis;
8. Pond A Surface Water are sampled for surface water quality analysis;
9. Pond A Outfall 001 are sampled for groundwater quality analysis; and
10. Pond B Outfall 002 are sampled for groundwater quality analysis.

Samples collected from the monitoring points were analyzed for the following:

WT Wells and Pond A Surface Water

- Detection Monitoring (DM) VOCs (DM List);
- Metals (RCRA List); and
- Field Parameters.

OCS Sand Lens Wells

- VOCs (DM List); and
- Field Parameters.

SBDs

- VOCs (DM List)

Perimeter FD and Section I FD Outfall

- VOCs (Appendix IX VOCs, cis-1,2 Dichloroethylene [cis-l,2 DCE] and l,4-Dioxane); and
- NPDES Permit Metals (except mercury).

Section I FD Manholes, Outfalls 001 and 002

- VOCs (Appendix IX VOCs, cis-l,2-DCE and l,4-Dioxane).

3.2 2010 DETECTION MONITORING PROGRAM

The GEL Detection Monitoring Reports provided by Kestrel for calendar years 2009 and 2010 were reviewed for the LTMO. The 2003 *Groundwater SAP Interim Status Monitoring* (October 15, 2003) includes the following guidance for detection monitoring:

- Quarterly analysis of groundwater collected from monitoring wells located downgradient in the TLS.
- Annual analysis performed of groundwater collected from monitoring wells located in the upgradient TLS.
- Annual analysis of groundwater collected from the OCS, SSDL, PSDL and UBC-A.
- Monitoring wells located in the UBC-B will be initially performed for four quarters only, to establish baseline data.

In the event of a confirmed statistical failure, wells located in both the vicinity of the detection and the next lower zone will be analyzed more frequently.

The 2010 DM groundwater monitoring network consists of 146 downgradient POC monitoring wells and 12 upgradient wells. A summary of wells in water bearing zones that were monitored during 2010 is provided below.

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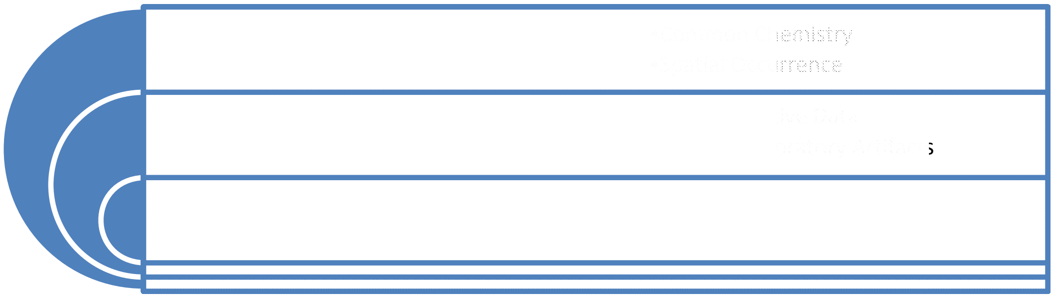
2010 Detection Monitoring Summary

2010 Quarter	Water Bearing Unit	Number of Wells Sampled
1	TLS	47
	TLS - Upgradient	3
	SSDL	36
	SSDL - Upgradient	3
	Total for Q1	*89*
2	TLS	47
	PSDL	24
	PSDL- Upgradient	3
	Total for Q2	*74*
3	TLS	47
	UBC-A	24
	UBC-A Upgradient	3
	Total for Q3	*74*

2010 Detection Monitoring Summary		
2010 Quarter	Water Bearing Unit	Number of Wells Sampled
4	TLS	47
	OCS	15
	Multiple Aquifers (Appendix IX)	5
	Total for Q4	*67*
	Total 2010 Samples	**304**

4.0 CHEMICAL DATA ANALYSIS

This section describes the data analysis techniques that were used to develop the LTMO and supplemental data gathering options. The fluid chemistry data were segregated into the following categories for independent analysis: 1) storm water, 2) surface water, 3) leachate, 4) SBDs, 5) FDs, and 6) groundwater. Groundwater was further segregated into two groups based on the current monitoring programs: 1) WTMP, and 2) DM. Both primary sample data and quality assurance (QA)/quality control (QC) data were subjected to probability statistics to validate laboratory control and to allow an unbiased evaluation of laboratory effects on data quality. This analysis identified numerous deficiencies in data quality from the laboratory. Results of this data analysis were used to identify site-specific tracers or key "indicator chemicals" that will be incorporated into the LTMO Program, and identified specific chemicals or elements that can be eliminated from the LTMO due to laboratory uncertainty.



4.1 LEACHATE COMPOSITION

Based on analytical results of the May 2010 analyses of leachate, detected constituents include VOCs, semi-volatile organic compounds (SVOCs), pesticides, herbicides, metals, and inorganics. Table 4.1-1 lists maximum concentrations of these constituents and compounds that have been detected in each landfill section are shaded to illustrate common components of landfill leachate at the Pinewood Site. Further screening of the data was performed to determine the most frequently detected compounds in leachate sampled from sumps in May 2010. For example, chloride was detected in every leachate sample analyzed in May 2010 at concentrations ranging from 394 to 19,800 milligrams per liter (mg/L), with an average of 9,000 mg/L.

Table 4.1-2 lists properties for specific organic compounds most frequently detected in leachate. As the table summarizes, compounds that are most soluble and have little or no tendency to volatilize (low Henry's Law Constant), or adsorb [low organic carbon partition coefficient (Koc)], such as 1,4-dioxane, tend to be transported in the aqueous phase through advective flow. In comparison, toluene and xylene volatilize more readily and adsorb to organic carbon so are less mobile in water than 1,4-dioxane. 1,4-dioxane is present in leachate in all three landfill sections and therefore, recommended for use as an indicator parameter for the Detection Monitoring program. The chemical formula of 1,4-dioxane is $C_4H_8O_2$, and its molecular weight is 88.10 gram per mole (g/mol). 1,4-Dioxane, also referred to as 1,4-

diethyleneoxide, occurs as a colorless flammable liquid that is miscible in water and travels essentially un-retarded with advective groundwater flow. 1,4-Dioxane is used in industry as a stabilized in chlorinated solvents. Thus, it is commonly found with chlorinated ethenes and ethanes. 1,4-Dioxane has a faint pleasant odor, with an odor threshold of 24 mg/L. The vapor pressure for 1,4-dioxane is 30 mm Hg at 20 °C. The physical and chemical properties along with its distribution in leachate make it an excellent indicator parameter to monitor for potential future releases of liquid leachate to the environment.

Metals (arsenic, barium, calcium, iron, and magnesium) were also frequently detected in the May 2010 analyses of leachate. These and other metals do not volatilize under most environmental conditions. Their solubility and adsorption depend on geochemical conditions, concentrations of other ions, and the mineralogy of soil and subsurface materials. These metals are not unique to leachate and occur naturally in soil and groundwater; therefore, the use of metals as indicator parameters is not recommended.

The leachate includes petroleum fuel compounds such as benzene, toluene, ethyl benzene and xylene (BTEX); chlorinated volatile organic compounds (CVOCs) including high percentages of tetrachloroethylene (PCE) and trichloroethylene (TCE); and metals including zinc, iron, chromium and cadmium. Inorganics in the database including the anion chloride were also evaluated as a potential indicator parameter.

4.2 STATISTICAL COMPARISON

Based on a comprehensive screening of leachate data, only a select number of constituents reported in groundwater from each group (fuels, CVOCs, metals and inorganics) were subjected to a detailed statistical data analysis. This included reviewing the laboratory QA/QC data to determine if reported concentrations of potential indicators are the result of field or laboratory contamination.

Leachate is sampled at sumps designated with the landfill Section (I, II, and III), cell (A through E), and sump number. For example, sump IIA1 is the first enumerated sump in cell A of Section II. Sampling locations for leachate collection, the landfill sumps, were digitized from as-built drawings, entered into Microsoft Excel™, and then merged with analytical data using Microsoft Access™. Maps were then produced using Surfer, a mapping program from Golden Software, Inc. to compare constituent concentrations in the leachate and surrounding groundwater within the various water bearing zones. Data is visually depicted on plan view maps using colored symbols; generally symbol size increases and color darkens with increasing constituent concentration; however, the actual concentration value for each symbol varies with each analyte. The distribution of selected chemicals in leachate is presented in Figures 4.2-1, 4.2-2, 4.2-3, and 4.2-4 for toluene, iron, arsenic, PCE, and TCE, respectively.

Toluene

Figure 4.2-1 illustrates the relative distribution of toluene in landfill sumps and in the surficial WT zone aquifer wells. Sump IIC2 had the highest concentration of 8,670,000 micrograms (µg/L) (0.8%) detected in May 2010. Sump IIA2 has up to 0.5% toluene; however the concentrations vary greatly between sampling events. Section I sumps with orange squares average around 15,000 µg/L, or 0.015%. A summary of the laboratory blank results compared to primary groundwater samples collected from the surficial Water Table Aquifer during the monitoring period from January 2001 through March 2010 is summarized below.

Statistical Analysis for Toluene

Sample Type	Variable				
	Mean	Standard Deviation	Minimum	Maximum	N
Laboratory Blanks	1.6600	3.480	0.190	20.2	77
Shallow Groundwater	*0.6804*	*1.263*	*0.172*	*14.2*	*127*

Data presented in this table show that all of the reported groundwater detections for toluene are within the range reported for blanks during the same time period and should be therefore disregarded. Thus no credible toluene detections have been reported in groundwater samples collected during the monitoring period of record at Pinewood Site. Thus, with 98% confidence, we can conclude that there is no statistical difference between detections of toluene in groundwater and in the method blanks.

Xylenes (total)

During the period January 2001 through March 2010, there were no reported detections of xylenes in groundwater samples. There were 5 reported detections in 96 trip or field blanks during this period. The average of these detects was 0.71 µg/L, with a standard deviation of 0.33. Xylenes have been reported in leachate from Sections II and I, with very low concentrations reported in Section III leachate. The highest concentrations of xylenes are in cells IIA2 and IIC2.

Benzene

Benzene has been reported at detectable concentrations in groundwater several times in approximately 5000 records. Scattered benzene detections in laboratory blanks and samples are in the very low µg/L range (<1.0 µg/L). Results from 5 blanks averaged 0.48 µg/L +/- 0.104 and results from 21 samples averaged 0.54 µg/L +/- 0.47.

Iron

Iron is a naturally occurring element and a prominent constituent in leachate with concentrations above 9,240,000 µg/L in cell IE. In general, concentrations decreased over the period June 2007 through May 2009 represented by the database. Figure 4.2-2 illustrates the relative distribution of iron in leachate samples and Section I of the landfill has the highest iron concentrations in leachate. The Section II landfill also has one sump (IIB3) with high iron content. Based on the occurrence and distribution of iron in leachate, monitoring for iron as a potential indicator parameter for a release of leachate is an option for consideration.

Arsenic

Arsenic is a naturally occurring element, a constituent in the leachate, and has also been detected in groundwater. Figures 4.2-5 and 4.2-6 present a summary of arsenic concentrations detected in leachate and groundwater, respectively. The geographic distribution of arsenic is presented in Figure 4.2-3.

Statistical analysis of arsenic data from groundwater and laboratory blanks is summarized below. Two values from WT027 and WT030 (January 2002) were not used due to uncertainty regarding the reported units. One outlier of 534 µg/L (result from WT024 in January 2002) was omitted from the analysis.

Statistical Analysis for Arsenic

Sample Type	Variable				
	Mean	Standard Deviation	Minimum	Maximum	N
Laboratory Blanks	5.14	4.03	1.2	10.7	4/58
All Groundwater	*5.94*	*9.09*	*0.09*	*8.12*	*120/3512*

Four of 58 blanks reported detections for arsenic. The mean of 5.14 and standard deviation of 4.03 was calculated for these blanks. If these values are applied to a normal curve, the 90th percentile would occur at about 12 µg/L, and 17.5 µg/L is well out of the range expected for blank results. Figure 4.2-3 shows the ranges 0 to 3.76 µg/L, 3.76 to 15 µg/L, 15 to 19.9 µg/L, and greater than 19.9 µg/L for arsenic in groundwater. Of 3512 data records for wells, 120 detections were reported. The 95th percentile is at 22 µg/L whether the extreme value of 534 µg/L is included or not.

Analysis of the data suggests that only well UBC004 has levels of arsenic that are representative of actual groundwater conditions and the reported concentrations are within the range expected for fluvial/delta plain sediments. Arsenic is not recommended as an indicator for parameter at the Pinewood Site.

Mercury

During the period August 2005 through June 2007, 64 trip blanks and field blanks were analyzed for mercury. Sixteen of these were reported as <0.2 U or non-detect. The remaining 48 results average 0.45 µg/L with a standard deviation of 0.35 µg/L and most of those data had an estimated J-flag qualifier. The minimum reported was 0.18 µg/L, and the maximum 2.35 µg/L. Three thousand fifty-two mercury analyses were reported for groundwater. Of these only 83 detections were reported. Mercury concentrations average 0.67 µg/L with a standard deviation of 1.05. The minimum concentration was 0.02 µg/L and the maximum concentration was 7.11 µg/L.

Statistical Analysis for Mercury

Sample Type	Variable				
	Mean	Standard Deviation	Minimum	Maximum	N
Laboratory Blanks	0.45	0.35	0.18	2.35	48/64
Groundwater	*0.67*	*1.05*	*0.02*	*7.11*	*83/3,052*

The hypothesis that the means of these two groups (samples and blanks) are the same can only be rejected at the 45% confidence level (Alder and Roessler, 1968). There is no significant difference between groundwater sample results and laboratory blank results; therefore, mercury reported in groundwater samples collected from the Pinewood Site may not represent actual site conditions. Mercury should be removed from the WTMP and DM programs and should not be used as an indicator parameter.

CVOCs

From 2001 through 2009, PCE and TCE are strongly associated in several WT groundwater samples. Out of 3526 reported analyses, there were 103 detections of PCE and 62 detections of TCE. These data are plotted on Figure 4.2-7. The cluster of data points with elevated TCE and PCE are all from sample locations SBD1 and SBD2. Six data points under 5 µg/L TCE and extending to over 250 µg/L PCE are all from monitoring well WT022 which is screened in the WT. When these three sampling points (SBD1, SBD2, and WT022) are eliminated as illustrated on Figure 4.2-8, data plotted from wells OCS002 and UBC035 fall along a line at a ratio of 10:1 PCE:TCE.

Figure 4.2-4 illustrates the distribution of PCE and TCE in leachate and groundwater. These two constituents are predominately detected in groundwater collected from the WT hydraulically upgradient of the FFB. During construction of the FFB, the Water Table Aquifer and upper OCS were removed and SBDs were constructed to capture groundwater moving from the upgradient direction. Analytical results from SBD1 and SBD2 indicate that the SBDs are performing as designed, and CVOCs are being captured in the SBDs and do not migrate past the FFB.

Zinc and Chloride

Zinc and chloride are both present in high concentrations in leachate landfill from Sections I, II and III. Both constituents are very soluble in water, so it is logical to assume that each constituent would serve as a good indicator to monitor future potential releases and therefore these constituents were evaluated together.

Figure 4.2-9 is a cross plot of zinc versus chloride using zinc concentrations greater than 15 μg/L. On this graph, several well data indicate a correlation of elevated zinc and chloride in groundwater sampled from wells located along the northwest corner of Section II. Monitoring wells OC008, OC007, and MW030 are close together and show zinc and high chloride.

At the extreme southwest corner of Section I, wells MW005A and MW006TR have zinc detections. These are near high zinc levels in leachate. It is difficult to conceive of zinc escaping from the landfill without being accompanied by other constituents such as chloride and chlorocarbon solvents, so a landfill source is considered unlikely for these two wells.

Statistical Analysis for Chloride

Sample Type	Variable				
	Mean	Standard Deviation	Minimum (mg/L)	Maximum (mg/L)	N
Laboratory Blanks	17.3	9.8	0.2	28	10
Groundwater	*3.1*	*2.9*	*1.0*	*27.5*	*3378*

Blank concentrations of chloride reported from 2002 and 2010 range between 0.2 and 28 mg/L. The mean is 17.3 and the standard deviation is 9.8. Samples range between 1.8 and 27.5 mg/L and average 3.6 mg/L with a standard deviation of 3.3. This suggests that most reported detections of chloride in the historical database are within the range of laboratory concentrations and therefore likely are not representative of actual site conditions. Although historical chloride data for groundwater may not be useful, if the laboratory can reconcile the presence of chloride in blank samples, then chloride can be used as an indicator parameter at the Pinewood Site.

Field Conductivity

There were 3724 measurements of electrical conductivity in the database that represent mobile charged ions in solution at the time of measurement. Conductivity is the reciprocal of resistivity, which is measured by the resistance in Ohms between two one-centimeter square plates one centimeter apart in the solution. The units are reciprocal Ohms – called “mhos” per centimeter (mhos/cm). In most natural waters conductivity is so low that one millionth mho, or micro-mho, is normally reported. The conductivity of groundwater samples is 254 +/- 188 micro-mhos per centimeter (μmhos/cm). A few wells (e.g. WT024, WT025 and WT030) are routinely three times the standard deviation above the mean. There are not sufficient cation and anion analytical data to explain the conductivity values observed. Therefore, the analysis of groundwater samples for major cations and anions is recommended.

4.3 CHEMICAL FATE AND TRANSPORT

Based on the leachate composition and statistical data analyses, potential release indicators were further screened to evaluate their physical properties and fate and transport in the environment. Chemical properties that were compared include solubility/precipitation, volatility/condensation, and adsorption/desorption, which transfer contaminants from one media to another. Abiotic degradation and biodegradation was also evaluated since the chemicals found in leachate transform to other substances such as oxygen, carbon dioxide, and chloride. The rate of degradation of a constituent can vary widely and depends on the presence and activity of microbes, subsurface matrix materials, iron mineralogy, geochemical conditions, the presence of a growth medium, and the concentration of contaminants (Lawrence, 2006; He and others, 2009). This analysis was performed because chloride was identified as a potential indicator chemical.

Groundwater has been monitored since 1981 (Kestrel Horizons, 2010); however, reported detections of potential constituents in groundwater are typically low in concentration and infrequently detected with no temporal trend. Table 4.3-1 lists the maximum concentrations of organic compounds detected in groundwater within each water bearing zone from January 2001 to February 2010. Also listed in Table 4.3-1 are the total number detections of each compound greater than 1 µg/L. Two detections occurred in shallow groundwater at well WT008, located near an area of old SWMUs. These November, 2009 detections did not occur in groundwater collected during the February 2010 sampling event[1].

Spatial and temporal trends of naturally occurring constituents were evaluated to provide evidence of water flow paths, connections among hydrogeologic units, and potential current or future transport pathways of landfill constituents. Geochemical "fingerprinting" using major anions and cations is a useful way to identify interconnected systems. Of these, only chloride data are currently available and are discussed below. Metals, such as chromium or lead, are unreliable for evaluating flow paths because these constituents adsorb to aquifer matrix material and can precipitate under various geochemical conditions.

Major Ion Evaluation of Groundwater Transport

Since only chloride data have been collected in groundwater, these data were used to evaluate potential communication between landfill leachate and water bearing zones. Chloride almost always moves in water by advection and dispersion and is unaffected by retardation mechanisms or degradation. This

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[1] The most recent groundwater data available during the evaluation was February, 2010.

makes it a good tracer or “indicator parameter” of water movement and it also can be used as an indicator of a potential future release of leachate.

Figures 4.3-1 through 4.3-5 illustrate the spatial distribution of chloride in the OCS, TLS, SSDL, PSDL, and UBC-A, respectively. Data shown were selected from 2009 and first quarter (Q1) 2010 sampling events (5 quarters). Most chloride concentrations (76 percent) analyzed during 2009 and Q1 2010 were less than 3 mg/L (the detection limit is 2 mg/L). Concentrations greater than 3 mg/L occurred in only 20 percent of the wells. Figure 4.3-7 shows the most recent (2009 and 2010) chloride concentration of 3 mg/L or greater for the five hydrogeologic units sampled. The most elevated concentrations in groundwater occur at wells screened in the OCS and TLS on the northwest side of landfill Section II.

As described above, the reported concentrations of chloride in site groundwater samples in the historical database do not provide useful information due to the presence of chloride in blank samples. If the analytical laboratory detections related to chlorides in the blanks can be rectified, than chloride should make a good performance indicator analyte for future monitoring.

Chemical Indicators for Evaluating Potential Releases and Contaminant Transport

Chloride can provide information about groundwater movement because it is highly elevated in leachate (up to 19,800 mg/L), is transported with groundwater through advective flow and is not retarded or dissipated by adsorption or volatilization. Chloride is naturally present in small concentrations in groundwater and surface water and this should be factored in the analysis of site-related chloride in the environment. As discussed in Section 4.1 above, 1,4-dioxane has been detected in leachate from cells in each of the three landfill sections. Due to its physical properties (e.g., low volatility and adsorption, high solubility, and a long half-life) and its association with chlorinated solvents, 1,4-dioxane is recommended as a tracer for leachate and groundwater.

5.0 MONITORING TECHNOLOGY EVALUATION

The Pinewood Site currently has an environmental monitoring program that is designed to frequently sample and test various media for the presence of chemicals originating from the closed landfill cells. AECOM has researched, screened, and evaluated innovative and recently developed monitoring methods and technologies that may be applicable at the Pinewood Facility. The goal of the evaluation was to identify technologies that can provide rapid data reporting and have the potential to improve the cost effectiveness of the monitoring program without sacrificing the quality of the data or level of assurance provided by the methodology. The monitoring technologies described below focus on point-source monitoring (e.g., groundwater or surface water), and site-wide geophysical techniques that can supplement the point source monitoring program. Literature and specifications for monitoring technologies evaluated by AECOM are included in Appendix B.

5.1 SINGLE-POINT MONITORING

The technologies presented in this section are classified as 'single point' techniques, in that they provide information on the chemical quality of water at a single location. These technologies were evaluated as potential alternatives for the standard single point monitoring techniques that are currently employed at the site. A brief description of these monitoring technologies, advantages/disadvantages and approximate costs are summarized in Table 5.1-1.

5.1.1 Continuous Monitoring

Continuous monitoring alternatives involve techniques that can provide analyses of various parameters on either a continuous basis with minimal field oversight. These alternatives generally involve the measurement gross geochemical parameters, such as pH, conductivity, temperature, etc. These techniques are advantageous, as they can easily produce the most frequent analytical data.

5.1.1.1 *In Well Sonde*

In well sondes are multiparameter sensors or transducers that are deployed beneath the water surface. These sensors are capable of measuring a variety of chemical parameters, including dissolved oxygen, temperature, conductivity, salinity, conductance, resistivity, depth, pH, oxidation reduction potential (ORP) and total dissolved solids (TDS). Since the geochemical characteristics of landfill leachate are very distinctive, the use of an in well sonde can provide preliminary indication of the presence of landfill leachate (e.g., decreasing pH and/or increasing conductivity/TDS). Sondes are commonly used for long term deployment for water quality monitoring (USGS, 2006), and the technology is commercially available from several vendors. The resolution and accuracy of these instruments depend on the measurement parameter, but are comparable to standard field-deployed geochemical sensors. Geochemical parameters typically have an accuracy of between 0.5 to 2 percent of the reading; pressure measurements have an accuracy as low as 0.01 ft of water. Similar to standard geochemical sensors, sondes must be serviced and calibrated at regular intervals to ensure adequate accuracy and precision of measurements.

These sensors are capable of permanent deployment, offer data logging capabilities and can be incorporated in a programmable logic control (PLC) or supervisory control and data acquisition (SCADA) system. Periodic maintenance will be required for probe cleaning, calibration and replacement. Sondes are typically powered via either battery or energy-efficient and sustainable solar power and most sondes have telemetry functionality, thus they could be monitored on a remote basis. The advantage of the sonde is that it can provide nearly continual measurements with only periodic maintenance and downloading. Electronic data transfer eliminates the potential for human transcription error. Since the parameters measured by an in well sonde are ‘indicator’ parameters, the results of the sonde measurements may be used to trigger follow-up analyses for specific constituents of concern (COCs; e.g., VOCs). The sonde could be deployed to monitor for geochemical changes within the water, which would trigger additional monitoring for more specific parameters. In-well sondes could be used to reduce the quarterly monitoring frequency of TLS wells as required in Section VIII.A.12c of the Part B RCRA Permit. Specifically, in-well sondes are recommended for the new monitoring wells proposed along the northern and eastern perimeter of the site to evaluate the downgradient water quality trends after installation.

5.1.1.2 *In Well Purging*

In well purging is a technology specific to groundwater monitoring, and involves the automatic purging of groundwater within the casing of a well. A permanent submersible pump, typically pneumatically operated, is placed within the saturated zone the target well. Purging activities are performed based on a programmable control system, and the extracted water is transferred to an aboveground location and subjected to analyses. Depending on the analytical instruments attached to the in well purging apparatus, the extracted groundwater can be analyzed for geochemical constituents (dissolved oxygen, temperature, conductivity, salinity, conductance, resistivity, depth, pH, ORP, TDS) or volatile organics.

The Robowell technology is an in well purging method that yields information on geochemical parameters (USGS, 2002). Groundwater is extracted from the target monitoring well and subjected to analysis via standard in-line groundwater sampling meters (m). If groundwater is impacted, purged groundwater must be stored on-site for eventual disposal. This technology was developed and tested by the USGS and was determined to provide reliable, real-time data for groundwater geochemical parameters. The resolution and accuracy of the Robowell technology was comparable to measurements taken using standard field-deployed geochemical sensors. A commercial supplier of in well purging technology is Burge Environmental (Tempe, Arizona), which markets both a well sampling device (BJ-100) and a companion analytical module (HJ-100), which can perform analysis of TCE. The well sampling device was piloted by the USEPA, and was determined to yield accurate results, as compared to standard techniques (USEPA, 2000). The analytical module was investigated by AECOM, although not in a groundwater sampling application. The unit was utilized to measure influent and effluent TCE concentrations from a wastewater treatment process. The analytical module was determined to yield acceptable quantitative values for the influent stream, but the lower concentration effluent stream yielded acceptable results on only 50 percent of analyzed samples (USAF, 2006). The average accuracy of the instrument was determined to be approximately 5 percent of the measured reading. The unit was also prone to frequent O&M requirements.

In well purging is most suitable for use in sentinel wells at the Pinewood Site. Similar to the in well sonde, these units could periodically monitor groundwater for changes in geochemistry or TCE concentrations, which could serve as early warning alerts for the presence of leachate. Each unit has the ability to incorporate remote monitoring components (e.g., modem access, telemetry). The deployment of either the Robowell or Burge technologies would require the construction of specialized well vaults or above ground structures to house system components. A source of power would also be required, as both units require power to operate various components. In addition, wells would require a groundwater storage tank to store extracted groundwater. Because this technology has not been fully developed, and due to the O&M requirements discussed above, this technology is not recommended for implementation at the Pinewood Site.

5.1.1.3 *Headspace Monitoring*

VOC headspace monitoring is a technology that employs the continuous monitoring of gaseous VOC constituents above a target fluid flow stream. Used at a discharge outfall, for example, this system allows quick detection of VOC release events. The technology detects the presence of low concentrations of VOCs in the vapors immediately above the target fluid. The concentration of total VOCs in the headspace has been shown to directly correlate with relative concentration of VOCs in solution in the fluid being monitored. The system compares each data point to the prior data point, or a 12-hour average, and records percent change. The system will log the data locally and can transmit the data remotely via standard telemetry options.

The VOC headspace monitoring system (Multisensor 1000 VOC monitor) is commercially available through Multisensor Systems Ltd., Cheadle, United Kingdom. The VOC monitor uses metal oxide sensors installed in the headspace of small basin/container through which the target fluid is flowing. Multiple sensors can be installed to allow multiple parameters to be monitored simultaneously. Because the sensors do not contact the fluid, concerns with fouling are minimal. The resolution of the VOC Monitor is in the parts per billion range; data concerning the accuracy was not available.

AECOM has participated in a laboratory study on the ability of the VOC monitor to detect low levels of various VOCs (Haas and others, 2009). This study demonstrated that the VOC monitor can detect different VOCs (e.g., benzene, PCE, TCE) in headspace of water containing as little as 1 µg/L.

For the Pinewood Site, the VOC monitor would be appropriate to monitor storm water/surface water as an early detection system for the presence of VOCs. However, the sensor was not capable of producing quantitative values of aqueous phase concentrations, and does not differentiate between different VOCs. Discrete water sampling could then be performed to quantify the VOCs present in the fluid. Due to the potential impact of humidity and temperature on the rate that the VOCs will volatize, the unit needs to be installed in a climate controlled building (e.g., with air conditioning and heat). The unit also requires a steady stream of the fluid to be monitored flowing through the sensor container [approximately 0.5 gallons per minute (gpm)]. Appendix B contains literature from Multisensor Systems Ltd. with additional information about the unit. The website for this technology is www.multisensor.co.uk.

AECOM recommends a pilot study to evaluate the feasibility of the VOC monitor for long-term use at the Pinewood Site to verify the compatibility of this technology under actual site conditions. The VOC Monitor technology could be used at Pond A and/or Pond B outfalls to monitor the surface water discharge for VOC release events from the site. Presently, a potential release could only be detected during routine monthly NPDES sampling. Continuous monitoring would add another level of assurance that the receiving waters of Lake Marion are being protected. Excluding operation costs, the approximate cost for installing a single VOC headspace monitoring system at Pinewood would be $60,000, as outlined below:

• Multisensor 1000 VOC Monitor unit	$15,000
• Prefabricated wooden building and slab	$ 9,500
• Sample pump and piping	$ 5,000
• Electrical supply to building and pump	$10,000
• Equipment electrical and control wiring	$10,000
• Engineering Design	$ 8,000
• Contingency	$ 2,500

5.1.1.4 *Water Level Transducers*

Pressure transducers and data recorders are used to provide monitoring of groundwater levels in-situ. These instruments can be placed in a well to automatically record pressure head (feet of water column) which can then be converted to water level elevations. The transducers can be programmed to record data at varying rates and are applicable for extended duration deployment. Data can be periodically downloaded, reduced and evaluated throughout the deployment period.

Down-well water level transducers are recommended to be deployed in select wells screened in the PSDL and UBS aquifers to monitor the effects of off-site pumping on groundwater hydraulics beneath the site. Quarterly water level measurements indicate that the natural groundwater flow direction has been altered by pumping and the capture zone of the off-site pumping wells extend beneath the landfill from the northeast. Specific recommendations for continuous water level monitoring are provided in Section 7.0 and Appendix B provides costs and specifications at several down-well transducers/dataloggers.

5.1.2 Intermittent Monitoring

Intermittent monitoring alternatives can provide analyses of various parameters on an intermittent basis, and require a certain amount of field oversight. These alternatives involve the measurement of specific geochemical parameters, and are advantageous, as they can produce the most accurate, quantifiable data.

5.1.2.1 *Fiber Optic Biosensors*

Fiber optic biosensors are an emerging technology that can be used to provide real-time measurements of dissolved VOCs in a fluid. These sensors are comprised of a two-layer tip that contains a VOC-specific enzyme and a pH-sensitive fluorescent dye. The enzyme reacts with the target VOC, which elicits a change in pH and consequently a change in fluorescence. This tip is deployed on the end of an optical fiber, which measures the change in fluorescence. This reading can be correlated to a quantitative VOC concentration using a standard calibration curve. Tips are specific to only one type of VOCs; analysis of multiple VOCs would therefore require multiple sensors.

Fiber optic biosensors were evaluated by the Environmental Security Technology Certification Program (ESTCP, 2006). The biosensors were evaluated specifically for measurement of groundwater concentrations of VOCs. Four measurement techniques were investigated, as described below.

1. Vial measurements – Groundwater was collected and placed in a fixed volume vial for measurement.
2. In-line measurement – Biosensor was deployed within a standard groundwater sampling flow-through cell to record measurements during well purging.
3. Down-hole profiling – Biosensor was lowered down the water column of a well, and readings were taken at specific depths.
4. Sentinel well – Biosensor was installed at a fixed depth within the water column of a groundwater well for longer term readings.

Of these four techniques, the vial measurements are the only method that yielded quantitative data. However, the data quality was biased low when compared to standard laboratory analyses. Specifically, the accuracy of the method was unacceptably high (greater than 25 percent difference when compared to a laboratory measurement). The remaining techniques yielded only qualitative data regarding the presence of VOCs (i.e., changes in concentration). ESTCP (2006) identified potential limitations for use of this technology, listed below:

- pH Effect – The sensor tip is sensitive to changes in pH, which can affect readings. Based on recent conversations with the vendor, AECOM has learned that more recent prototypes of the biosensor have the functionality to correct for pH.
- Calibration – Calibration techniques have not been developed for in-line measurement or well deployment.
- Robustness – The probe tips were not rugged enough to endure conditions typically encountered in a field setting.

Although tested for their applicability for groundwater monitoring, fiber optic biosensors may be used for screening either groundwater or surface water at the Pinewood Site. Grab samples could be sampled from either wells or surface water and tested using the vial measurement procedure in an enclosed environment. As the fiber optic biosensors are semi-quantitative, VOCs detected during this screening process would have to be verified using standard laboratory analyses. This technology is not currently commercially available and AECOM does not recommend the use of fiber optics at this time; however, the technology should be re-evaluated in the future for potential use.

5.1.2.2 *Passive Sampling Devices*

Passive sampling is a common groundwater sampling technology that involves the deployment of a sampling device, either a plastic bag or glass/plastic vial, below the water column within a monitoring well. The samplers are either collected as an instantaneous grab sample, or via diffusion processes. The Snap Sampler (Pro Hydro, Inc., Rochester, NY) and the HydraSleeve™ (Geoinsight, Las Cruces, New Mexico) are instantaneous samplers that collect grab samples. These samplers can provide water that can be analyzed for most groundwater constituents, although the collection volume is limited.

Passive diffusion bags, rigid porous polyethylene samplers and regenerated cellulose dialysis membrane diffusion samplers (dialysis samplers) are the most common diffusion-based samplers. Diffusion samplers are first filled with ultrapure water prior to deployment. The sampler is then allowed to equilibrate for a minimum time (days to weeks) to allow dissolved groundwater constituents to diffuse into the sampling bag. Diffusion sampling devices are commercially available via several different vendors. Passive samplers are advantageous as they can be collected rapidly, and generate minimal to no purge water for disposal. A third-party investigation of passive sampling devices has shown the precision and accuracy of the results to be comparable to standard groundwater sampling techniques (Parsons, 2006). However, some diffusion samplers are not effective for all analytes. Passive diffusion bags are not recommended for soluble organics (i.e., 1,4-dioxane), whereas rigid porous polyethylene and dialysis samplers are effective (ESTCP, 2007). Passive samplers could be utilized as a potential method for site-wide groundwater monitoring techniques at the Pinewood Site, but caution must be exercised in order to select the appropriate sampler/analyte pairing. AECOM does not recommend the use of passive sampling devices at the Pinewood Site for the reasons discussed in Table 5.1-1.

5.2 SITE-WIDE MONITORING

This section presents a summary of potential site-wide geophysical techniques to identify potential releases of high conductivity leachate from the landfill cells. A description of these monitoring technologies' advantages/disadvantages and approximate costs are summarized in Table 5.2-1.

5.2.1 Electrical Conductivity

A technique for performing site-wide monitoring of leachate plume development is the use of electromagnetic (EM) survey. A Geonics Limited EM-34/3RT instrument equipped with a digital data logger for the data collection process would be utilized for the survey. Data are recorded as apparent electrical conductivity along transects parallel to landfill cell perimeters. EM methods provide a non-intrusive, non-destructive means to map gross subsurface electrical conductivity variations. Measurements are sensitive to buried metal, variations in dissolved ion concentrations (e.g. salts or leachate) in groundwater, and conductive soil components (e.g. cinders and ash, clay). For this particular instrument, measurement accuracy is within +/- 5% at 20 millisiemens per meter (mS/m). Measurement precision is +/- 0.1% of full scale deflection within a given range. Noise levels are approximately 0.2 mS/m, but can be higher near power lines and utilities. Since no known or suspected releases have been identified at the Pinewood Landfill, this technique could be integrated into the current monitoring program and a "baseline" survey can be performed for comparison to future survey results. Data would also be compared to background to identify contemporary anomalies, if present.

Apparent electrical conductivity represents a composite value for all geo-electric layers or anisotropic media within a predicted zone of exploration. Depth of exploration for this electromagnetic method is dependent on inter-coil spacing and coil orientation between the transmitter and receiver coil loops and the frequency of the transmitting loop current. The intercoil spacing between the transmitter and receiver coils can be fixed at 10, 20 or 40 m, with readings in the vertical dipoles (VD) and horizontal dipoles (HD) collected at each station by changing the coil orientation. Both the HD and VD are typically utilized with effective depths of investigation of approximately 25 and 50 ft below ground surface, respectively, using the 10 m coil separation. The technique can be used to rapidly cover large spatial areas within a relatively short amount of time. Data are generally plotted as contours of measured apparent resistivity. Anomalies (high or low conductivity features) appear as bullseye-like features. Matias and others, (1994) identified a conductive groundwater plume emanating from the Ovar landfill on the west coast of Portugal using electromagnetic methods.

AECOM recommends a pilot study to evaluate this technology. Two areas are recommended to be surveyed as part of the EM-34 pilot study. One area is along the southwest perimeter of landfill Section I where zinc and chloride levels are elevated in wells MW005A and MW006TR. One EM-34 survey grid should be established and a survey performed over this area. The survey grid should cover a portion of the edge of the landfill and areas presumed to be downgradient from this area. In addition to this survey area, a background survey should be performed adjacent to the landfill within the southern portion of the site. The background survey will provide a means of comparison for the pilot study survey data to natural background conditions. Soundings should be performed every 25 ft along transects measured parallel to the landfill boundary. VD and HD coil orientations should be utilized with intercoil spacings of 20 and 40 m to investigate various depths within the surface aquifer.

5.2.2 Electrical Resistivity/Induced Polarization Methods

Electrical resistivity (ER)/induced polarization (IP) is a technique performed by applying (injection) very low amperage, direct current (DC) electrical current in the subsurface between stainless steel electrodes spaced equally along a profile. For ER, the electrical potential is measured during current injection at the ground surface using a high-sensitivity resistivity meter. IP measurements are made by measuring the voltage decay once DC current is shut off. ER/IP can be used to image bedrock topography, freshwater/saltwater interfaces, fracture zones, near-surface geologic stratigraphy, and air-filled or clay-filled voids (Sharma, 2002). IP measures chargeable units in the subsurface to help differentiate between conductive anomalies (e.g. clays and leachate-saturated sands), since some anomalies will hold their charge longer. These geologic features represent zones of variable electrical resistivity and chargeability. Soil electrical properties are affected by lithology, pore fluid chemistry (natural waters versus leachate), and water content (Binley and Kemna, 2005). Field data is inverted to determine a suitable electrical resistivity/chargeability model of the subsurface at the profile location. Grellier and others, (2006) successfully utilized ER to image leachate recirculation within a landfill, thus leachate from the Pinewood Landfill likely represents a good target for these techniques.

An Advanced GeoSciences, Inc. (AGI) Sting R-8 (8-channel) resistivity meter can be used for ER/IP surveys. Each resistivity profile is recorded automatically utilizing an operator-defined data collection sequence programmed on the resistivity meter. Total line length and electrode spacing predict the anticipated depth of investigation and resolution, respectively. As a rule of thumb, ER/IP can reliably image up to a depth between 1/3 and 1/5 the total line length (e.g. 100 m line length will “see” 20 to 30 m deep). Anomalies smaller than the inter-electrode spacing are generally unresolved. As a feasibility check prior to mobilization, average resistivity values are assigned for the materials expected to be encountered during the collection of the resistivity data from available geological information (e.g. boring logs and cross-sections) generated from previous environmental assessment activities conducted at the site or published values for site materials. This information is entered into the AGI processing software in an effort to create a forward model of the expected resistivity profile results. For the Sting R-8, measurement accuracy is generally +/- 1%. The instrument flips the electric dipole several times and records multiple measurements for QA/QC purposes. Measurement standard deviation is recorded with the measurement. Measurement resolution is 30 nanovolts (nV). The instrument implements noise suppression at power line frequencies. Reciprocal measurements are made (flip voltage and current dipoles) to assess noise in the field.

AECOM proposes a pilot study to evaluate this technology. Two areas should be surveyed as part of the ER/IP pilot study. The ER/IP survey should be performed at the same location as the EM survey so both methods can be compared to each other and to background. Two ER/IP survey lines should be completed in each area. One survey line should be performed approximately 100 ft from the landfill boundary to minimize the potential for noise to be introduced into the inverse model, which assumes homogeneities into and out of the plane of the survey line. The second line should be located approximately 150 ft away from the first, farther out from the landfill boundary to detect potential for migration away from the landfill boundary. The length of the survey line should be approximately 275 m (56 electrodes with 5 m inter-electrode spacing). The depth of investigation is a function of the electrical resistivity structure, but generally achieves between 1/5 and 1/3 the total line spacing, which is between approximately 50 and 90 m. Two survey geometries should be collected at each line location; Wenner and Dipole-Dipole take advantage of the strengths of the two survey geometries. IP measurements (voltage decay) are performed immediately after the ER measurement, thus the two surveys at each location should be performed simultaneously.

5.2.3 Mise-a-la-masse Electrical Resistivity Method

The mise-a-la-masse electrical resistivity method is a mineral exploration technique that involves DC electric current application (injection) into a conductive body (e.g., landfill leachate) and measuring the resulting potential field distribution (Telford and others, 1990), effectively electrically illuminating the conductive body. In a homogeneous environment, the potential field falls off in a predictable manner as a function of distance from the current source. If a conductive body is present such as a leachate plume, the potential field will be skewed in a manner that follows the conductive body. Contour plots can be generated to map the potential distribution.

An AGI MiniSting resistivity meter can be used to perform these surveys. The near current electrodes can be embedded in leachate sumps within the landfill cell. The other current electrode is placed far away (beyond the conductive body) to simulate a pole source. A single potential electrode is moved around the site with the other being placed at a very large distance away. Stierman (1984) used this method to successfully identify a major leak from disposal pond in bedrock classified as impermeable. The landfill liners will not conduct the induced electrical current; therefore, the electrical potential field would not be measurable outside the landfill boundary. However, this method may be useful to identify a conductive plume originating from a breach in the landfill liner if the current electrode is placed within the landfill leachate and potential measurements are made outside the boundaries of the landfill. Escaping current will produce a potential field outside the landfill if the electrically resistive barrier (plastic liners) is punctured, torn, or otherwise compromised. The AGI MiniSting has similar resolution and accuracy characteristics to the Sting R-8.

AECOM proposes to implement mise-a-la-masse around the perimeter of landfill Section I. In addition to landfill Section I, a background survey should be performed adjacent to the landfill in southern portions of the site. Electrical measurements should be performed every 25 ft along transects measured parallel to the landfill boundary. If no current is escaping the landfill liner, then the potential measurements will be very small and incoherent. If leachate is present outside the landfill liner, current will follow the conductive leachate and create a coherent potential distribution beyond the landfill boundary that can be mapped.

5.2.4 Borehole Logging Methods

Geophysical borehole logging represents a suite of techniques which involve lowering a probe to measure earth properties as a function of depth in boreholes or existing monitoring wells at Pinewood. EM induction and gamma logging are two extremely useful and readily available well logging methods. Like ERT and surface EM techniques, EM induction logs are sensitive to contrasts in the electrical properties of subsurface materials. EM induction measurements are sensitive to variations up to a meter beyond the well casing. Gamma logging measures radiation emitted from natural sources. Clay units often emit natural gamma radiation. By incorporating both tools into a geophysical monitoring program, layers with similar electrical resistivity can be differentiated (e.g. clays versus sands saturated with conductive leachate). Mack (1993) successfully identified landfill leachate using natural gamma and EM induction logs in glacial deposits of Vermont. When used as a part of a long term monitoring strategy, lithology is not expected to change, thus changes in electrical resistivity of suspect layers may be attributed to changes in groundwater quality.

A Mt. Sopris system can be used to log and record vertical geophysical data in existing wells. The tool is attached by a wire cable to a winch mounted in the back of a truck. A digital counting mechanism records the depth of the tool while data from the down-well sensors are transmitted up the winch wire to a data logger. Logging can be performed in the up-well and down-well directions, and often both as a QA/QC procedure. Data from sequential logs can be directly compared to previous results without the need for extensive post processing procedures to see changes over time. The EM induction tool is accurate to within +/- 5% of full scale. Precision is +/- 0.02% of full scale. Generally, QA/QC procedures are employed by logging the borehole in the downward and upward directions.

AECOM proposes that multiple monitoring wells from the two areas of interest should be logged to develop a subsurface distribution of electrical resistivity. Monitoring wells OCS007 and OCS008 should be logged since elevated levels of zinc and chloride may indicate the potential for a release of leachate. In addition to these wells, monitoring wells screened within the same water bearing unit should be logged with EM induction and gamma to determine if impacts have migrated farther beyond these particular wells. Wells determined to be in background areas of the OCS should also be logged.

6.0 MONITORING PROGRAM OPTIMIZATION

This section provides recommendations for the optimization of the Pinewood Site LTM programs.

6.1 OPTIMIZATION STRATEGY FOR PROGRAM MANAGEMENT

The environmental monitoring program at the Pinewood Landfill is complex, consisting of multiple components, sampling frequencies, analytical testing programs, and reporting requirements. Optimization of the program should therefore go beyond recommending sampling, points, analytes and frequencies. The following section provides a structure that will allow the Trust to better control the management of the program, more easily identify current costs, and project and control future costs. The recommended program has been designed to control costs, while providing adequate data for the protection of the environment.

Over the history of the site, the monitoring program at the Pinewood Landfill has changed often and therefore, lacked long-term consistency. The overarching objective of this optimization is to create a monitoring program that is stable over at least a five-year period. The advantages of this approach are to:

1. Enable the construction and maintenance of consistent, high-quality databases, resulting in better, more accurate identification and interpretation of changes in site conditions; and
2. Provide a technical basis for management decisions and the accurate forecasting of future monitoring costs.

PROGRAM ORGANIZATION STRUCTURES

Typically, monitoring programs have been classified according to the following types:

- Detection Monitoring – used to detect releases from RCRA facilities.
- LTM – used to evaluate the performance of a remedy after a response action has been put in place.
- Characterization Monitoring – used to evaluate contaminant migration patterns and extent.
- Compliance Monitoring – used to assess movement of contaminants to designated compliance points.

While, detection and long-term monitoring have been performed routinely throughout the history of the site, the above classification does not address all of the needs of the Pinewood Facility. Based on review of the historical data, and familiarity with the site and the monitoring program, AECOM has developed a system that identifies and incorporates all of the elements of the Pinewood monitoring program.

The system developed divides the monitoring into two broad categories: long-term programs and short-term programs (Figure 6.1-1). In this case, the term long-term program does not refer to LTM as described above but rather is defined as any monitoring required for a minimum of five years, at which time, review and optimization will again be undertaken. These long-term programs will provide a stable basis for all future monitoring. Short-term programs are those that are required for specific purposes but will not last for more than five years.

The long-term programs can be further divided as follows:

- Water Table Monitoring – used to monitor effectiveness of the corrective measures constructed to control and mitigate groundwater contamination detected within the Water Table Aquifer and OCS sand lenses (source removal and installation of the SBDs). This program has been referred to as WT, WT Monitoring, or WTMP in the past.
- Detection Monitoring – used to monitor whether a release from any of the landfill sections is occurring.
- Operations Monitoring of Built Infrastructure – used to monitor such items as leachate characteristics, landfill-cap settlement, surface-water discharge regulated under NPDES requirements, etc.

Short-term programs can be divided as follows:

- Characterization Monitoring – short-term, characterization-monitoring programs are used to define the extent of contamination, migration patterns and pathways.
- Supplemental Monitoring – short-term supplemental-monitoring programs are used to collect additional data to support or verify results from a long-term program. For example, increasing the sampling frequency at a specific point or group of points to confirm a result from the LTM program (or other long-term program) would be classified as Supplemental Monitoring within this strategy.

Figure 6.1-1 illustrates the organizational structure described above. Short-term programs are shown separately from long-term programs. Though a particular short-term program may be related to a long-term program, they are not considered part of it. It is recommended that costs be tracked separately for each program in order to facilitate more accurate cost forecasting and planning.

OPTIMIZATION OF PROGRAM

In order to optimize each of the monitoring programs, AECOM developed:

1. Monitoring objectives;
2. Monitoring hypothesis; and
3. Decision rules.

Monitoring Objectives

Program objectives for monitoring are to (1) identify potential threats to human health and the environment (detection monitoring in this case), (2) evaluate the performance of the corrective measures (LTM), and (3) to evaluate the performance of the landfill built infrastructure (operations monitoring).

The WT LTM program (aka WTMP) should be designed to evaluate whether the interim corrective measures (FFB) is accomplishing its objectives (reduce or eliminate groundwater contamination). The detection monitoring program should be designed to identify changes in groundwater quality that may be a result of landfill release. Therefore the LTM should be based upon constituents of concern (COCs) while the detection monitoring program should be based on indicator parameters (identified in Section 4.0).

The Operations monitoring program includes leachate, settlement, storm water, FD, and NPDES permit monitoring. The objectives of each are dependent upon the sampling type. Leachate sampling is necessary to evaluate off-site treatment and disposal options. Settlement plate monitoring is necessary to evaluate the condition of the landfill covers over time, and NPDES monitoring is a permit requirement necessary for surface-water discharge to Lake Marion. Storm water monitoring is necessary to characterize runoff that might be leaving the property and FD monitoring is necessary to evaluate the performance of the landfill caps and liners. FD sampling may also provide useful information for monitoring groundwater (WT and DM programs) as the systems dewater the Water Table Aquifer.

Monitoring Hypothesis

A hypothesis is a proposition set forth as an explanation for observable facts. AECOM's hypotheses described in the subsections below provide a point of view that guides the development of the monitoring programs. Data collected during the monitoring program provides the information necessary to determine whether or not a specific hypothesis is true or false.

Decisions Rules

Decision rules were primarily developed to aid in understanding when monitoring activities need to be modified or stopped.

The type of decision rule used in developing logic for monitoring programs is formulated as an **if/then statement** that specifies the conditions under which a specific action will be undertaken. For example, a general decision rule can be formulated to govern the overall selection of a monitoring point, or analyte for inclusion in a long-term program. This **decision rule** is as follows: If data from a monitoring point or the inclusion of an analyte is necessary for a minimum five years to accomplish objectives, then it should be included in the appropriate long-term program.

> If data from a monitoring point or the inclusion of an analyte is necessary for a minimum five years to accomplish objectives, then it should be included in the appropriate long-term program.

Short-Term Versus Long-Term

Short-term programs include characterization and supplemental monitoring. Characterization monitoring should be used to assess the extent of contamination or determine if a potential source exists (and if so identify it). Supplemental monitoring should be used to collect additional data, usually on a shorter frequency for LTM (5 years). Prior to undertaking a short-term program, specific objectives should be defined. Decision rules for when the program should be terminated should be developed [such as all analytes are below maximum contaminant levels (MCLs) for two consecutive sample events]. In addition, decision rules defining the criteria for including all or part of a short-term program in a long-term program should also be developed. A monitoring location or increased sampling frequency for a specific point should be added to a long-term program only if it is necessary to detect a release or monitor the migration of an existing plume over a long period of time. Reduction in sampling frequency might be applicable when an existing plume is shown to be stable and/or all concentration trends are decreasing. An increasing trend could trigger increased sampling frequency until the trend reverses or becomes stable.

If characterization monitoring moves to a long-term program, contaminants of specific concern will have been identified and the number of analytes can then be reduced. The spatial distribution of contaminants has also been defined so the number of monitoring points can be reduced, along with the sampling frequency. Since the objectives and decision rules governing short-term programs are different from long-term monitoring, they should be viewed separately.

Figure 6.1-2 illustrates the use of monitoring objectives and decision rules. This logic flow chart is not intended to be all-encompassing but rather provides guidelines for using these tools to govern short-term programs. The decision rules developed for these programs should define the conditions under which all or part of the short-term monitoring should be included in a long-term program and also define the conditions under which the short-term monitoring will be terminated. The results of each monitoring event (or group of events if appropriate) should be compared to the program objective to determine if the monitoring meets the intended purpose. It should also be compared to the decision rule to determine if another sample should be collected.

We recommend that the data from these programs be entered into the database. However, a field should be included in the database stating what type of program the data was generated from (i.e.: characterization, supplemental, LTM, detection monitoring or operations monitoring). In this way, all of the data can be accessed, as needed, and analyzed in the future with the understanding that the objectives of the data are different. The concepts described above have been used in the following presentation of the optimization. The optimized LTM Program is summarized in Appendix D.

6.2 WATER TABLE LTM PROGRAM

The structure of the current WT LTM program is discussed in Section 3.0. Section 6.2.1 describes the proposed optimization of this program and a summary of the WT LTM program is provided in Table 6.2-1.

6.2.1 Description of the Corrective Measures

Prior to construction of Section I, contaminants were introduced into the Water Table Aquifer from previous operations (mining of the OCS) via an open pit for waste-oil solidification. These contaminants consisted of VOCs and metals. A large portion of the contaminated “hot-spot” area was excavated and the soils disposed of during construction of the FFB, which is used to collect storm water runoff from most of the site. The excavation went to a depth below the Water Table Aquifer sands and two sand lenses within the upper part of the OCS. A sand blanket and network of drains were installed in the bottom and along the side walls of the FFB excavation (SBDs). The FFB was then lined to prevent storm water from mixing with contaminated groundwater and thus, potentially requiring treatment. The groundwater from the SBDs is collected at sumps and pumped to one of two aeration basins for treatment for VOCs (if needed). The corrective measures removed contaminated soils that likely would have been a continuing source of contaminants to groundwater, and captures contaminated groundwater at the SBDs.

6.2.2 Monitoring Objective

The major objective of the WT LTM is to monitor the effectiveness of the interim corrective measures.

6.2.3 Monitoring Hypothesis

The system of SBDs beneath the FFB controls groundwater flow within the Water Table Aquifer and captures contamination migrating from up-gradient before a release from the site can occur. The impacts of the SBDs are discussed in Section 2.0.

6.2.4 Constituents of Concern

VOCs and metals associated with the OCS mine have been detected in wells near the “hot-spot”. The VOCs are PCE, TCE and related daughter products. Metals have been detected above MCLs in groundwater. Table 6.2-2 presents a summary of this data. Only one metal, mercury, exceeded the MCL in more than ten percent of the samples (at WT008). However, as discussed in Section 4.0, mercury detects are within the range of the laboratory blanks and therefore, the data is not definitive and cannot be used for decision purposes. Mercury did not exceed the MCL in any other well in this program. Not all metals sampled exceeded standards and those that did exceeded in less than ten percent of the samples. Selenium exceeded only at well WT027 in five percent of the samples. For these reasons it is not included in the list of COCs. NOTE: As shown in Table 6.2-1, concentrations in groundwater from several wells exceeded their respective metals screening criteria in November 2009. This event appears to be an anomaly and the data was not considered when identifying metals COCs.

Based on these data, the metals COCs are: cadmium, chromium, lead and arsenic.

LONG-TERM MONITORING ACTIVITIES

6.2.5 Water Table Long-Term Monitoring Wells

Because of the nature of the corrective measures and the induced groundwater flow in the Water Table Aquifer and OCS, it is unlikely that contaminants in the vicinity of wells WT008 and OCS002 will migrate past the FFB, since the basin is excavated to elevations below those of the OCS sands. Therefore, quarterly sampling of the WT down-gradient of the FFB is unnecessary.

> If it is determined that the trends indicate that the plume is either stable or decreasing, reduce the sampling frequency for wells WT008 and OCS002 to annually.

AECOM completed statistical trend analysis on WT monitoring wells WT008 and OCS002 using the Air Force Center for Engineering and the Environment (AFCEE) Monitoring and Remediation Optimization System (MAROS) software statistical analyses (AFCEE, 2006). The software was used to conduct linear regression and Mann Kendall trend analyses and the results are presented in Appendix C. Based on both linear regression and Mann Kendall statistical trend analyses, the trends for PCE, TCE and cis-1,2-DCE are increasing at the two wells mentioned above. Therefore, these two wells should be sampled quarterly for the VOCs listed as COCs. **Decision rule:** If it is determined that the trends indicate that the plume is either stable or decreasing, reduce the sampling frequency for wells WT008 and OCS002 to annually.

Wells WT026, OCS006A and OCS006B should be sampled to evaluate whether VOCs are migrating from the area of well WT008. These wells should be sampled annually for the VOCs identified as COCs. Well

WT032 should be sampled annually for the same constituents to evaluate whether contaminants are migrating toward the Section I FD.

An effective and economical way of monitoring whether groundwater bypasses FFB would be to sample surface water at the head waters of the outfall channel. However, storm water discharges and discharges from the aeration basins make this approach problematic. Therefore, well WT030 should be sampled for all COCs on an annual schedule. **Decision rule:** If it is determined that the plume is either stable or shrinking, discontinue sampling wells WT026, WT030, OCS006A and OCS006B.

If it is determined that the plume is either stable or shrinking, discontinue sampling wells WT026, WT030, OCS006A and OCS006B.

If the current flow patterns are maintained, any contaminants potentially migrating toward wells OCS005, OCS008, OCS011 and WT027 will be captured by the SBDs. Therefore, it is recommended that these wells be eliminated from LTM.

6.2.6 Sand Blanket Drains

The monitoring of the interim corrective measures should continue by sampling the discharges from the SBDs (SBD#1 and SBD#2) on a quarterly basis. The purpose of this sampling is to evaluate when PCE contamination that has been increasing since 2009 at well WT008 reaches the FFB. This result should be indicated by a decrease in concentrations at well WT008 followed by an increase in concentrations in SBD#1 and/or SBD#2. Once concentration trends in the discharges from the SBDs have stabilized (based on statistical analysis), sampling can be decreased to semi-annual and possibly to annual.

6.2.7 Section I French Drain

The Section I FD runs part way around Section I. Since this drain likely creates a depression in the WT, it may be possible that contaminants from the SWMU could migrate through this drain around the SBDs. Sample this drain for identified VOCs on an annual basis. **Decision rule:** If it is determined that the plume is stable or shrinking, discontinue sampling the Section I FD. Currently, this drain is sampled monthly. This monitoring should be considered supplemental and discontinued when sufficient data have been collected.

If it is determined that the plume is stable or shrinking, discontinue sampling the Section I FD.

The water level monitoring frequency should be the same as the sampling frequency. A summary of the WTMP LTMO is provided below and monitoring locations are illustrated on Figures 6.2-1 and 6.2-2 for the WT and OCS, respectively.

Sample Location	Sampling Frequency	Analytical Protocol
WT008 and OCS002	Quarterly	VOCs and Metals
WT026, WT032, OCS006A and OCS006B	Annual	VOCs
WT030	Annual	VOCs
SBD#1 and SBD#2	Quarterly	VOCs
FD - Sec I	Annual	VOCs

Notes:

VOCs – PCE, TCE, cis-1,2-DCE, vinyl chloride (VC)
Metals – Cadmium, Chromium, Lead and arsenic

SHORT-TERM MONITORING ACTIVITIES

6.2.8 Characterization Monitoring

Contaminants from the old SWMU have been detected at wells WT008 and OCS002. The highest concentrations are at well WT008. This area is near an excavation in Section III where a hot-spot soil removal occurred. It is likely that the contamination detected in these two wells is a localized plume that could be the result of the excavation and/or the changes in groundwater flow directions after construction of the FFB. A characterization monitoring program that includes ten new wells installed in 2010 is currently under way to evaluate groundwater quality in this area. These wells are not considered part of the WT LTM program and decision rules for including any portion of this program in the LTM should be developed. Assuming quarterly sampling, a suggested **decision rule** is as follows: If samples from any of the new wells indicate that COC concentrations are above MCLs, include them in the LTM program. An additional decision rule for including a characterization monitoring well is given in Section 6.2.8 - Perimeter FDs.

If samples from any of the new wells indicate that concentrations are above MCLs, include them in the LTM program.

6.2.9 Perimeter French Drains

The perimeter FD runs around the perimeter of the property and are generally either up-gradient, side-gradient, or on the other side of the landfill sections. Based on the data available thus far, samples from these outfalls provide no useful information regarding the migration of the COCs related to the “hot-spot”. Therefore they should be dropped from the LTM program unless new data collected during the characterization monitoring program indicates that there is a groundwater flow direction from the area of contamination toward the drains. **Decision rules** for including the perimeter FDs in the WT LTM can be

If water level data indicate that there is a flow direction from well WT008 toward the perimeter drains and there are insufficient monitoring wells to detect contaminant migration, then resume sampling outfall at Pond B for the VOCs identified as COCs on a quarterly basis until trends have been established.

formulated as follows: If water level data indicate that there is a flow direction from well WT008 toward the perimeter drains and there are insufficient monitoring wells to detect contaminant migration, then resume sampling outfall at Pond B for the VOCs identified as COCs on a quarterly basis until trends have been established. If the data indicates stable or decreasing trends, then monitor outfall at Pond B on an annual basis. These decision rules assume that the necessary data will be collected during the recently begun characterization monitoring. An additional **decision rule** for including a characterization monitoring well in the LTM is as follows: If a characterization monitoring well is between well WT008 and the perimeter FD and it is shown by water level measurements to be down-gradient of well WT008, include this well in the LTM program.

6.2.10 Pond A and Section I French Drain Manholes

Currently, Pond A, downstream of the SBDs, and five manholes in the Section I FD are sampled as part of the WTMP. Pond A should be eliminated from this LTM since it is unlikely that contamination will pass the SBDs and if so, probably will not be detected since this is a large pond. Sampling of Pond A should be considered part of surface water and storm water monitoring. Very low VOC concentrations have been detected in Manhole 5 of the Section I FD. These concentrations are likely the result of gas migration from the Section I cap. Sampling of five manholes is being done as part of the WT LTM. This sampling should be removed from the LTM and considered part of a short-term program designed to evaluate the condition of the cap.

6.3 DETECTION MONITORING PROGRAM

The DM Program described in Section 3.0 is a long-term program to evaluate the design performance of the landfill system. Indicator parameters, chloride and 1,4-dioxane (Section 4.0), were screened, evaluated and developed for recommended use in the future DM Program. This section presents the optimization of this program based on site-specific indicator parameters and the current groundwater hydraulics. Table 6.3-1 summarizes the DM LTMO and DM sampling locations and these are illustrated on Figures 6.3-1 through 6.3-4. The fourth quarter 2009 water level data was used to develop groundwater potentiometric surface contour maps to determine the downgradient direction of water bearing units beneath each landfill cell. The maps show locations for new proposed monitoring wells and also highlight (in blue) DM LTMO well locations.

6.3.1 Monitoring Objective

To determine if a leachate release has occurred from any of the three landfill sections to groundwater.

6.3.2 Monitoring Hypothesis

The landfill containment structures and the geologic formation into which the landfill sections were excavated are sufficient to prevent a release of landfill contents to groundwater.

6.3.3 Constituents of Concern

The landfill accepted a variety of waste materials that includes a wide range of chemicals and materials of differing composition. Based on the screening and detailed analyses of common constituents found in leachate collected from all three landfill Sections, chloride and 1,4-dioxane have been selected as indicator COCs to monitor the potential future release of landfill contents to groundwater.

LONG-TERM MONITORNIG ACTIVITIES

6.3.4 OCS Monitoring Wells

Quarterly water level monitoring is recommended for all OCS monitoring wells and no new wells are recommended in the OCS. OCS wells screened in sand lenses within the OCS are included in the WT LTMO as described in Section 6.2. OCS groundwater sampling for analytical testing is not included in the DM LTMO.

6.3.5 TLS Monitoring Wells

Quarterly water level monitoring is recommended for all TLS monitoring wells. A total of five (5) new monitoring wells are proposed in the TLS (Figure 6.3-1) at the locations described below for both characterization monitoring (hydraulic evaluation) and DM LTMO.

Well Location	Number of Wells	Rationale	Monitoring Program
Northern Perimeter of Landfill Section II	2	To evaluate hydraulic properties along the northern perimeter of Section II.	Hydraulic Characterization
Northeast Perimeter of Landfill Section III	2	To evaluate hydraulic properties along the northeastern perimeter of Section III and groundwater quality hydraulically downgradient of landfill Section III.	Hydraulic Characterization and DM
Paleo-channel	1	To evaluate hydraulic properties within the paleo-channel in the southeastern portion of the property.	Hydraulic Characterization

DM sampling locations in the TLS are illustrated on Figure 6.1-3. A groundwater divide is present within the TLS across landfill Sections I and II that is oriented southeast-northwest. The flow direction east of the divide is primarily toward the northeast and flow west of the divide is toward the southwest. Since a groundwater divide transects landfill Sections I and II, there are two hydraulic downgradient directions for each cell. The downgradient direction for landfill Section III is toward the northeast.

6.3.6 SSDL Monitoring Wells

Quarterly water level monitoring is recommended for all SSDL monitoring wells. A total of six (6) new monitoring wells are proposed in the SSDL at the locations described below.

Well Location	Number of Wells	Rationale	Monitoring Program
Northeast Perimeter of Landfill Section III	3	To evaluate hydraulic properties along the northeastern perimeter of Section III and groundwater quality hydraulically downgradient of landfill Section III.	Hydraulic Characterization and DM
Paleo-channel	3	To evaluate hydraulic properties within the paleo-channel in the southeastern portion of the property.	Hydraulic Characterization

DM sampling locations in the SSDL are illustrated on Figure 6.3-2. The primary flow direction in the SSDL is toward the northeast and DM wells are located hydraulically downgradient of each landfill Section. A groundwater divide is present similar to the overlying TLS; therefore, several DM LTMO wells are located on the southwest perimeter of landfill Sections I and II. All six new wells described above will be used to evaluate the hydraulic characteristics of the paleo-channel and off-site groundwater withdrawal, and three wells will be incorporated into the DM LTMO to monitor groundwater quality hydraulically downgradient of landfill Section III.

6.3.7 PSDL Monitoring Wells

Quarterly water level monitoring is recommended for all PSDL monitoring wells. A total of seven (7) new monitoring wells are proposed in the PSDL at the locations described below.

Well Location	Number of Wells	Rationale	Monitoring Program
East of Landfill Section I	1	To evaluate hydraulic properties and groundwater quality hydraulically downgradient of landfill Section I.	DM

Well Location	Number of Wells	Rationale	Monitoring Program
North and East Perimeter of Landfill Section III	4	To evaluate hydraulic properties along the north and east perimeters of landfill Section III and groundwater quality hydraulically downgradient of landfill Section III.	Hydraulic Characterization and DM
Paleo-channel	2	To evaluate hydraulic properties within the paleo-channel in the southeastern portion of the property.	Hydraulic Characterization

DM sampling locations in the PSDL are illustrated on Figure 6.3-3. The gradient of the PSDL is relatively flat; however the primary flow direction in the PSDL is toward the south and southeast and DM wells are located hydraulically downgradient of each landfill Section (east perimeters). Two of the seven new wells described above will be used to evaluate the hydraulic characteristics of the paleo-channel and off-site groundwater withdrawal, four new wells will be incorporated into the DM LTMO to monitor groundwater quality hydraulically downgradient of landfill Section III, and one new well will be incorporated into the DM LTMO to monitor groundwater quality hydraulically downgradient of landfill Section I.

6.3.8 UBC-A Monitoring Wells

Quarterly water level monitoring is recommended for all UBC-A monitoring wells. A total of two (2) new monitoring wells are proposed in the UBC-A at the locations described below.

Well Location	Number of Wells	Rationale	Monitoring Program
Paleo-channel	2	To evaluate hydraulic properties within the paleo-channel along the southeastern property boundary	Hydraulic Characterization

DM sampling locations in the UBC-A are illustrated on Figure 6.3-4. The primary flow direction in the UBC-A is toward the north and east and DM wells are located hydraulically downgradient of each landfill Section. The two new wells described above will be used to evaluate the hydraulic characteristics of the paleo-channel and off-site groundwater withdrawal.

SHORT-TERM MONITORING ACTIVITIES

Currently, there are no short-term monitoring activities on-going are recommended as part of the DM program.

6.4 OPERATIONS MONITORING PROGRAM

The purpose of the Operations Monitoring Program (OMP) is to monitor operation and performance of built infrastructure.

PSCT is currently performing monitoring that falls under this program. Much of this monitoring is beyond the scope of this report such as leachate pumping, leachate sampling and analysis, volume of leachate being transported off-site, etc.

Several of the recommendations included in the *Volume 1, Projects 1 and 2 - 2010 Pinewood Site Improvement Projects Report* (AECOM, February 2011) fall under the OMP. NOTE: Some of the recommendations have been modified as part of the optimization process. Some of the recommended monitoring would be part of the LTM Program (at least 5 years) and some are short-term activities related to characterizing the source of VOCs in the Section I FD. Operations monitoring have been segregated into two categories listed below.

Long-Term Monitoring Activities

- PVC Geomembrane
- Leachate generation rate
- Landfill cover settlement
- FDs
- Storm water
- Surface water (NPDES permit)

Short-Term Monitoring Activities

- Soil gas
- Shallow cover wells
- Section I FD

The objectives and hypothesis that lead to LTMO recommendations are outlined below. Applicable decision rules are provided to guide in determining when to eliminate these monitoring activities or make them part of the long-term monitoring program.

Table 6.4-1 provides more detailed information regarding the recommended monitoring requirements described below.

6.4.1 LONG-TERM MONITORING ACTIVITIES

6.4.1.1 *PVC Geomembrane Monitoring*

Recommendation – Re-evaluate the cover geomembrane at five year intervals.

Objective – Determine if the condition of the geomembrane is still adequate for continued service.

Hypothesis – The geomembrane thickness and elasticity are adequate to serve as a barrier to surface water infiltration and contaminant exfiltration.

6.4.1.2 *Leachate Generation Rate Monitoring*

6.4.1.2.1 Leachate Generation Versus Rainfall Trends

Recommendation – Compare leachate generation rate trends to rainfall rates annually.

Objective – Determine if there is evidence that rainfall infiltrating the cover is a significant contributor to volume of leachate being generated.

Hypothesis – The leachate being generated is the result of infiltration of surface water through the landfill cover system.

Decision Rule – If correlations between rainfall and leachate generation do not develop within 5-years and the landfill cover is still in good condition, or if another cause of the high leachate generation rates is identified, this monitoring could be discontinued.

6.4.1.2.2 *Leachate Generation Versus Groundwater Surfaces*

Recommendation – Compare leachate generation rate trends to changes in groundwater surface elevations and potentiometric surfaces.

Objective – Determine if there is evidence that groundwater infiltrating through the landfill liner system is a significant contributor to volume of leachate being generated.

Hypothesis – The leachate being generated is the result of infiltration of groundwater through the landfill liner system.

Decision Rule – If correlations between groundwater surface elevations and leachate generation do not develop within 5-years or if another cause of the high leachate generation rates is identified, this monitoring could be discontinued.

6.4.1.3 *Landfill Cover Settlement Monitoring*

6.4.1.3.1 *Installing Additional Settlement Markers*

Recommendation – Install seven (7) new settlement markers. See Figure 6.4-1 for proposed location of the new markers.

Objective – Obtain more complete settlement information via a more uniform distribution of settlement markers.

Hypothesis – Settlement could be occurring in locations where settlement is not currently being monitored.

6.4.2 Defining Settlement Surveying QA/QC Requirements

Recommendation – Employ more rigorous survey requirements (turning on each marker rather than taking sides shot to allow checking of survey loop closure, verification same datum is used each time, verifying the same location on the marker is used each time, etc.)

Objective – Obtain more consistent and accurate data.

Hypothesis – Inconsistent data may be leading to an inaccurate understanding of settlement.

6.4.3 Monitoring Settlement Data

Recommendation – Surveying the settlement marker elevations and graphing the data to identify notable increases in settlement.

Objective – Identify any localized settlement that could jeopardize the integrity of the cover system.

Hypothesis – Significant localized settlement could result in additional stress on the cover components leading to a breach in the cover or increased infiltration.

6.4.4 French Drain Monitoring

Recommendation – Sample outfalls of Section I FD and Perimeter FD in Ponds A and B. See Figure 6.4-2 for proposed FD sampling locations.

Objective – Determine if landfill constituents are reaching the FDs.

Hypothesis – Landfill constituents could be diffusing out of the landfill into the WT where they are captured by the FD system.

6.4.5 Storm Water Monitoring

Recommendation – Monitor four new sampling locations that contribute to Pond A and the two storm water outfalls into Pond B. See Figure 6.4-3 for proposed storm water sampling locations.

Objective – Determine if any storm water contaminants from landfills are discharging into Pond A and Pond B.

Hypothesis – Storm water may be one of the sources of contaminants discharging from Pond A or Pond B.

Decision Rule – If constituents are consistently detected above MCLs, supplemental sampling should be performed to identify source.

6.4.6 Surface Water Monitoring

Recommendation – Monitor Outfalls 001, 002 and 01A per the NPDES permit requirements. See Figure 6.4-3 for proposed surface water sampling locations.

Objective – Determine compliance with the NPDES permit.

Decision Rule – If constituents are consistently above NPDES Permit limits, additional monitoring or treatment may be required.

6.4.7 SHORT-TERM MONITORING ACTIVITIES

The following monitoring activities are related to the objective of characterizing of the source of the VOCs detected in the Section I FD Manholes 4 and 5.

Hypothesis – The source of the VOCs is vapors diffusing through the cover of the Section I landfill.

6.4.8 Soil Gas Investigation

6.4.8.1 *Soil Gas Monitoring Adjacent to Section I*

Recommendations – Install 14 reusable soil gas point around to the Section I cover adjacent to soil gas hot spots on the cover. See Figure 6.4-4 for locations. Point to be installed three depths, 2 ft, 5 ft and 8 ft. Approximately 1/3 of the point in each location should be installed at each depth.

Objective – Determine if soil gas from hot spots on the cover the landfill is migrating beyond the landfill. Points are to be installed at differing depth to help profile the results and determine if soil gas is from the cover or from the side wall of the landfill.

Hypothesis – The source of VOC constituents in Manholes 4 and 5 is soil gas resulting from diffusion through the Section I landfill cover.

Decision Rule – If the hypothesis is confirmed the sampling frequency of Manholes 4 and 5 can be reduced to annual and made part of the long-term monitoring activities. If the hypothesis is not confirmed continue quarterly sampling of Manholes 4 and 5 until the source is confirmed.

Decision Rule – If the investigation indicates that the soil gas is at depths of 5 ft or 8 ft additional investigation to confirm the source of the soil gas should be considered.

6.4.8.2 *Soil Gas Monitoring on Section I*

Recommendation – Install 18 reusable soil gas points on Section 1. See Figure 6.4-4 for locations.

Objectives – Evaluate trends of soil gas diffusion through cover.

Hypothesis – Soil gas is not migrating off cover so as to impact groundwater or surface water.

Decision Rule – If soil gas diffusion is not impacting surface water or groundwater reduce, to annual sampling.

6.4.9 Shallow Groundwater Monitoring

Recommendations – Install four (4) monitoring wells (Figure 6.2-1) around to the Section I cover adjacent to soil gas hot spots on the cover. Install one (1) monitoring well in a less impacted location as a control well. The wells should be screened in the Water Table Aquifer. Well should be samples quarterly and analyzed for VOCs, chloride, and 1,4-dioxane. See Figure 6.4-4 for well locations.

Objective – Determine if soil gas is migrating from the landfill and impacting the Water Table Aquifer.

Hypothesis – The Water Table Aquifer adjacent to soil gas vapor hot spots are being impacted by VOCs.

Decision Rule – Any wells impacted by contaminant constituent would be incorporated into a long-term WTMP.

Decision Rule – If any wells are impacted by chloride or 1,4-dioxane additional characterization would be required to identify the non-vapor source.

Decision Rule – If the wells are only impacted by VOCs only those wells would continue to be monitored quarterly until they are shown to be stable or decreasing at which time they would be transferred to the long-term WTMP.

6.4.10 Shallow Cover Well Monitoring

Recommendation – Five shallow cover wells and one (1) background well should be sampled quarterly for chlorides, 1,4-dioxane, and RCRA metals. See Figure 6.4-5 for well locations.

Objective – Determine if constituents are indicative of vapors only or show indications of leachate that may related to leachate management spills or leaks.

Hypothesis – Ongoing source of VOCs in shallow cover wells is vapor diffusing through the cover.

Decision Rule – If the hypothesis is confirmed the sampling can be stopped. If the hypothesis is not confirmed then the sampling may need to continue to assist in defining the ongoing source of non-vapor related constituents.

6.4.11 Section I French Drain Monitoring

Recommendation – Sample Manholes 4 and 5 quarterly for VOCs, chlorides and 1,4-dioxane. See Figure 6.4-2 for location of Manholes 4 and 5.

Objective – Determine if constituents are indicative of vapors only or show indications of leachate.

Hypothesis – The source of the VOCs in the Section I FD is vapors diffusing through the Section I cover.

Decision Rule - If the hypothesis is confirmed the sampling can be stopped. If the hypothesis is not confirmed then the sampling may need to continue to assist in defining the ongoing source of non-vapor related constituents.

7.0 OPTIMIZED MONITORING PROGRAM RECOMMENDATIONS

AECOM's LTMO has resulted in the following recommendations for future management of the Pinewood Site.

1. A facility-wide SAP should be prepared that describes each current LTM program, program objectives and decision rules. As described in Section 3.0, the 2003 SAP is out of date and does not include modifications to the monitoring program since its development. The facility-wide SAP can be amended to include short-term programs describing objectives and decision rules. The SAP should be evaluated annually and updated, as needed.
2. A facility-wide Quality Assurance Project Plan (QAPP) should be prepared to govern all environmental sampling at the facility. Achievable but adequate quantitation limits (QLs) should be established, particularly for metals. The QAPP should be evaluated annually and updated, as needed.
3. Conduct an audit of the analytical laboratory to rectify data quality deficiencies (e.g., target COC analytes in laboratory blank samples).
4. During future collection and testing of water quality samples, AECOM recommends periodic analysis of quality assurance split samples, blind audit samples and reference samples by an independent laboratory to permit an unbiased evaluation of laboratory proficiency.
5. Segregate the monitoring programs in accordance with the following structure:
    - LTM – used to monitor of the corrective measures constructed to control and mitigate groundwater contamination detected within the Water Table Aquifer (source removal and installation of the SBDs). This program has been referred to as WTMP.
    - Detection Monitoring – used to monitor whether a release from any of the landfill sections is occurring.
    - Operations Monitoring of Built Infrastructure – used to monitor such items as leachate characteristics, landfill-cap settlement, surface-water discharge regulated under NPDES requirements, etc.
    - Characterization Monitoring – short-term, characterization-monitoring programs are used to define the extent of contamination, migration patterns and pathways, such as the assessment of the "Hot-Spot" area.
    - Supplemental Monitoring – short-term supplemental-monitoring programs are used to collect additional data to support or verify results from a long-term program. For example, increasing the sampling frequency at a specific point or group of points to confirm a result from the LTM (or other long-term program) would be classified as Supplemental Monitoring within this strategy.

6. Background concentrations for metals in groundwater should be established and used for comparison to future metals groundwater quality data.
7. The numerical flow and transport model should be updated to reflect the changed Site conditions. The updated model should be able to better simulate the effects of infrastructure such as French drains and off-site groundwater withdrawal since much more detail is available now than when model was first constructed in 2002. The updated model will also simulate the capture zone of the SBDs.
8. There is a correlation between constituents detected in soil gas and shallow cap water at landfill Section I. This indicates a potential transport pathway from soil vapor to water ponded on top of, and within, the landfill cover soils. Perched water may migrate laterally off the cap into the Water Table Aquifer. Therefore, to test this hypothesis, install four (4) water table monitoring wells along the perimeter of landfill Section I adjacent to areas exhibiting elevated VOCs in soils.
9. Install a total of five (5) new wells in the TLS zone to evaluate groundwater hydraulics at all locations, including the paleo-channel, and monitor groundwater quality hydraulically downgradient of landfill Section III.
10. Install a total of six (6) new wells in the SSDL zone to evaluate groundwater hydraulics at all locations, including the paleo-channel, and monitor groundwater quality hydraulically downgradient of landfill Section III.
11. Install a total of seven (7) new wells in the PSDL zone to evaluate groundwater hydraulics at six of the seven locations, including the paleo-channel, and to monitor groundwater quality hydraulically downgradient of landfill Sections I and III.
12. Install two (2) new wells in the Upper Black Creek – Unit A to evaluate groundwater hydraulics in the paleo-channel.
13. The paleo-channel has been studied extensively by numerous investigators; however; the hydraulic characteristics of the paleo-channel and its influence on groundwater flow during natural and pumping conditions is not fully understood. A 12 month supplemental groundwater hydraulic evaluation program should be implemented to determine the predominant groundwater flow direction in the DM water bearing zones resulting from seasonal water level variations and periods of off-Site groundwater withdrawal. The objectives of this study are to: 1) evaluate annual variations of the groundwater flow directions and gradients; 2) determine the predominant groundwater flow direction beneath the landfill Sections; and 3) obtain the necessary data to update the numerical flow and transport model. In order to achieve this objective, the following should be performed:
    - Install pressure transducers and data-loggers in the monitoring wells listed below for a period of 12 months to obtain long-term water level data. Data loggers can be synchronized and data can be collected twice daily for the duration of the study. Data from each datalogger can be downloaded monthly during the 12-month hydraulic assessment period for interim data analysis.

Hydraulic Evaluation Wells

Water Bearing Unit	Monitoring Well Identification
TLS (8)	MW097T, P114D, P112D, MW101T, MW098TR, New Wells (3)
SSDL (11)	MW001, MW102S, MW038SR, MW09SR, New Wells (6), MW135S
PSDL (13)	MW077P, MW103P, New Wells (6), MW095P, MW093PR, MW094PR, MW091PR, MW125P
UBC-A (9)	UBC024, UBC034, P042B, UBC021, UBC025, UBC027, UBC028AR, New Wells (2)
Total 41	

- Obtain local precipitation data from the National Climatic Data Center (nearest Weather Station) during the 12-month study to correlate to groundwater level data to evaluate aquifer recharge/discharge beneath the site. Alternatively, collect Site-specific precipitation data using digital self-purging electronic rain gauges strategically located on-Site.

14. The VOC Headspace Monitor is recommended for implementation at Pond A and/or Pond B outfalls to monitor the surface water discharge for VOC release events from the site. Presently, a potential release could only be detected during routine monthly NPDES sampling. Continuous monitoring would add another level of assurance that the receiving waters of Lake Marion are being protected. If this technology is considered for deployment at the Pinewood site, a field pilot study is recommended at one location to verify the compatibility of this technology under actual site conditions.

15. Additional "baseline" data are needed to allow chemical interpretation using standard methods such as Piper or Stiff diagrams, and to use pattern recognition methods such as factor and cluster analysis to understand water variations between aquifers and water-matrix interactions along flow paths. Some of the data may already be available from GEL's Laboratory Information Management Computer System (LIMS), [i.e., SW-846 Method 6010B by Inductively Coupled Plasma (ICP) is a multi-element analysis and therefore, additional inorganic results (cations) may have been obtained as part of the standard analytical suite but not reported]. The following parameters should be acquired from each water bearing unit in the DM program: Major cations: calcium, magnesium, potassium, sodium; Major anions: alkalinity, chloride (already analyzed/reported), and sulfate. Analysis for elemental metals is also recommended to fingerprint the water bearing units and to develop a baseline metals data set for groundwater to compare to future monitoring data.

16. AECOM recommends the use of in well sondes in new wells installed in the TLS along the northern perimeter of landfill Section II. This area is recommended because it is hydraulically downgradient of landfill Section II and the close proximity of landfill Section II to the northern property boundary. In well sondes can be powered by either an internal battery or solar cell and data can be downloaded daily (if necessary) to monitor perimeter groundwater indicators.

17. Implement WTMP and DM LTMO in accordance with recommendations provided in Section 6.0. Analytical testing should be reduced to WTMP COCs (VOCs and metals) and DM indicator parameters (chloride and 1,4-dioxane).
18. Forward geophysical modeling for site-specific scenarios is recommended based on historical site-specific resistivity values. Forward models allow practitioners to assess the utility of various geophysical methods prior to engaging in field activities for a particular problem. Additionally, various data collection strategies (e.g. electrode spacing, survey geometry) can be tested in forward models. To perform a forward model, the subsurface resistivity distribution is defined and a synthetic geophysical survey is performed. The data set is then inverted using specialized geophysical software to recover the defined subsurface resistivity distribution. This can be performed for impacted/non-impacted scenarios to compare the expected responses and assess method resolution, and sensitivity to the expected anomalies.
19. Pilot-scale studies are recommended along the perimeter of landfill Section I using the geophysical and electrical techniques described in Section 5.0 to assess the feasibility of identifying potential future leachate releases outside the landfill perimeters. An EM survey can be completed within/off the landfill boundaries to determine whether leachate is migrating from a particular cell. ER/IP imaging can be performed adjacent to the landfill boundary and in an off-site or background location. As part of the pilot-study, several survey geometries (e.g. Wenner, Schlumberger, Dipole-Dipole) should be tested since all offer various advantages with respect to sensitivity as a function of depth and resolution of suspected anomalies. IP measurements should be included as part of a Dipole-Dipole survey to reduce the likelihood of interference from electromagnetic coupling (Sharma, 2002). A *Mise-a-la-masse* survey is recommended at landfill Section I. The roving potential electrode should collect data within the landfill cell and outside the landfill boundaries. By incorporating the use of multiple geophysical methods (e.g. a surface method with borehole logging) in one area at the Site, geophysical data can be compared and correlated to geologic, hydrogeologic and groundwater quality data so that multiple lines of evidence can be formulated to support the CSM. Based on the results of the site-wide geophysical monitoring techniques, determine if these monitoring techniques are appropriate as supplemental lines of evidence for the WTM or DM programs.
20. Expenditures should be tracked separately for individual parts of the environmental monitoring program, as described herein. Long-term and short-term program costs can then be compared to determine whether costs are reasonable. Short-term program cost should ideally be reduced to zero over a period of time. This cost-tracking procedure should facilitate this analysis.
21. Perform optimization of the entire monitoring program every five years to continue to refine the CSM and monitoring program.

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TABLES

TABLE 2.0-1
Vertical Hydraulic Gradients - January 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
Surficial Water Table Aquifer/Opaline Claystone							
WT032	119.7 - 114.7	117.2	33.7	WT	119.1	-0.32	Down
OC015	88.5 - 78.5	83.5		OCS	108.26		
WT027	112.1 - 107.1	109.6	22.6	WT	109.38	-0.38	Down
OC013	92.0 - 82.0	87.0		OCS	100.74		
WT008	135.5 - 130.5	133.0	32.0	WT	144.59	-0.49	Down
OCS001	106.0 - 96.0	101.0		OCS	128.92		
Opaline Claystone/Transitional Lang Syne Aquifer							
OC002	80.0 - 75.0	77.5	6.4	OCS	93.47	0.54	Up
SL006	73.6 - 68.6	71.1		TLS	96.91		
OC013	92.0 - 82.0	87.0	16.9	OCS	100.74	-0.26	Down
SL003	72.7 - 67.7	70.2		TLS	96.42		
OC012	93.7 - 83.7	88.7	17.2	OCS	101.94	-0.33	Down
SL002	74.0 - 69.0	71.5		TLS	96.2		
OC003	85.9 - 80.9	83.4	8.9	OCS	101.52	-1.36	Down
SL001	77.0 - 72.0	74.5		TLS	89.41		
OC010	88.3 - 78.3	83.3	20.0	OCS	98.57	-0.61	Down
MW008TR	68.3 - 58.3	63.3		TLS	86.43		
OC004	82.4 - 77.3	79.8	16.1	OCS	99.85	-0.80	Down
PSDL021	65.7 - 61.7	63.7		TLS	87.01		
OC009	95.2 - 85.2	90.2	23.6	OCS	106.83	-0.73	Down
MW006TR	69.1 - 64.1	66.6		TLS	89.70		
OC015	88.5 - 78.5	83.5	18.7	OCS	108.26	-0.52	Down
MW033	67.3 - 62.3	64.8		TLS	98.54		
OC008	96.1 - 91.1	93.6	8.6	OCS	105.4	-0.84	Down
MW030	87.5 - 82.5	85.0		TLS	98.20		
OCS001	106.0 - 96.0	101.0	72.6	OCS	128.92	-0.80	Down
MW114T	33.3 - 23.3	28.3		TLS	70.82		
OC014	82.9 - 72.9	77.9	23.5	OCS	98.33	-0.51	Down
MW071T	56.9 - 51.9	54.4		TLS	86.33		
Transitional Lang Syne/Secondary Sawdust Landing Aquifers							
MW061T	82.7 - 77.7	80.2	16.6	TLS	101.65	-1.47	Down
MW059S	68.6 - 58.6	63.6		SSDL	77.30		
MW029	89.3 - 84.3	86.8	16.6	TLS	97.55	-1.11	Down
MW057S	72.7 - 67.7	70.2		SSDL	79.07		
MW028A	88.7 - 83.7	86.2	16.5	TLS	96.77	-0.93	Down
MW028B	74.7 - 64.7	69.7		SSDL	81.45		
MW026ART	85.8 - 80.8	83.3	17.3	TLS	92.67	-0.42	Down
MW026B	76.1 - 56.1	66.1		SSDL	85.37		

TABLE 2.0-1
Vertical Hydraulic Gradients - January 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
MW023ATR	80.7 - 75.7	78.2	17.3	TLS	87.23	-0.24	Down
MW023SR	65.9 - 55.9	60.9		SSDL	83.14		
MW020A	76.7 - 71.7	74.2	16.0	TLS	92.97	-0.74	Down
MW020B	65.7 - 50.7	58.2		SSDL	81.09		
MW050T	73.8 - 68.8	71.3	19.8	TLS	96.94	-1.15	Down
MW128S	54.0 - 49.0	51.5		SSDL	74.09		
MW081T	73.1 - 68.1	70.6	17.9	TLS	108.64	-1.94	Down
MW082S	55.2 - 50.2	52.7		SSDL	73.98		
MW080TR	59.0 - 54.0	56.5	13.0	TLS	73.51	-0.15	Down
MW063SR	46.0 - 41.0	43.5		SSDL	71.58		
MW089T	56.0 - 51.0	53.5	6.9	TLS	74.38	-0.39	Down
MW090SR	49.1 - 44.1	46.6		SSDL	71.67		
MW027BTR	85.2 - 80.2	82.7	9.9	TLS	95.49	-0.51	Down
MW027A	75.3 - 70.3	72.8		SSDL	90.45		
MW024TR	82.6 - 77.6	80.1	18.7	TLS	88.46	-0.34	Down
MW025SR	63.8 - 58.9	61.3		SSDL	82.01		
MW052T	78.8 - 73.8	76.3	9.3	TLS	87.15	-0.16	Down
MW021	72.0 - 62.0	67.0		SSDL	85.67		
MW127T	76.7 - 71.7	74.2	14.3	TLS	95.33	-1.00	Down
MW018B	65.0 - 55.0	60.0		SSDL	81.07		
MW049T	68.4 - 63.4	65.9	14.0	TLS	95.7	-1.56	Down
MW129S	54.4 - 49.4	51.9		SSDL	73.81		
MW101T	57.5 - 47.5	52.5	12.7	TLS	72.40	-0.11	Down
MW102S	42.2 - 37.2	39.7		SSDL	71.02		
MW098TR	43.2 - 38.2	40.7	15.0	TLS	65.73	-0.04	Down
MW092SR	28.2 - 23.2	25.7		SSDL	65.10		
MW033	67.3 - 62.3	64.8	17.7	TLS	98.54	-1.54	Down
MW036SR	49.5 - 44.5	47.0		SSDL	71.30		
MW071T	56.9 - 51.9	54.4	8.9	TLS	86.33	-0.95	Down
MW035S	48.0 - 43.0	45.5		SSDL	77.86		
SL003	72.7 - 67.7	70.2	16.5	TLS	96.42	-1.37	Down
MW017	58.7 - 48.7	53.7		SSDL	73.81		
SL002	74.0 - 69.0	71.5	15.4	TLS	96.20	-0.50	Down
MW015	61.1 - 51.1	56.1		SSDL	88.50		
MW045T	75.6 - 70.6	73.1	20.1	TLS	98.58	-0.54	Down
MW014	58.0 - 48.0	53.0		SSDL	87.76		
SL001	77.0 - 72.0	74.5	18.7	TLS	89.41	-0.40	Down
MW013	60.8 - 50.8	55.8		SSDL	81.96		
MW043T	77.4 - 72.4	74.9	20.9	TLS	93.25	-0.54	Down
MW012	58.9 - 48.9	53.9		SSDL	81.88		

TABLE 2.0-1
Vertical Hydraulic Gradients - January 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
MW042TR	69.4 - 64.4	66.9	14.5	TLS	87.67	-0.40	Down
MW011	57.4 - 47.4	52.4		SSDL	81.89		
MW041T	69.6 - 59.6	64.6	12.9	TLS	85.41	-0.27	Down
MW010	56.7 - 46.7	51.7		SSDL	81.96		
MW009A	67.6 - 62.6	65.1	15.9	TLS	84.27	-0.12	Down
MW009	54.2 - 44.2	49.2		SSDL	82.35		
PSDL021	65.7 - 61.7	63.7	17.7	TLS	87.01	0.00	No Gradient
PSDL021A	48.7 - 43.4	46.0		SSDL	87.01		
MW005A	80.9 - 75.9	78.4	28.6	TLS	100.93	-0.73	Down
MW005BSR	52.3 - 47.3	49.8		SSDL	79.98		
PSDL017	65.5 - 61.5	63.5	16.5	TLS	100.00	-0.46	Down
PSDL017A	49.5 - 44.5	47.0		SSDL	92.33		
Secondary Sawdust Landing/Primary Sawdust Landing Aquifers							
MW060SR	61.8 - 56.8	59.3	9.3	SSDL	77.03	0.03	Up
MW100P	52.5 - 47.5	50.0		PSDL	77.33		
MW028B	74.7 - 64.7	69.7	23.0	SSDL	81.45	-0.17	Down
SL022	49.2 - 44.2	46.7		PSDL	77.65		
MW026B	76.1 - 56.1	66.1	19.0	SSDL	85.37	-0.41	Down
MW056P	52.0 - 42.0	47.0		PSDL	77.57		
MW021	72.0 - 62.0	67.0	28.5	SSDL	85.67	-0.33	Down
SL023	41.0 - 36.0	38.5		PSDL	76.33		
MW018B	65.0 - 55.0	60.0	23.9	SSDL	81.07	-0.23	Down
MW018APR	41.0 - 31.0	36.0		PSDL	75.68		
SL019SR	30.2 - 25.2	27.7	-11.0	SSDL	71.78	0.05	Up
MW099P	43.6 - 33.6	38.6		PSDL	71.24		
MW090SR	49.1 - 44.1	46.6	14.7	SSDL	71.67	-0.01	Down
MW091PR	34.4 - 29.4	31.9		PSDL	71.51		
MW102S	42.2 - 37.2	39.7	10.3	SSDL	71.02	-0.06	Down
MW103P	31.9 - 26.9	29.4		PSDL	70.45		
MW092SR	28.2 - 23.2	25.7	10.7	SSDL	65.10	0.00	No Gradient
MW093PR	17.4 - 12.4	14.9		PSDL	65.13		
MW036SR	49.5 - 44.5	47.0	13.8	SSDL	71.3	-0.05	Down
SL016	35.8 - 30.8	33.3		PSDL	70.64		
MW014	58.0 - 48.0	53.0	23.4	SSDL	81.76	-0.33	Down
MW046P	32.1 - 27.1	29.6		PSDL	74.07		
MW010	56.7 - 46.7	51.7	20.2	SSDL	81.96	-0.42	Down
MW040P	34.1 - 29.1	31.6		PSDL	73.57		
MW005BSR	52.3 - 47.3	49.8	15.3	SSDL	79.98	-0.48	Down
MW039P	39.5 - 29.5	34.5		PSDL	72.70		

TABLE 2.0-1
Vertical Hydraulic Gradients - January 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
Primary Sawdust Landing/Upper Black Creek-A Aquifers							
SL023	41.0 - 36.0	38.5	13.8	PSDL	76.33	0.00	No Gradient
PBC004	26.8 - 22.8	24.8		UBC-A	76.39		
MW099P	43.6 - 33.6	38.6	28.0	PSDL	71.24	-0.11	Down
UBC029AR	13.1 - 8.1	10.6		UBC-A	68.25		
MW091PR	34.4 - 29.4	31.9	4.2	PSDL	71.51	-0.80	Down
UBC026	30.2 - 25.2	27.7		UBC-A	68.10		
MW130P	29.3 - 24.3	26.8	16.1	PSDL	71.21	-0.19	Down
UBC034	13.2 - 8.2	10.7		UBC-A	68.11		
MW103P	31.9 - 26.9	29.4	18.3	PSDL	70.45	-0.16	Down
UBC031	13.6 - 8.6	11.1		UBC-A	67.55		
MW094PR	14.5 - 9.5	12.0	9.6	PSDL	65.81	0.12	Up
UBC025	4.9 - -0.1	2.4		UBC-A	67.00		
MW093PR	17.4 - 12.4	14.9	15.5	PSDL	65.13	0.05	Up
UBC027	1.9 - -3.1	-0.6		UBC-A	65.95		
MW095P	22.2 - 17.2	19.7	-32.2	PSDL	64.74	0.00	No Gradient
UBC028AR	99.4 - 4.4	51.9		UBC-A	64.75		
MW077P	30.4 - 25.4	27.9	22.3	PSDL	70.19	-0.07	Down
UBC021	10.6 - 0.6	5.6		UBC-A	68.73		
MW047P	47.4 - 37.4	42.4	13.2	PSDL	74.03	-0.02	Down
UBC014	34.2 - 24.2	29.2		UBC-A	73.76		
MW044P	37.9 - 32.9	35.4	7.6	PSDL	73.85	0.00	No Gradient
UBC012	30.3 - 25.3	27.8		UBC-A	73.88		
SL014PR	34.2 - 26.5	30.3	15.8	PSDL	73.54	-0.01	Down
UBC053	17.0 - 12.0	14.5		UBC-A	73.36		

Notes:
ft bls - feet below land surface
ft msl - feet mean sea level
ft btoc - feet below top of casing
WT - Surficial Water Table Aquifer
OCS - Opaline Claystone
TLS - Transitional Lang Syne Aquifer
SSDL - Secondary Sawdust Landing Aquifer
PSDL - Primary Sawdust Landing Aquifer
UBC - Upper Black Creek
Top of Casing Elevations Referenced to NGVD 29 feet mean sea level.
Horizontal Datum referenced to feet NAD 1983.

TABLE 2.0-2
Vertical Hydraulic Gradients - July 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
Surficial Water Table Aquifer/Opaline Claystone							
WT032	119.7 - 114.7	117.2	33.7	WT	118.15	-0.34	Down
OC015	88.5 - 78.5	83.5		OCS	106.82		
WT027	112.1 - 107.1	109.6	22.6	WT	107.57	-0.43	Down
OC013	92.0 - 82.0	87.0		OCS	97.89		
WT008	135.5 - 130.5	133.0	32.0	WT	140.2	-0.44	Down
OCS001	106.0 - 96.0	101.0		OCS	126.19		
Opaline Claystone/Transitional Lang Syne Aquifer							
OC002	80.0 - 75.0	77.5	6.4	OCS	93.07	0.45	Up
SL006	73.6 - 68.6	71.1		TLS	95.94		
OC013	92.0 - 82.0	87.0	16.9	OCS	97.89	-0.15	Down
SL003	72.7 - 67.7	70.2		TLS	95.38		
OC012	93.7 - 83.7	88.7	17.2	OCS	100.69	-0.28	Down
SL002	74.0 - 69.0	71.5		TLS	95.89		
OC003	85.9 - 80.9	83.4	8.9	OCS	98.83	-1.07	Down
SL001	77.0 - 72.0	74.5		TLS	89.34		
OC004	82.4 - 77.3	79.8	16.1	OCS	96.81	-0.59	Down
PSDL021	65.7 - 61.7	63.7		TLS	87.37		
OC009	95.2 - 85.2	90.2	23.6	OCS	99.13	-0.39	Down
MW006TR	69.1 - 64.1	66.6		TLS	89.99		
OC015	88.5 - 78.5	83.5	18.7	OCS	106.82	-0.44	Down
MW033	67.3 - 62.3	64.8		TLS	98.54		
OC008	96.1 - 91.1	93.6	8.6	OCS	105.49	-1.15	Down
MW030	87.5 - 82.5	85.0		TLS	95.63		
OCS001	106.0 - 96.0	101.0	72.6	OCS	126.19	-0.66	Down
MW114T	33.3 - 23.3	28.3		TLS	77.99		
OC014	82.9 - 72.9	77.9	23.5	OCS	99.05	-0.48	Down
MW071T	56.9 - 51.9	54.4		TLS	87.84		
Transitional Lang Syne/Secondary Sawdust Landing Aquifers							
MW061T	82.7 - 77.7	80.2	16.6	TLS	100.67	-1.33	Down
MW059S	68.6 - 58.6	63.6		SSDL	78.58		
MW029	89.3 - 84.3	86.8	16.6	TLS	95.42	-0.90	Down
MW057S	72.7 - 67.7	70.2		SSDL	80.47		
MW028A	88.7 - 83.7	86.2	16.5	TLS	94.84	-0.76	Down
MW028B	74.7 - 64.7	69.7		SSDL	82.36		
MW026ART	85.8 - 80.8	83.3	17.3	TLS	90.15	-0.34	Down
MW026B	76.1 - 56.1	66.1		SSDL	84.27		

TABLE 2.0-2
Vertical Hydraulic Gradients - July 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
MW023ATR	80.7 - 75.7	78.2	17.3	TLS	84.83	-0.16	Down
MW023SR	65.9 - 55.9	60.9		SSDL	82.10		
MW020A	76.7 - 71.7	74.2	16.0	TLS	92.15	-0.65	Down
MW020B	65.7 - 50.7	58.2		SSDL	81.81		
MW050T	73.8 - 68.8	71.3	19.8	TLS	95.82	-0.90	Down
MW128S	54.0 - 49.0	51.5		SSDL	77.98		
MW081T	73.1 - 68.1	70.6	17.9	TLS	108.72	-1.65	Down
MW082S	55.2 - 50.2	52.7		SSDL	79.15		
MW080TR	59.0 - 54.0	56.5	13.0	TLS	78.05	-0.12	Down
MW063SR	46.0 - 41.0	43.5		SSDL	76.50		
MW089T	56.0 - 51.0	53.5	6.9	TLS	79.29	-0.38	Down
MW090SR	49.1 - 44.1	46.6		SSDL	76.65		
MW027BTR	85.2 - 80.2	82.7	9.9	TLS	93.54	-0.44	Down
MW027A	75.3 - 70.3	72.8		SSDL	89.22		
MW024TR	82.6 - 77.6	80.1	18.7	TLS	85.42	-0.21	Down
MW025SR	63.8 - 58.9	61.3		SSDL	81.52		
MW052T	78.8 - 73.8	76.3	9.3	TLS	84.84	-0.01	Down
MW021	72.0 - 62.0	67.0		SSDL	84.72		
MW127T	76.7 - 71.7	74.2	14.3	TLS	94.38	-0.88	Down
MW018B	65.0 - 55.0	60.0		SSDL	81.82		
MW049T	68.4 - 63.4	65.9	14.0	TLS	95.54	-1.21	Down
MW129S	54.4 - 49.4	51.9		SSDL	78.58		
MW101T	57.5 - 47.5	52.5	12.7	TLS	78.06	-0.11	Down
MW102S	42.2 - 37.2	39.7		SSDL	76.64		
MW098TR	43.2 - 38.2	40.7	15.0	TLS	76.75	-0.18	Down
MW092SR	28.2 - 23.2	25.7		SSDL	74.08		
MW033	67.3 - 62.3	64.8	17.7	TLS	98.54	-1.20	Down
MW036SR	49.5 - 44.5	47.0		SSDL	77.29		
MW071T	56.9 - 51.9	54.4	8.9	TLS	87.84	-0.67	Down
MW035S	48.0 - 43.0	45.5		SSDL	81.92		
SL003	72.7 - 67.7	70.2	16.5	TLS	95.38	-1.02	Down
MW017	58.7 - 48.7	53.7		SSDL	78.54		
SL002	74.0 - 69.0	71.5	15.4	TLS	95.89	-0.44	Down
MW015	61.1 - 51.1	56.1		SSDL	89.08		
MW045T	75.6 - 70.6	73.1	20.1	TLS	98.03	-0.75	Down
MW014	58.0 - 48.0	53.0		SSDL	83.02		
SL001	77.0 - 72.0	74.5	18.7	TLS	89.34	-0.33	Down
MW013	60.8 - 50.8	55.8		SSDL	83.21		
MW043T	77.4 - 72.4	74.9	20.9	TLS	92.53	-0.45	Down
MW012	58.9 - 48.9	53.9		SSDL	83.16		

TABLE 2.0-2
Vertical Hydraulic Gradients - July 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
MW042TR	69.4 - 64.4	66.9	14.5	TLS	88.11	-0.34	Down
MW011	57.4 - 47.4	52.4		SSDL	83.14		
MW041T	69.6 - 59.6	64.6	12.9	TLS	86.14	-0.22	Down
MW010	56.7 - 46.7	51.7		SSDL	83.25		
MW009A	67.6 - 62.6	65.1	15.9	TLS	85.19	-0.11	Down
MW009	54.2 - 44.2	49.2		SSDL	83.48		
PSDL021	65.7 - 61.7	63.7	17.7	TLS	87.37	-0.26	Down
PSDL021A	48.7 - 43.4	46.0		SSDL	82.73		
MW005A	80.9 - 75.9	78.4	28.6	TLS	100.93	-0.73	Down
MW005BSR	52.3 - 47.3	49.8		SSDL	79.98		
PSDL017	65.5 - 61.5	63.5	16.5	TLS	100.14	-0.37	Down
PSDL017A	49.5 - 44.5	47.0		SSDL	94.00		
Secondary Sawdust Landing/Primary Sawdust Landing Aquifers							
MW060SR	61.8 - 56.8	59.3	9.3	SSDL	78.38	0.03	Up
MW100P	52.5 - 47.5	50.0		PSDL	78.70		
MW028B	74.7 - 64.7	69.7	23.0	SSDL	82.36	-0.27	Down
SL022	49.2 - 44.2	46.7		PSDL	76.07		
MW026B	76.1 - 56.1	66.1	19.0	SSDL	84.27	-0.44	Down
MW056P	52.0 - 42.0	47.0		PSDL	75.99		
MW021	72.0 - 62.0	67.0	28.5	SSDL	84.72	-0.31	Down
SL023	41.0 - 36.0	38.5		PSDL	75.87		
MW018B	65.0 - 55.0	60.0	23.9	SSDL	81.82	-0.25	Down
MW018APR	41.0 - 31.0	36.0		PSDL	75.90		
SL019SR	30.2 - 25.2	27.7	-11.0	SSDL	77.52	0.05	Up
MW099P	43.6 - 33.6	38.6		PSDL	76.92		
MW090SR	49.1 - 44.1	46.6	14.7	SSDL	76.65	-0.01	Down
MW091PR	34.4 - 29.4	31.9		PSDL	76.44		
MW102S	42.2 - 37.2	39.7	10.3	SSDL	76.64	-0.09	Down
MW103P	31.9 - 26.9	29.4		PSDL	75.76		
MW092SR	28.2 - 23.2	25.7	10.7	SSDL	74.08	-0.01	Down
MW093PR	17.4 - 12.4	14.9		PSDL	73.97		
MW036SR	49.5 - 44.5	47.0	13.8	SSDL	77.29	-0.07	Down
SL016	35.8 - 30.8	33.3		PSDL	76.32		
MW014	58.0 - 48.0	53.0	23.4	SSDL	83.02	-0.28	Down
MW046P	32.1 - 27.1	29.6		PSDL	76.40		
MW010	56.7 - 46.7	51.7	20.2	SSDL	83.25	-0.35	Down
MW040P	34.1 - 29.1	31.6		PSDL	76.29		
MW005BSR	52.3 - 47.3	49.8	15.3	SSDL	82.08	-0.38	Down
MW039P	39.5 - 29.5	34.5		PSDL	76.30		

TABLE 2.0-2
Vertical Hydraulic Gradients - July 2010
Pinewood Landfill
Pinewood, South Carolina

Well ID	Screen Interval (ft msl)	Screen Midpoint Elevation (ft msl)	Distance between Screen Midpoints (ft)	Aquifer Unit	Groundwater Elevation (ft msl)	Vertical Gradient	Gradient Direction
Primary Sawdust Landing/Upper Black Creek-A Aquifers							
SL023	41.0 - 36.0	38.5	13.8	PSDL	75.87	0.00	No Gradient
PBC004	26.8 - 22.8	24.8		UBC-A	75.87		
MW099P	43.6 - 33.6	38.6	28.0	PSDL	76.92	-0.10	Down
UBC029AR	13.1 - 8.1	10.6		UBC-A	74.12		
MW091PR	34.4 - 29.4	31.9	4.2	PSDL	76.44	-0.75	Down
UBC026	30.2 - 25.2	27.7		UBC-A	73.26		
MW130P	29.3 - 24.3	26.8	16.1	PSDL	76.78	-0.17	Down
UBC034	13.2 - 8.2	10.7		UBC-A	74.11		
MW103P	31.9 - 26.9	29.4	18.3	PSDL	75.76	-0.15	Down
UBC031	13.6 - 8.6	11.1		UBC-A	73.10		
MW094PR	14.5 - 9.5	12.0	9.6	PSDL	49.91	2.39	Up
UBC025	4.9 - -0.1	2.4		UBC-A	72.77		
MW093PR	17.4 - 12.4	14.9	15.5	PSDL	73.97	-0.10	Down
UBC027	1.9 - -3.1	-0.6		UBC-A	72.43		
MW095P	22.2 - 17.2	19.7	-32.2	PSDL	73.51	0.01	Up
UBC028AR	99.4 - 4.4	51.9		UBC-A	73.16		
MW077P	30.4 - 25.4	27.9	22.3	PSDL	77.19	-0.09	Down
UBC021	10.6 - 0.6	5.6		UBC-A	75.21		
MW047P	47.4 - 37.4	42.4	13.2	PSDL	76.46	0.00	No Gradient
UBC014	34.2 - 24.2	29.2		UBC-A	76.47		
MW044P	37.9 - 32.9	35.4	7.6	PSDL	76.35	0.00	No Gradient
UBC012	30.3 - 25.3	27.8		UBC-A	76.32		
SL014PR	34.2 - 26.5	30.3	15.8	PSDL	76.43	-0.01	Down
UBC053	17.0 - 12.0	14.5		UBC-A	76.27		

Notes:
ft bls - feet below land surface
ft msl - feet mean sea level
ft btoc - feet below top of casing
WT - Surficial Water Table Aquifer
OCS - Opaline Claystone
TLS - Transitional Lang Syne Aquifer
SSDL - Secondary Sawdust Landing Aquifer
PSDL - Primary Sawdust Landing Aquifer
UBC - Upper Black Creek
Top of Casing Elevations Referenced to NGVD 29 feet mean sea level.
Horizontal Datum referenced to feet NAD 1983.

TABLE 4.1-1
Maximum Concentrations of Constituents
Detected in Leachate - May 2010 Samples
Pinewood Landfill
Pinewood, South Carolina

Parameter / Sample Identification	Section I	Section II	Section III
VOCs (μg/L)			
1,1,1,2-Tetrachloroethane	1140000	32.0 J	ND
1,1,1-Trichloroethane	9110000	3080	ND
1,1,2,2-Tetrachloroethane	1080 J	1990	ND
1,1,2-Trichloroethane	2890000	6070	ND
1,1-Dichloroethane	1450000	10600	*1140*
1,1-Dichloroethylene	643000	153 J	0.930 J
1,2,4-Trichlorobenzene	65000 J	10000000	*2060*
chloropropane	2730	ND	ND
1,2-Dibromoethane	2850	ND	ND
1,2-Dichlorobenzene	2570000	23100000	*3090*
1,2-Dichloroethane	210000	4200	0.950 J
1,2-Dichloropropane	700 J	0.310 J	ND
1,2,3-Trichloropropane	--	11.8	--
1,3-Dichlorobenzene	221000	*7580000*	34.3
1,4-Dichlorobenzene	1340000	*25300000*	*5550*
1,4-Dioxane	1300000	154000	2480
2-Butanone	648000	665000	3210
2-Hexanone	2460 J	ND	ND
4-Methyl-2-pentanone	788000	35800	6300
Acetone	619000	463000	3830
Acetonitrile	15900	6580	176
Benzene	ND	13.2 J	*918*
Bromodichloromethane	380 J	ND	ND
Bromoform	1680 J	ND	ND
Carbon disulfide	ND	358 J	148
Carbon tetrachloride	319000	6.80 J	ND
Chlorobenzene	1520	858	172
Chloroethane	7680	47	2.4
Chloroform	182000	28600	ND
cis-1,2-Dichloroethylene	259000	6020	22.3
Dibromomethane	128000	ND	ND
Ethylbenzene	2710000	710000	*8660*
Iodomethane	ND	1.45 J	ND
Isobutyl alcohol	143000	285000	2780
Methacrylonitrile	637	5570	ND
Methanol	6060000 H	359000	146000 J
Methylene chloride	2960000	168000	ND
Propionitrile	ND	28.5	ND
Styrene	691	ND	ND
Tetrachloroethylene	13300000	12000000	*1240*
Toluene	3460000	1510000	*55900*
trans-1,2-Dichloroethylene	ND	ND/18.3	0.760 J
Trichloroethylene	2230000	4650	1.16
Vinyl chloride	4300	673	1.88
Xylenes (total)	7980	3960000	*60100*

TABLE 4.1-1
Maximum Concentrations of Constituents Detected in Leachate - May 2010 Samples
Pinewood Landfill
Pinewood, South Carolina

Parameter / Sample Identification	**Section I**	**Section II**	**Section III**
SVOCs (µg/L)			
1,4-Dioxane	--	25.2	--
Acenaphthene	--	2.26	--
Aniline	--	3.98 J	--
Anthracene	--	1.43	--
Benzoic acid	--	ND	--
Butylbenzylphthalate	--	5.03 J	--
Carbazole	--	ND	--
Dibenzofuran	--	2.37 J	--
Fluoranthene	--	2.48	--
Fluorene	--	2.59	--
Naphthalene	--	0.985 J	--
Phenanthrene	--	0.212 J	--
Phenol	--	3.74 J	--
Pyrene	--	1.44	--
bis(2-Ethylhexyl)phthalate	--	5.75 J	--
Pesticides (µg/L)			
4,4'-DDD	31.7	3.11	*3320 J*
4,4'-DDE	240000 P	0.747	ND
4,4'-DDT	599	0.435	ND
Aldrin	282	ND	ND
Chlordane (tech.)	3130000	*2380000 P*	ND
Dieldrin	1250	0.742	ND
Endosulfan II	409000	ND	ND
Endrin	263000	5.84	ND
Endrin aldehyde	210 P	0.270 J	ND
Endrin ketone	1400	3.46 J	ND
gamma-BHC (Lindane)	ND	0.776	ND
Heptachlor	429000	*3790000*	*1290 JP*
Toxaphene	19900000	ND	ND
Herbicides (µg/L)			
2,4,5-TP	ND	27.8	ND
2,4-D	1370 P	72.7	ND
2,4-DB	825	1870	*3.59 P*
Dicamba	1070	ND	ND
Dichlorprop	ND	86.3 JP	902 P
Dinoseb	ND	9.48	ND
MCPA	6630 BP	35900 JP	ND
MCPP	290000	132000	ND

TABLE 4.1-1
Maximum Concentrations of Constituents Detected in Leachate - May 2010 Samples
Pinewood Landfill
Pinewood, South Carolina

Parameter / Sample Identification	Section I	Section II	Section III
Metals			
Arsenic	788000	173000	212 J
Barium	11700	8180	377
Cadmium	39300	936	ND
Calcium	3310000	1960000	228000
Chromium	44500	38400	188
Iron	8390000	1400000	163000
Lead	8200	8640	ND
Magnesium	942000	385000	39500
Selenium	624 J	135 J	143 J
Silver	207 J	ND	ND
Zinc	1860000	423000	63.3 J
Inorganics			
Chloride (mg/L)	15800	18500	19800
Chlorine (mg/kg)	*54900*	*71600*	*802*
Hardness as CaCO3 (mg/l)	11300	6470	616

Notes:

H - Out of holding (analyzed out of holding due to overrange hits).
J - Estimated value.
ND - below detection limit.
Italic - indicates sample was analyzed as an oil.
<u>Underline</u> - sample from secondary leachate analysis;
others from primary leachate analysis.
Common constituents in all 3 Landfill Cells (I, II and III).

TABLE 4.1-2
Properties of Common Leachate Constituents
Pinewood Landfill
Pinewood, South Carolina

Parameter	Toluene	1,4-Dioxane	Xylenes (total)	Acetone	4-Methyl-2-pentanone
Percent Detections[a]	91%	79%	77%	74%	72%
Minimum[b] mg/L	5.71	59.8	3.15	5.34	25.4
Maximum mg/L	3460	1300	3960	619	788
Solubility[c] mg/L	5.20E+02	**1.00E+06**	1.80E+02	**1.00E+06**	1.60E+04
HLC[c] atm-m3/mol	5.90E-02	**4.10E-06**	6.00E-02	3.60E-04	3.70E-05
Koc[c] L/kg	210	**3.3**	410	**4.2**	18
Average Half-life[d] days	12	28 - 180	41	1.2	0.6

Notes:

Constituents listed were detected in at least one sample in every landfill cell.

[a] - Percent detections of May 2010 data; "J" qualified considered detected.

[b] - Minimum concentration of non-qualified detections.

[c] - Average value from the Risk Assessment Information System accessed Dec 22, 2010 at: http://rais.ornl.gov/tools/profile.php

[d] - Example values provided for toluene and xylenes from Lawrence, 2006, anaerobic field/in situ studies; acetone and 4-methyl-2-pentanone calculated from Quesnel, D. and Nakhala, G., 2006, *Removal kinetics of acetone and MIBK from a complex industrial wastewater by an acclimatized activated sludge,* Journal of Hazardous Materials, v. 132, p. 253-260; 1,4-dioxane from Howard, P., Boethling, R., Jarvis, W., Meylan, W. and Michalenko, E. 1991. *Handbook of Environmental Degradation Rates,* Lewis Publishers, soil data.

Bold - indicates favorable characteristic for a tracer.

Koc - organic carbon partition coefficient - indicates tendency to adsorb.

HLC - Henry's Law constant - indicates tendency to volatilize.

mg/L - milligrams per liter

atm-m^3/mol - atmosphere - cubic meters per mole

L/kg - liters per kilogram

TABLE 4.3-1

Summary of Maximum Reported Concentrations of Organic Contaminants in Groundwater

January 2001 to February 2010

Pinewood Landfill

Pinewood, South Carolina

Sample Location	Screened Interval	Sampling Date	Parameter	Lab Result	Lab Qualifier	MDL	Detections> 1 µg/L since 2001
MW018APR	PSDL	11/6/2008	Carbon disulfide	1.35	J	1.25	1
MW024TR	TLS	10/21/2009	Acrolein	18.3	J	1.25	1
MW030	TLS	11/14/2006	1,2-Dichloroethane	2.25	J	0.250	7
MW071T	TLS	12/28/2006	Acetone	3.27	J	1.25	6
MW086SR	SSDL	11/7/2002	bis(2-Ethylhexyl)phthalate	2.5	J		5
MW098TR	TLS	2/8/2007	Ethylbenzene	2.03	J	0.250	1
MW133T	TLS	4/13/2004	Toluene	14.2			7
OCS008	OC	8/15/2007	cis-1,2-Dichloroethylene	20.5		0.300	25
UBC009	UBC-A	11/6/2003	Diethylphthalate	1.16	BJ	0.873	2
UBC035	UBC-A	4/7/2003	Vinyl chloride	10			14
WT008	WT	5/2/2005	Benzene	2.5	J	0.300	1
WT008	WT	11/5/2009	1,1-Dichloroethylene	15		0.300	5
WT008	WT	11/5/2009	Tetrachloroethylene	1060		6.00	57
WT020	WT	8/19/2003	1,1,1-Trichloroethane	10.5		0.340	4
WT020	WT	8/19/2003	Trichloroethylene	18.3		0.360	39
WT030	WT	7/22/2002	1,1-Dichloroethane	3.36		0.410	30
WT030	WT	7/22/2002	Bromoform	1.41		0.500	2
WT030	WT	7/22/2002	trans-1,2-Dichloroethylene	1.58		0.370	2
WT030	WT	11/11/2008	Methylene chloride	9.41		2.00	228

Notes:

Concentrations as micrograms per liter.

µg/L - micrograms per liter

TABLE 5.1-1
Single Point Monitoring Alternatives Technology Matrix
Pinewood Landfill
Pinewood, South Carolina

Monitoring System	Description	Continuous or Discrete Sampling	Matrix	Commercial Availability	Parameters[1]	Range[1]	Precision[1]	Accuracy[1]	Estimated Cost	Advantages	Disadvantages	Recommendation
Continuous Monitoring												
Water Quality Sonde (In-well)	Multi-parameter sensor or transducer that is deployed beneath the water surface to measure long-term water quality; These systems have on-board data logging capabilities and can be incorporated into a PLC or SCADA system	Continuous	Groundwater	Yes: YSI 600XML-M Multi-Parameter Water Quality Logger	Dissolved Oxygen[2] Temperature[3] Conductivity[3] Salinity[3] Specific Conductance[3] Resistivity[3] Depth[2] pH[2] ORP[2] TDS[2]	0 to 50 mg/L -5 to 50°C 0 to 100 mS/cm 0 to 70 ppt NA NA 0 to 200 m (0 to 656 ft) 0 to 14 units -999 to +999 mV NA	0.01 mg/L 0.01°C 0.001 to 0.1 mS/cm[4] 0.01 ppt NA NA 0.001 m (0.001 ft) 0.01 unit 0.1 mV NA	±2% of reading or 0.2 mg/L ±0.15°C ±0.5% of reading + 0.001ms/cm ±1% of reading or 0.1 ppt, whichever is greater NA NA ±0.018 m to 0.3 m (±0.06 ft to 1 ft)[5] ±0.2 unit ±20 mV in Redox standard solutions NA	$7,200 per sonde $1,800 for display	In well measurement and data logging capabilities for up to seven parameters (DO, conductivity, temperature, pH, ORP, depth/level). Data can be communicated back to PLC/SCADA system.	Parameters measured only serve as groundwater quality indicator. Requires periodic O&M. One sonde is needed for each monitoring point (well). Costs could make this technology prohibitive to implement site-wide.	In well sondes are recommended in select new monitoring wells across the northern and eastern perimeter of the site to provide cost effective monitoring of baseline geochemical parameters.
In Well Purging - USGS	USGS patented system that provides continuous monitoring of several parameters (water levels, geochemical parameters). Robowell uses a computer to control a pump and a series of electronic instruments, which monitor the quality of ground water pumped through the system from a monitoring well or multilevel sampler.	Continuous	Groundwater	No; USGS prototypes in development	Water level Specific conductance pH Temperature Dissolved oxygen	No published information available	No published information available	No published information available	Not commercially available	USGS patented system that provides continuous monitoring of several parameters (water levels, geochemical parameters). Data can be communicated back to a PLC/SCADA system.	Systems only developed as prototypes and not commercially available. Parameters measured only serve as indicator parameters. System represents older technology; could be replaced by downhole sensors (e.g., YSI sonde). System requires purging of well, therefore system must incorporate pumping and capture of purge water.	Not recommended. Not commercially available.
In Well Purging - Burge	Discrete, multi-level sampler designed for permanent deployment in a well. Designed for use with an automated well head analyzer for VOCs	Continuous	Groundwater	Yes: Burge Environmental Multiprobe 100 with Optrode System	Total VOCs	NA	3 to 21% (based on relative standard deviation)*	-30% to +15% of reading*	NA	Provides real time analysis of dissolved VOC concentrations.	AECOM performed pilot study of the Burge TCE Monitoring System for influent/effluent of wastewater for the US Air Force. Unit required significant O&M due to communication system failures. Accuracy of system was only within acceptable limits in approximately 50% of samples. Due to the unit's size, it cannot be installed in a well with a diameter less than 4 inches. The system requires a source of compressed nitrogen at the well head.	Not recommended. Requires 4" diameter well, required compressed nitrogen at well head and inadequate sensitivity/accuracy for detection level monitoring.
Continuous VOC Headspace Monitor	Analyzes headspace above water for concentrations of total VOCs. Provides real time data that can be logged.	Continuous	Surface water, groundwater	Yes: Multisensor Systems Ltd.	VOCs	>1 ug/L	1 ug/L total VOC in headspace above liquid	No published information available	$15,000 per unit + engineering and installation	Analyzes headspace above water for concentrations of VOCs. Provides real time data that can be logged.	Unit may respond to natural volatile organics, which could produce false positives. Requires A/C power, climate controlled space and 0.5 gpm flow of water being monitored.	Recommend to retain for further consideration for use to monitor a potential VOC release to Pond A or Pond B. Piloting recommended to determine verify the compatibility of this technology under actual site conditions.
Down-Well Transducers / Dataloggers	Completely submersible pressure transducer and cable; Compact, rugged design for easy installation; Minimal maintenance and care; Water level sensor compatible with most monitoring equipment; Multiple level ranges available from 3 to 500 feet; Wet-wet water level sensor eliminates vent tube concerns; Dynamic temperature compensation systems;	Continuous	Surface water, groundwater	Yes; numerous manufacturers' and models available at a wide range of prices	Water level corrected to barometric pressure	3 to 100 feet head	High accuracy and reliability	Storms and elevation cause changes in barometric pressure. Stormy weather can produce typical barometric pressure differences in the range of 25 mb during a single day. Since one millibar (mb) equals one centimeter of water this equates to almost 10 inches of water level error or an error of over 2.5% for a 30 ft range sensor. AECOM recommends differential water level monitors for accuracy rather than absolute water level sensors that do not use vented cables to automatically compensate for barometric pressure changes. Accuracy varies per equipment manufactures' specifications but are typically +/- 0.05 feet	$385 - $1328 per unit	Accurate data acquisition, real time download option for continuous data evaluation during 1-year study, comprehensive water level database development to further evaluate groundwater hydraulics and interaction related to the pale-channel and off-Site groundwater withdrawal.	None; care should be taken during monitoring activities in wells that have dedicated pressure transducers deployed.	Recommended for 12-month hydraulic evaluation of aquifer units.

TABLE 5.1-1
Single Point Monitoring Alternatives Technology Matrix
Pinewood Landfill
Pinewood, South Carolina

Monitoring System	Description	Continuous or Discrete Sampling	Matrix	Commercial Availability	Parameters[1]	Range[1]	Precision[1]	Accuracy[1]	Estimated Cost	Advantages	Disadvantages	Recommendation
Intermittent Monitoring												
Fiber Optic Biosensors	Emerging technology that can provide real-time measurements of dissolved VOCs in fluid. Sensors have a 2-layer tip that reacts with the target VOC, resulting in a change in fluorescence that is measured with an optical fiber.	Continuous	Groundwater	No: Colorado State University is testing a developmental model	VOCs	< 5 µg/L to > 500 µg/L 1,2-DCA	Average RPD for vial measurements: 45.6% Overall, RPDs higher than reference method;	Accuracy was dependent on ability to correct for non-analyte related pH changes. For vial measurements: r2 = 0.934) r2 > 0.9	$15,000 for base station $1,000 per year per probe (tips are expendable)	Biosensors can be utilized to provide real-time analysis of volatiles. Biosensor could either be used above ground or deployed in well.	Developmental technology. Availability of sensors and technical support may be limited. ESTCP report on this technology states that sensors can only be used in vial measurements, due to pH effects. Multiple sensors would be required for multiple analytes.	Not recommended. Not commercially available.
Snap™ Samplers	Grab-sampling device that collects a whole water sample at a fixed sampling depth within a well without purging or agitating the well.	Discrete	Groundwater	Yes: ProHydro, Inc.	VOCs SVOCs Inorganic Geochemical Para-meters	NA[7]	NA[7]	NA[7]	$1,000 per well capital cost to include sampler, trigger and dock for six, 125 mL VOA samplers. Recurring cost of $100 per per sampling event for 6-125 mL bottles.	Grab-sampling device that collects a whole water sample at a fixed sampling depth within a well without purging or agitating the well. Sample can usually be shipped in collection container Applicable for any analyte	Limited sample volume (1,000 mL) may not be sufficient for all required analyses. Sampling method has the potential to increased turbidity in collected samples, which may effect metals analyses.	Not recommended. Additional costs does not appear to be off set by saving in sampling time or purge water disposal costs.
Hydrasleeve™	Collect a representative sample for most physical and chemical parameters without purging the well. It collects a water sample from a defined interval within the well screen without mixing fluid from other intervals.	Discrete	Surface water, groundwater	Yes: GeoInsight	VOCs SVOCs Inorganics Geochemical Parameters	NA[7]	NA[7]	NA[7]	$30 per sampler	Eliminates the need for low flow purging of well and management of purge water. Sampler collects groundwater that can be analyzed for volatiles, semivolatiles and metals.	Limited sample volume (750 mL) may not be sufficient for all required analyses. Sampling method has the potential to increased turbidity in collected samples, which may effect metals analyses.	Not currently recommended unless it can be demonstrated that analytical results for all COCs are statistically similar with current low flow purging methods.
Passive Diffusion Bag Samplers	Sampler is filled with ultrapure water, submerged in groundwater and allowed to reach equilibrium with the chemical content of groundwater.	Discrete	Surface water, groundwater	Yes: Columbia Analytical Services, Inc.	VOCs	NA[7]	NA[7]	NA[7]	$30 per sampler;	Eliminates the need for low flow purging of well and management of purge water. Sampler can be placed in well during prior sampling event and retrieved at the next sampling event.	This method is only applicable for volatiles. Semi volatiles and metals do not diffuse into the bag. Sampling requires a minimum 14 day equilibration period. The diffusion samplers are representative of a time-weighted average of chemical concentrations in groundwater due to the time-lag between when the groundwater enters a well and the diffusion of the chemicals in the groundwater into a diffusion sampler.	Not recommended due to inability to monitor semi volatile or metal Constituents of Concern.
Rigid Diffusion Samplers	Rigid sampling device composed of polyethylene which is filled with analyte-free water and placed in the well. The chemical constituents in the well interval diffuse across the membrane and reach equilibrium over time.	Discrete	Groundwater	Yes: Columbia Analytical Services, Inc.	VOCs Inorganic Geochemical Para-meters	NA[8]	NA[8]	NA[8]	$65 each	Avoid the need for low flow purging of well and management of purge water. Sampler can be placed in well during prior sampling event and retrieved at the next sampling event.	Not suitable for certain hydrophobic VOCs and SVOCs unless longer equilibration times Must be stored and shipped fully immersed in deionized water; required advanced analytical extraction techniques when analyzing for VOCs. Literature states the results for VOCs tended to be biased low relative to select traditional sampling methods.	Not recommended due to tendency for VOCs results to be biased low relative to select traditional sampling methods.
Regenerated-cellulose Dialysis Membrane Sampler	Sampling device made of a combination of a high-grade regenerated cellulose tubular dialysis membrane with protective materials (e.g., perforated PVC pipe and/or LDPE mesh). Water in the sampling device comes to equilibrium with water in the well.	Discrete	Groundwater	No: Can be constructed from commercially available materials	VOCs Inorganics Geochemical Para-meters	NA[9]	NA[9]	NA[9]	$50 - $70 per sampler to assemble	Disposable samplers, no decontamination needed; Can be used in low-yield wells. Avoid the need for low flow purging of well and management of purge water. Sampler collects groundwater that can be analyzed for volatiles, semivolatiles and metals.	Samples must be kept wet from construction and may biodegrade with time in some groundwater conditions; perforations can develop in 4-6 weeks, perhaps sooner if groundwater is warm; not commercially available.	Not recommended due to tendency for VOCs results to vary out of range relative to select traditional sampling methods. Not commercially available.

Notes:
1 - Specifications provided are for the identified commercially available unit
2 - Customer Selectable
3 - Standard
4 - ranged-dependent
5 - depth dependent
6 - Not used
7 - Exact specifications are not available but literature shows that the performance of these units is within the range of traditional sampling methods
8 - Exact specifications are not available but literature shows that the performance of these units is within the range of traditional sampling methods for metals and anions.
9 - Exact specifications are not available but literature shows that the performance of these units is within the range of traditional sampling methods for metals and anions. Literature states the results for VOCs were mixed.
* - Based on results presented in the ETV Joint Verification Statement
** - as compared to traditional sampling methods

DO - Dissolved Oxygen	ppb - parts per billion
ESTCP - Environmental Security Technology Certification Program	RPD - relative percent difference
i.d. - Identification	SCADA - System Control and Data Acquisition
O&M - Operation and Maintenance	SVOC - Semi-Volatile Organic Compound
ORP - Oxidation-reduction potential	VOC - Volatile Organic Compound
PAH - Polyaromatic Hydrocarbon	USGS - United States Geological Survey
PLC - Programmable Logic Control	

TABLE 5.2-1
Geophysical Methods
Site-Wide Monitoring Techniques
Pinewood Landfill
Pinewood, South Carolina

Method	Advantages	Disadvantages	Approximate Cost	Anticipated Data Product
Surface Methods				
EM-34	Rapid data collection, multiple depth levels, large spatial coverage,	Apparent conductivity measurement represents averaged value	Pilot Study: $5,850[a] Additional Work: $2,200/day[a]	Contour map of apparent conductivity values for varying depth levels (when intercoil spacing is varied)
Electrical Resistivity and Induced Polarization	2D or 3D electrical resistivity models, generally high signal to noise Ratio	Slow deployment and data collection, modeling requires special software, tomograms may represent blurry, blunted versions of reality	*Equipment Rental: $450/day (5 day minimum), plus insurance/shipping Software: $30/day	2D or 3D images of subsurface bulk resistivity distributions
Mise-a-la-masse	Focus is placed on conductive anomaly, may identify small leak areas	Presence of clay layers may skew results (leachate and clay are conductive)	*Can be performed with equipment listed above. Additional wires and connectors needed for $20/day	Contour map of voltage potential
Borehole Methods				
EM Induction	Electrical conductivity is determined as a function of depth, can be highly effective when coupled with surface methods	Spatial distribution depends on number and location of boreholes, small lateral coverage	*Winch/logger/ software: $115/day EM Induction Tool: $140/day Gamma Tool: $35/day Tripod: $6/day Checkout Fee: $190 Two way shipping 3 Day Minimum Rental	Plot of bulk resistivity as a function of depth
Natural Gamma	Aids in the interpretation of leachate-saturated sands and clays	Spatial distribution depends on number and location of boreholes, small lateral coverage		Plot of bulk resistivity as a function of depth

Notes:

[a] From Geophysical Surveys Investigations, PLLC proposal

*Does not include personnel/labor costs

TABLE 6.2-1
Recommended WTMP Summary
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly							Annual		Baseline		
		Water Level	pH, Conductivity, Temperature and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metal COCs	Water Level	VOC COCs	Metals(1)	Anions(2)	Cations(3)
WATER TABLE MONITORING PROGRAM													
WT008	WT	x	x	x			x	x	x		x	x	x
WT010	WT	x	x	x					x		x	x	x
WT011	WT	x	x	x					x		x	x	x
WT012	WT	x	x	x					x		x	x	x
WT015	WT	x	x	x					x		x	x	x
WT016	WT	x	x	x					x		x	x	x
WT020	WT	x	x	x					x		x	x	x
WT022	WT	x	x	x					x		x	x	x
WT023	WT	x	x	x					x		x	x	x
WT024	WT	x	x	x					x		x	x	x
WT025	WT	x	x	x					x		x	x	x
WT026	WT	x	x	x					x	x	x	x	x
WT027	WT	x	x	x					x		x	x	x
WT030	WT	x	x	x					x	x	x	x	x
WT032	WT	x	x	x					x	x	x	x	x
MW-33	WT	x	x	x					x		x	x	x
MW-34	WT	x	x	x					x		x	x	x
MW-35	WT	x	x	x					x		x	x	x
MW-36	WT	x	x	x					x		x	x	x
MW-37	WT	x	x	x					x		x	x	x
MW-38	WT	x	x	x					x		x	x	x
MW-39	WT	x	x	x					x		x	x	x
MW-40	WT	x	x	x					x		x	x	x
New MW	WT	x	x	x	x	x	x	x	x		x	x	x
New MW	WT	x	x	x	x	x	x	x	x		x	x	x
New MW	WT	x	x	x	x	x	x	x	x		x	x	x
New MW	WT	x	x	x	x	x	x	x	x		x	x	x
OC002	OC	x	x	x					x		x	x	x
OC003	OC	x	x	x					x		x	x	x
OC004	OC	x	x	x					x		x	x	x
OC005	OC	x	x	x					x		x	x	x
OC006	OC	x	x	x					x		x	x	x
OC007	OC	x	x	x					x		x	x	x
OC008	OC	x	x	x					x		x	x	x
OC009	OC	x	x	x					x		x	x	x
OC010	OC	x	x	x					x		x	x	x
OC011	OC	x	x	x					x		x	x	x
OC012	OC	x	x	x					x		x	x	x
OC013	OC	x	x	x					x		x	x	x
OC014	OC	x	x	x					x		x	x	x
OC015	OC	x	x	x					x		x	x	x
OC016	OC	x	x	x					x		x	x	x
OCS001	OC	x	x	x					x		x	x	x
OCS002	OC	x	x	x			x	x	x		x	x	x
OCS003A	OC	x	x	x					x		x	x	x
OCS003B	OC	x	x	x					x		x	x	x
OCS004	OC	x	x	x					x		x	x	x
OCS006A	OC	x	x	x					x	x	x	x	x
OCS006B	OC	x	x	x					x	x	x	x	x
OCS008	OC	x	x	x					x		x	x	x
OCS005	OC	x	x	x					x		x	x	x
OCS011	OC	x	x	x					x		x	x	x

Notes:

Baseline Metals[1] **-** Geochemical Water Analysis ICP-ES/ICP-MS (FullSuite of 70 elements)

Anions[2] - One time analysis of major anions (alkalinity, chloride, and sulfate) for water fingerprinting

Cations[3] - One time analysis of major cations (calcium, magnesium, potassium, and sodium) for water fingerprinting

ORP - Oxygen Reduction Potential

DO - Dissolved Oxygen

VOC COCs - PCE, TCE, cis-1,2-DCE, VC

Metals COCs - Cadmium, Chromium, Lead, Arsenic

TABLE 6.2-2
Summary of Selected Metals Detected in Groundwater
Pinewood Landfill
Pinewood, South Carolina

Station ID	Parameter	Dates Collected	Number of Detects	Number of Events	MCL (µg/L)	Number of MCL Exceedances	Date of Last MCL Exceedance
WT008	Arsenic	1/22/2001 - 11/12/10	0	40	10		
	Barium		40	40	2000		
	Cadmium		20	40	5	1	11/5/2009
	Chromium		33	38	100		
	Lead		24	39	15	3	10/28/2005
	Mercury		38	40	2	10	7/21/2004
	Selenium		6	39	50		
	Silver		2	40	100		
WT026	Arsenic	1/22/2001 - 11/12/10	2	40	10		
	Barium		40	40	2000		
	Cadmium		15	40	5	1	11/5/2009
	Chromium		31	40	100		
	Lead		8	40	15		
	Mercury		0	40	2		
	Selenium		8	40	50		
	Silver		1	40	100		
WT027	Arsenic	1/22/2001 - 11/12/10	12	40	10	3	11/5/2009
	Barium		39	40	2000		
	Cadmium		13	40	5	1	11/5/2009
	Chromium		34	40	100		
	Lead		13	40	15	2	11/5/2009
	Mercury		2	40	2		
	Selenium		13	40	50	2	5/2/2008
	Silver		9	40	100		
WT030	Arsenic	1/22/2001 - 11/12/10	11	36	10	2	11/5/2009
	Barium		36	36	2000		
	Cadmium		24	36	5	2	11/5/2009
	Chromium		32	36	100	1	1/28/2005
	Lead		14	36	15	4	11/5/2009
	Mercury		4	36	2		
	Selenium		9	36	50		
	Silver		1	36	100		
WT032	Arsenic	1/22/2001 - 11/12/10	3	40	10	2	5/3/2007
	Barium		40	40	2000		
	Cadmium		34	40	5	1	11/5/2009
	Chromium		24	40	100		
	Lead		7	40	15		
	Mercury		0	40	2		
	Selenium		14	40	50		
	Silver		1	40	100		

Notes:

MCL - United States Environmental Protection Agency Maximum Contaminant Level (October, 2009)
For lead the MCL is the action level.
For silver the MCL is the secondary drinking water regulation.
µg/L - microgram per liter

TABLE 6.3-1
Recommended DM Summary
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly				Annual						Baseline		
		Water Level	Chloride	1,4-dioxane	VOC COCs	Water Level	pH, Conductivity, and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metals$^{(1)}$	Anions$^{(2)}$	Cations$^{(3)}$
DETECTION MONITORING PROGRAM														
MW005A	TLS	x	x	x		x	x	x	x	x		x	x	x
MW006TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW008TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW009A	TLS	x	x	x		x	x	x	x	x		x	x	x
MW016TR	TLS	x				x	x	x	x	x		x	x	x
MW019A	TLS	x	x	x		x	x	x	x	x		x	x	x
MW020A	TLS	x	x	x		x	x	x	x	x		x	x	x
MW022TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW023ATR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW024TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW026ATR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW027BTR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW028A	TLS	x	x	x		x	x	x	x	x		x	x	x
MW029	TLS	x	x	x		x	x	x	x	x		x	x	x
MW030	TLS	x	x	x		x	x	x	x	x		x	x	x
MW031TR	TLS	x				x	x	x	x	x		x	x	x
MW033	TLS	x	x	x		x	x	x	x	x		x	x	x
MW034	TLS	x				x								
MW041T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW042TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW043T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW045T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW048TR	TLS	x				x	x	x	x	x		x	x	x
MW049T	TLS	x				x	x	x	x	x		x	x	x
MW050T	TLS	x				x	x	x	x	x		x	x	x
MW051T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW052T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW054T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW061T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW071T	TLS	x				x	x	x	x	x		x	x	x
MW073T	TLS	x				x	x	x	x	x		x	x	x
MW078T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW080TR	TLS	x	x	x		x	x	x	x	x		x	x	x
MW081T	TLS	x				x	x	x	x	x		x	x	x
MW089T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW096T	TLS	x				x								
MW097T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW098TR	TLS	x				x								
MW101T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW114T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW115T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW116T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW117T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW126T	TLS	x				x	x	x	x	x		x	x	x
MW127T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW131T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW132T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW133T	TLS	x	x	x		x	x	x	x	x		x	x	x
MW136T	TLS	x	x	x		x	x	x	x	x		x	x	x
PSDL009TR	TLS	x				x								
PSDL021	TLS	x	x	x		x	x	x	x	x		x	x	x
SL001	TLS	x				x								
SL002	TLS	x				x								
SL003	TLS	x				x								
SL004	TLS	x				x								
SL006	TLS	x				x	x	x	x	x		x	x	x
SL008	TLS	x				x								
MW134T	TLS	x	x	x		x	x	x	x	x		x	x	x

TABLE 6.3-1
Recommended DM Summary
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly				Annual						Baseline		
		Water Level	Chloride	1,4-dioxane	VOC COCs	Water Level	pH, Conductivity, and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metals$^{(1)}$	Anions$^{(2)}$	Cations$^{(3)}$
P042T	TLS	x				x	x	x	x	x		x	x	x
P112A	TLS/Paleo-channel	x				x								
P112B	TLS/Paleo-channel	x				x								
P112C	TLS/Paleo-channel	x				x								
P112D	TLS/Paleo-channel	x				x								
P114A	TLS/Paleo-channel	x	x	x		x	x	x	x	x		x	x	x
P114B	TLS/Paleo-channel	x	x	x		x	x	x	x	x		x	x	x
P114C	TLS/Paleo-channel	x	x	x		x	x	x	x	x		x	x	x
P114D	TLS/Paleo-channel	x	x	x		x	x	x	x	x		x	x	x
PSDL001	TLS	x	x	x		x								
PSDL005	TLS	x				x	x	x	x	x		x	x	x
PSDL012	TLS	x				x								
PSDL014	TLS	x				x								
PSDL017	TLS	x				x	x	x	x	x		x	x	x
New MW	TLS	x				x	x	x	x	x		x	x	x
New MW	TLS	x				x	x	x	x	x		x	x	x
New MW	TLS	x				x						x	x	x
New MW	TLS	x				x						x	x	x
New MW	TLS	x				x						x	x	x
MW001	SSDL	x				x								
MW005BSR	SSDL	x				x								
MW007SR	SSDL	x				x								
MW009	SSDL	x				x								
MW010	SSDL	x				x								
MW011	SSDL	x				x								
MW012	SSDL	x				x								
MW013	SSDL	x				x								
MW014	SSDL	x				x								
MW015	SSDL	x				x	x	x	x	x		x	x	x
MW017	SSDL	x				x								
MW018B	SSDL	x				x	x	x	x	x		x	x	x
MW020B	SSDL	x				x								
MW021	SSDL	x				x								
MW023SR	SSDL	x				x	x	x	x	x		x	x	x
MW025SR	SSDL	x				x	x	x	x	x		x	x	x
MW026B	SSDL	x				x								
MW027A	SSDL					x								
MW027AR	SSDL	x				x								
MW028B	SSDL	x				x								
MW032	SSDL	x				x								
MW035S	SSDL	x				x	x	x	x	x		x	x	x
MW036SR	SSDL	x				x	x	x	x	x		x	x	x
MW037SR	SSDL	x				x	x	x	x	x		x	x	x
MW038SR	SSDL	x				x	x	x	x	x		x	x	x
MW057S	SSDL	x				x								
MW059S	SSDL	x				x								
MW060SR	SSDL	x				x								
MW062S	SSDL	x				x	x	x	x	x		x	x	x
MW063SR	SSDL	x				x	x	x	x	x		x	x	x
MW082S	SSDL	x				x	x	x	x	x		x	x	x
MW086SR	SSDL	x				x	x	x	x	x		x	x	x
MW090SR	SSDL	x				x	x	x	x	x		x	x	x
MW092SR	SSDL	x				x	x	x	x	x		x	x	x
MW102S	SSDL	x				x	x	x	x	x		x	x	x
MW128S	SSDL	x				x	x	x	x	x		x	x	x
MW129S	SSDL	x				x	x	x	x	x		x	x	x
MW135S	SSDL	x				x								
PSDL004	SSDL	x				x								
PSDL007	SSDL	x				x								

TABLE 6.3-1
Recommended DM Summary
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly				Annual						Baseline		
		Water Level	Chloride	1,4-dioxane	VOC COCs	Water Level	pH, Conductivity, and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metals$^{(1)}$	Anions$^{(2)}$	Cations$^{(3)}$
PSDL009ASR	SSDL	x				x	x	x	x	x		x	x	x
PSDL014A	SSDL	x				x								
PSDL017A	SSDL	x				x	x	x	x	x		x	x	x
PSDL021A	SSDL	x				x	x	x	x	x		x	x	x
SL007	SSDL	x				x								
SL009	SSDL	x				x								
SL019SR	SSDL	x				x	x	x	x	x		x	x	x
SL020SR	SSDL	x				x	x	x	x	x		x	x	x
New MW	SSDL	x				x	x	x	x	x		x	x	x
New MW	SSDL	x				x	x	x	x	x		x	x	x
New MW	SSDL	x				x	x	x	x	x		x	x	x
New MW	SSDL	x				x						x	x	x
New MW	SSDL	x				x						x	x	x
New MW	SSDL	x				x						x	x	x
MW018APR	PSDL	x				x	x	x	x	x		x	x	x
MW039P	PSDL	x				x								
MW040P	PSDL	x				x								
MW044P	PSDL	x				x								
MW046P	PSDL	x				x								
MW047P	PSDL	x				x	x	x	x	x		x	x	x
MW053P	PSDL	x				x								
MW055P	PSDL	x				x								
MW056P	PSDL	x				x								
MW058P	PSDL	x				x								
MW064P	PSDL	x				x	x	x	x	x		x	x	x
MW072P	PSDL	x				x	x	x	x	x		x	x	x
MW077P	PSDL	x				x	x	x	x	x		x	x	x
MW087P	PSDL	x				x	x	x	x	x		x	x	x
MW091PR	PSDL	x				x	x	x	x	x		x	x	x
MW093PR	PSDL	x				x								
MW094PR	PSDL	x				x	x	x	x	x		x	x	x
MW095P	PSDL	x				x								
MW099P	PSDL	x				x	x	x	x	x		x	x	x
MW100P	PSDL	x				x								
MW103P	PSDL	x				x	x	x	x	x		x	x	x
MW123P	PSDL	x				x						x	x	x
MW124P	PSDL	x				x						x	x	x
MW125P	PSDL	x				x						x	x	x
MW130P	PSDL	x				x	x	x	x	x		x	x	x
PSDL013	PSDL	x				x								
PBC004	UBC-A	x				x								
SL005	PSDL	x				x								
SL013	PSDL	x				x								
SL014PR	PSDL	x				x								
SL015	PSDL	x				x	x	x	x	x		x	x	x
SL016	PSDL	x				x	x	x	x	x		x	x	x
SL021PR	PSDL	x				x	x	x	x	x		x	x	x
SL022	PSDL	x				x								
SL023	PSDL	x				x								
SL024	PSDL	x				x								
UBC003	PSDL	x				x								
New MW	PSDL	x				x	x	x	x	x		x	x	x
New MW	PSDL	x				x	x	x	x	x		x	x	x
New MW	PSDL	x				x	x	x	x	x		x	x	x
New MW	PSDL	x				x	x	x	x	x		x	x	x
New MW	PSDL	x				x	x	x	x	x		x	x	x
New MW	PSDL	x				x						x	x	x
New MW	PSDL	x				x						x	x	x
CBC004	UBC-A	x				x								

TABLE 6.3-1
Recommended DM Summary
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly				Annual						Baseline		
		Water Level	Chloride	1,4-dioxane	VOC COCs	Water Level	pH, Conductivity, and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metals$^{(1)}$	Anions$^{(2)}$	Cations$^{(3)}$
PBC002	UBC-A	x				x								
PBC006	UBC-A	x				x								
P042B	UBC-A	x				x								
UBC002AIR	UBC-A	x				x								
UBC004	UBC-A	x				x								
UBC010	UBC-A	x				x								
UBC011	UBC-A	x				x								
UBC012	UBC-A	x				x								
UBC013	UBC-A	x				x								
UBC014	UBC-A	x				x								
UBC015AR	UBC-A	x				x								
UBC016	UBC-A	x				x								
UBC017	UBC-A	x				x								
UBC018	UBC-A	x				x								
UBC019	UBC-A					x								
UBC021	UBC-A					x	x	x	x	x		x	x	x
UBC022AR	UBC-A	x				x								
UBC023	UBC-A	x				x								
UBC024	UBC-A	x				x	x	x	x	x		x	x	x
UBC025	UBC-A	x				x	x	x	x	x		x	x	x
UBC026	UBC-A	x				x	x	x	x	x		x	x	x
UBC027	UBC-A	x				x	x	x	x	x		x	x	x
UBC028AR	UBC-A	x				x	x	x	x	x		x	x	x
UBC029AR	UBC-A	x				x								
UBC030	UBC-A	x				x								
UBC031	UBC-A	x				x								
UBC034	UBC-A	x				x								
UBC035	UBC-A	x				x								
UBC036	UBC-A	x				x								
UBC048	UBC-A	x				x								
UBC049	UBC-A	x				x								
UBC051	UBC-A	x				x								
UBC052	UBC-A	x				x	x	x	x	x		x	x	x
UBC053	UBC-A	x				x								
New MW	UBC-A	x				x						x	x	x
New MW	UBC-A	x				x						x	x	x
CBC008	UBC-B	x				x								
PW004	UBC-B	x				x								
UBC001	UBC-B	x				x								
UBC005	UBC-B	x				x								
UBC006	UBC-B	x				x								
UBC008	UBC-B	x				x								
UBC009	UBC-B	x				x								
UBC017B	UBC-B	x				x								
UBC018B	UBC-B	x				x								
FDSecI											x			
SBD#1					x									
SBD#2					x									

Notes:

Baseline Metals^{1} **-** Geochemical Water Analysis ICP-ES/ICP-MS (FullSuite of 70 elements)

Anions^{2} - One time analysis of major anions (alkalinity, chloride, and sulfate) for water fingerprinting

Cations^{3} - One time analysis of major cations (calcium, magnesium, potassium, and sodium) for water fingerprinting

ORP - Oxygen Reduction Potential

DO - Dissolved Oxygen

VOC COCs - PCE, TCE, cis-1,2-DCE, VC

Metals COCs - Cadmium, Chromium, Lead, Arsenic

TABLE 6.4-1
Recommended Operations Monitoring Program
Pinewood Landfill
Pinewood, South Carolina

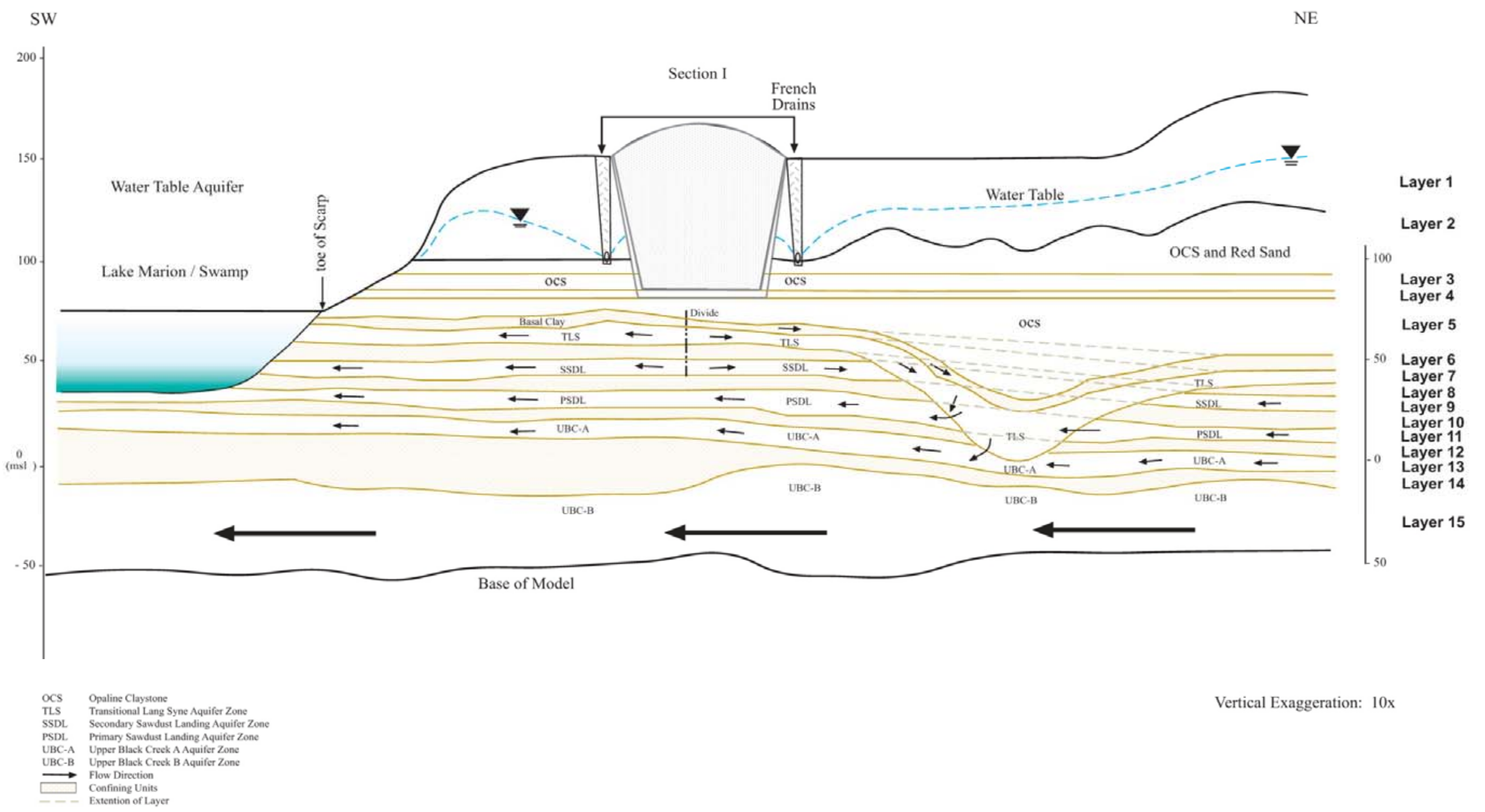
Environmental Matrix/Media	Location	Number	Parameters	Frequency	Objective
SHORT TERM OPERATIONS MONITORING PROGRAM					
Soil Gas	Section I Cover	Total			
	Cell A	3	GORE A1 Suite	Quarterly	Monitor Soil Gas in Section I Cover Soils "Hot Spot" Areas.
	Cell B	3	GORE A1 Suite	Quarterly	
	Cell C	3	GORE A1 Suite	Quarterly	
	Cell D	3	GORE A1 Suite	Quarterly	
	Cell E	6	GORE A1 Suite	Quarterly	
	Shallow Soil Gas Adjacent to Section I	Total			
	Adj to Cell E (SW)	5	GORE A1 Suite	Quarterly	Monitor Soil Gas in soils beyond the Section I cover to evaluate the potential for migration beyond the closed landfill.
	Adj to Cell E (NW)	3	GORE A1 Suite	Quarterly	
	Adj to Cells B&C (NW)	3	GORE A1 Suite	Quarterly	
	Adj to Cell B (East)	3	GORE A1 Suite	Quarterly	
	Shallow Groundwater	Total			
	Adj to Cell E (SW)	1	VOCs, chloride, 1,4-dioxane	Quarterly	Compare groundwater results with those from soil gas and results from French drain to evaluate low VOC detections in French drain.
	Adj to Cell E (NW)	1	VOCs, chloride, 1,4-dioxane	Quarterly	
	Adj to Cells B&C (NW)	1	VOCs, chloride, 1,4-dioxane	Quarterly	
	Adj to Cell B (East)	1	VOCs, chloride, 1,4-dioxane	Quarterly	
Shallow Cover Wells	Section I Section II Section III	Total			
	SILC-1 S2LC-03 S3LC-02		VOCs Select 1 well from each landfill Section and sample for chloride, 1,4-dioxane, RCRA Metals	Annual	Establish long term trends such as any increasing or decreasing concentrations of constituents in the cover pore water. 1,4 dioxane, chloride and RCRA metals monitoring proposed to determine the presence of any waste constituents in cover pore water not the result of diffusion through cover membrane (i.e. historical spills or leaks on cover of landfill).
	SILC-2 S2LC-04 S3LC-04		VOCs	Annual	
	SILC-3 S2LC-06 S3LC-06		VOCs	Annual	
	SILC-4 S2LC-07		VOCs	Annual	
	SILC-5 S2LC-08		VOCs	Annual	
	S2LC-09		VOCs	Annual	
	5 6 3	14			
	Water Table Aquifer	Total			
	WT032 (designated background)	1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Annual	Use as a comparison to water quality in Cover Wells.
French Drain	FD Section I	Total			
	MH-4	1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	To determine potential contribution of waste constituents to French drains from soil gas vapors or leachate from Section I.
	MH-5	1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	

TABLE 6.4-1
Recommended Operations Monitoring Program
Pinewood Landfill
Pinewood, South Carolina

Environmental Matrix/Media	Location			Number	Parameters	Frequency	Objective
LONG TERM OPERATIONS MONITORING PROGRAM							
French Drains	Pond A			Total			
	FDPond A			1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Annual	To determine potential contribution of waste constituents to French drains from cover pore water and to evaluate site-related drainage into onsite surface waters.
	FDSec1			1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Annual	
	Pond B			Total			
	FDPond B			1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Annual	
Storm Water	Pond A			Total			
	S1-SW-10	(new)		1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	To determine contribution of waste constituents from storm water runoff from landfill cover into onsite surface waters.
	S1-SW-11	(new)		1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	
	S1-SW-12	(new)		1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	
	S1-SW-13	(new)		1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	
	Pond B			Total			
	Main Influent Pipe			1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	To determine contribution of waste constituents from storm water runoff from landfill cover into onsite surface waters.
	Secondary Influent Pipe			1	VOCs, 1,4-dioxane, chloride, RCRA Metals	Quarterly	
Surface Water							
	Pond A, Outfall 001				See NPDES Permit SC0042170 Monitoring Requirements	As Required by NPDES Permit SC0042170	Compliance with NPDES Permit SC0042170.
	Pond B, Outfall 002				See NPDES Permit SC0042170 Monitoring Requirements		
	Aeration Basin Outfall 01A				tetrachloroethylene		
Settlement Plates		Existing	New	Total			
	Section I	13	7	20	Elevation, relative to NGVD 1988 or current benchmark control datum #403.	Quarterly	Identify location and amount of settlement in Section I Cover.
	Section II	32	0	32			
	Section III	11	0	11			
Precipitation							
	On-site or immediate vicinity.				Inches of precipitation and temperature.	Automated system to measure daily and upload and evaluate on monthly/annual.	Use to correlate with leachate production.
Leachate (Primary Sumps)	Section I	Section II	Section III	Total			
	A1,A2,A3,A4	A1,A2,A3	A1,A2,A3		Gallons pumped per sump.	Record daily, as necessary. Upload and evaluate on monthly/annual basis.	Use to correlate with quantities transported off site for disposal. Use to correlate with precipitation. Use to correlate with shallow groundwater levels. Determine trends in quantities of leachate generated by sump, by cell and by landfill Section.
	B1,B2,B3	B1,B2,B3	B1,B2,B3				
	C1,C2,C3	C1,C2,C3	C1,C2				
	D1,D2,D3	D1,D2,D3					
	E1,E2,E3	E1,E2,E3					
		F1,F2,F3					
		G1,G2,G3					
	16	21	8	45			
PVC Geomembrane	Section I Cover			Total			
	Cell A	1		1	Tensile Properties (ASTM D 882) Thickness (ASTM D 5199) Peel and Shear (ASTM D 6392 / GRI GM19/D4437/NSF 54, D 6214)	5-year period	Examine physical properties of PVC to evaluate its condition. Note, destructive testing of the Section II and Section III geomembrane liners is not recommended at this time.
	Cell B	1		1			
	Cell C	1		1			
	Cell D	1		1			
	Cell E	1		1			

FIGURES

CSM Schematic from Earth Tech, Inc., 2002



Updated CSM from 3-D Visualization

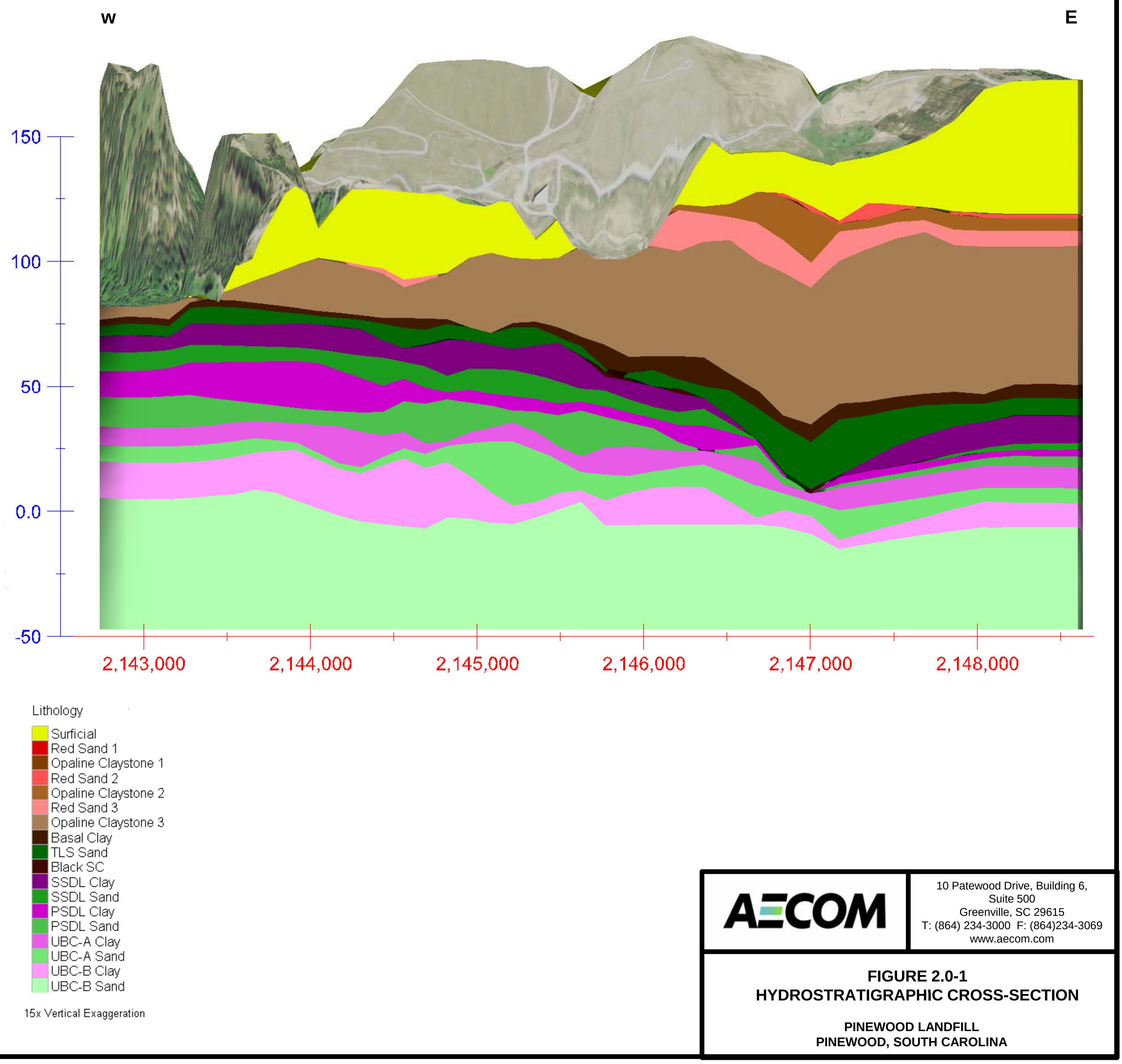


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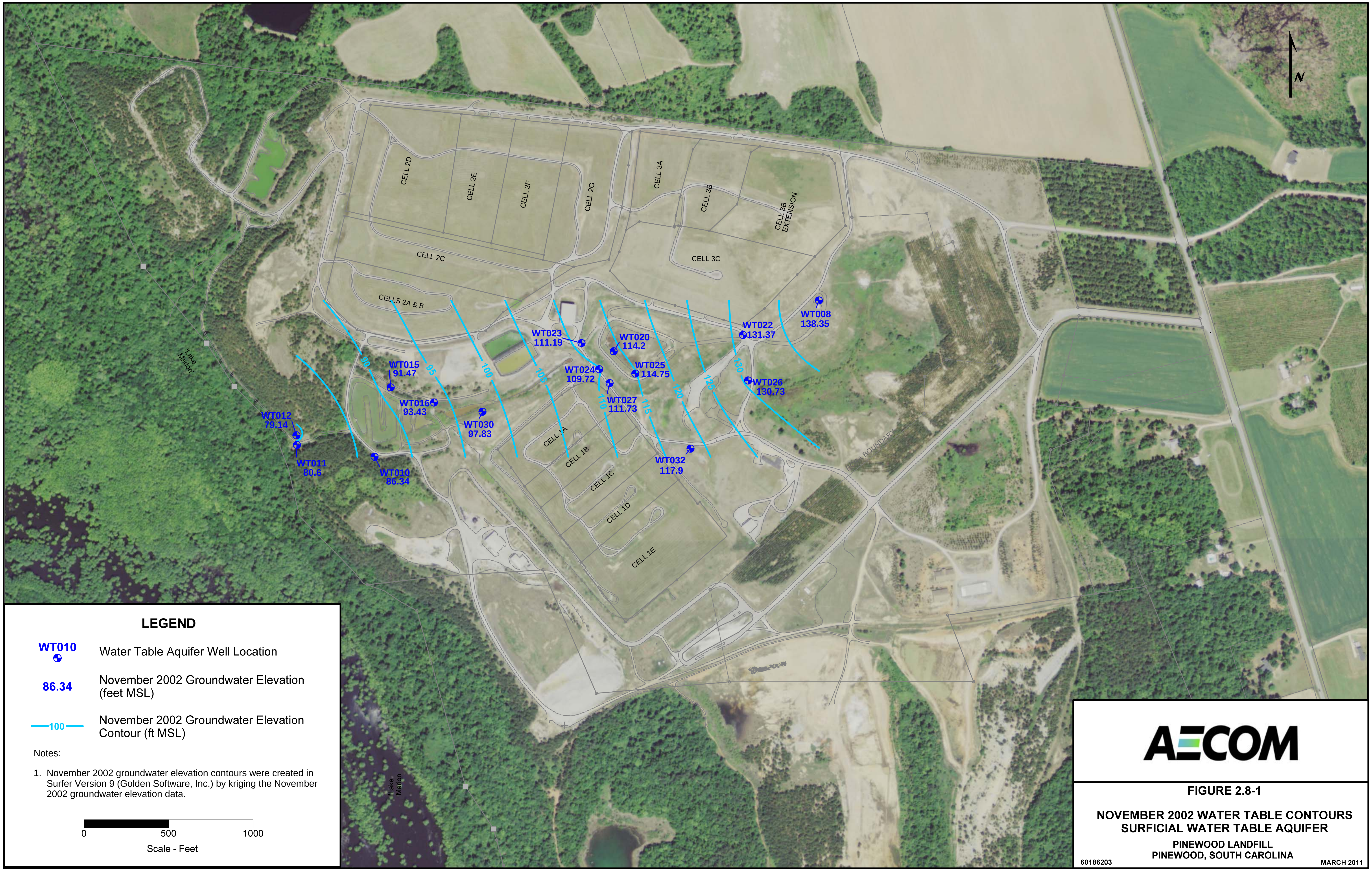
FIGURE 2.0-1
HYDROSTRATIGRAPHIC CROSS-SECTION

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



LEGEND

WT010 ●	Water Table Aquifer Well Location
86.34	November 2002 Groundwater Elevation (feet MSL)
—100—	November 2002 Groundwater Elevation Contour (ft MSL)

Notes:

1. November 2002 groundwater elevation contours were created in Surfer Version 9 (Golden Software, Inc.) by kriging the November 2002 groundwater elevation data.

0 500 1000

Scale - Feet

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FIGURE 2.8-1

NOVEMBER 2002 WATER TABLE CONTOURS
SURFICIAL WATER TABLE AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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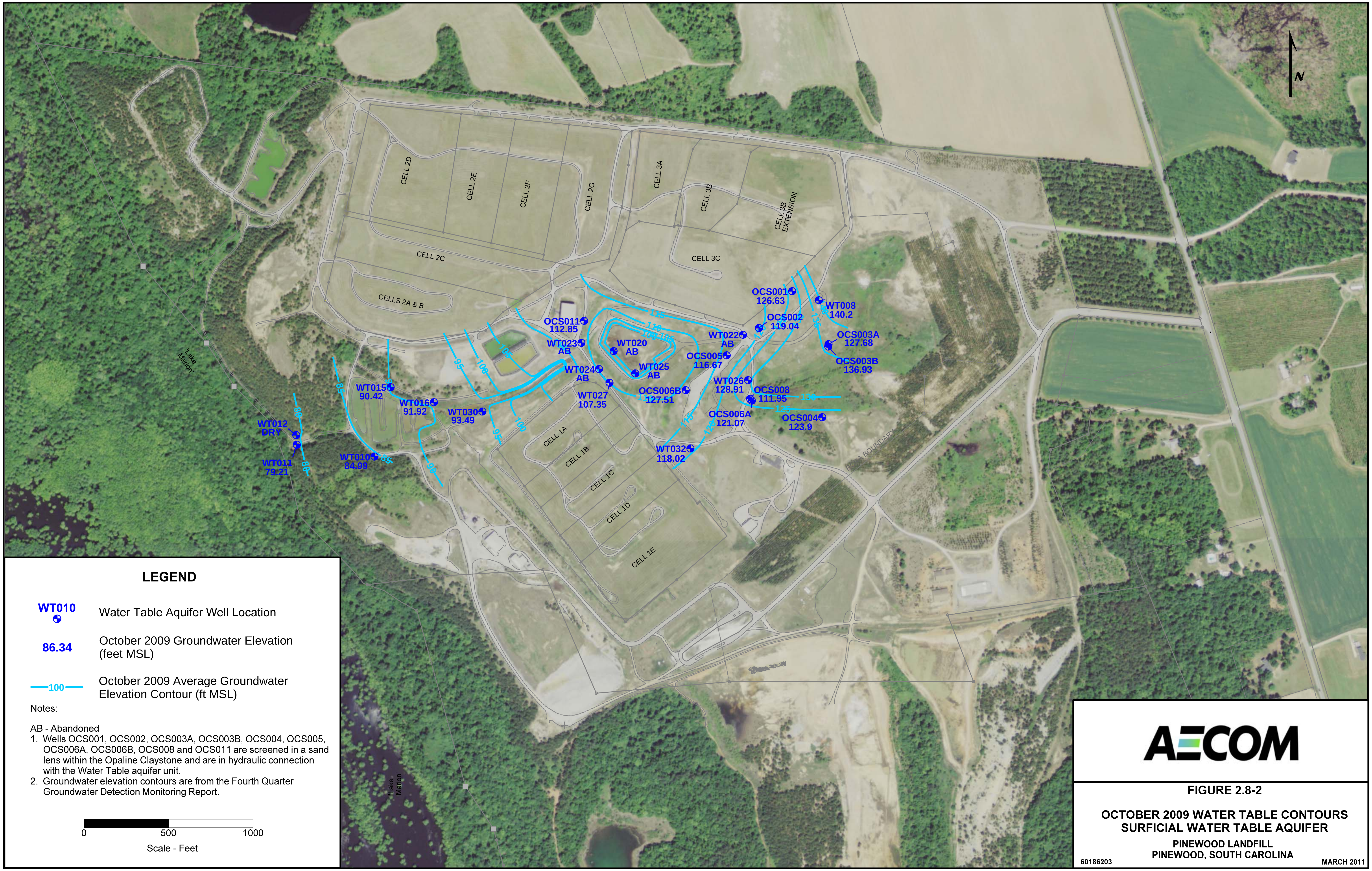
60186203/400 - TECHNICAL INFORMATION AND TECHNICAL DISCIPLINE FILES/480 - Project 3 Element 2 Environmental Mon Systems/2002 Water Table Surface Recreation/2002 WT Surface.srf



LEGEND

WT010	Water Table Aquifer Well Location
86.34	October 2009 Groundwater Elevation (feet MSL)
—100—	October 2009 Average Groundwater Elevation Contour (ft MSL)

Notes:

AB - Abandoned

1. Wells OCS001, OCS002, OCS003A, OCS003B, OCS004, OCS005, OCS006A, OCS006B, OCS008 and OCS011 are screened in a sand lens within the Opaline Claystone and are in hydraulic connection with the Water Table aquifer unit.
2. Groundwater elevation contours are from the Fourth Quarter Groundwater Detection Monitoring Report.

0 500 1000

Scale - Feet

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FIGURE 2.8-2

OCTOBER 2009 WATER TABLE CONTOURS
SURFICIAL WATER TABLE AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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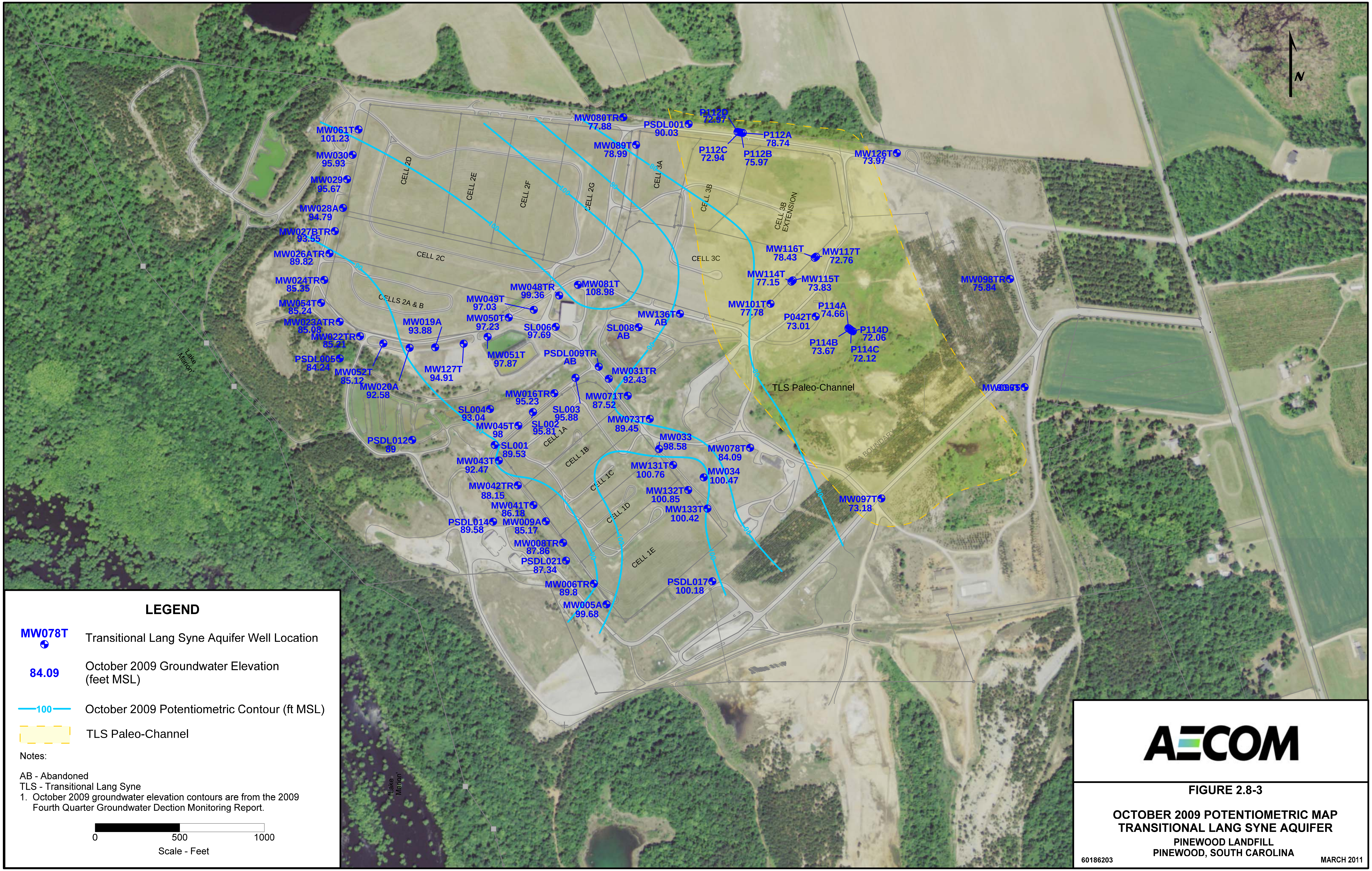

LEGEND

MW078T ●	Transitional Lang Syne Aquifer Well Location
84.09	October 2009 Groundwater Elevation (feet MSL)
—100—	October 2009 Potentiometric Contour (ft MSL)
▨	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. October 2009 groundwater elevation contours are from the 2009 Fourth Quarter Groundwater Dection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-3

OCTOBER 2009 POTENTIOMETRIC MAP TRANSITIONAL LANG SYNE AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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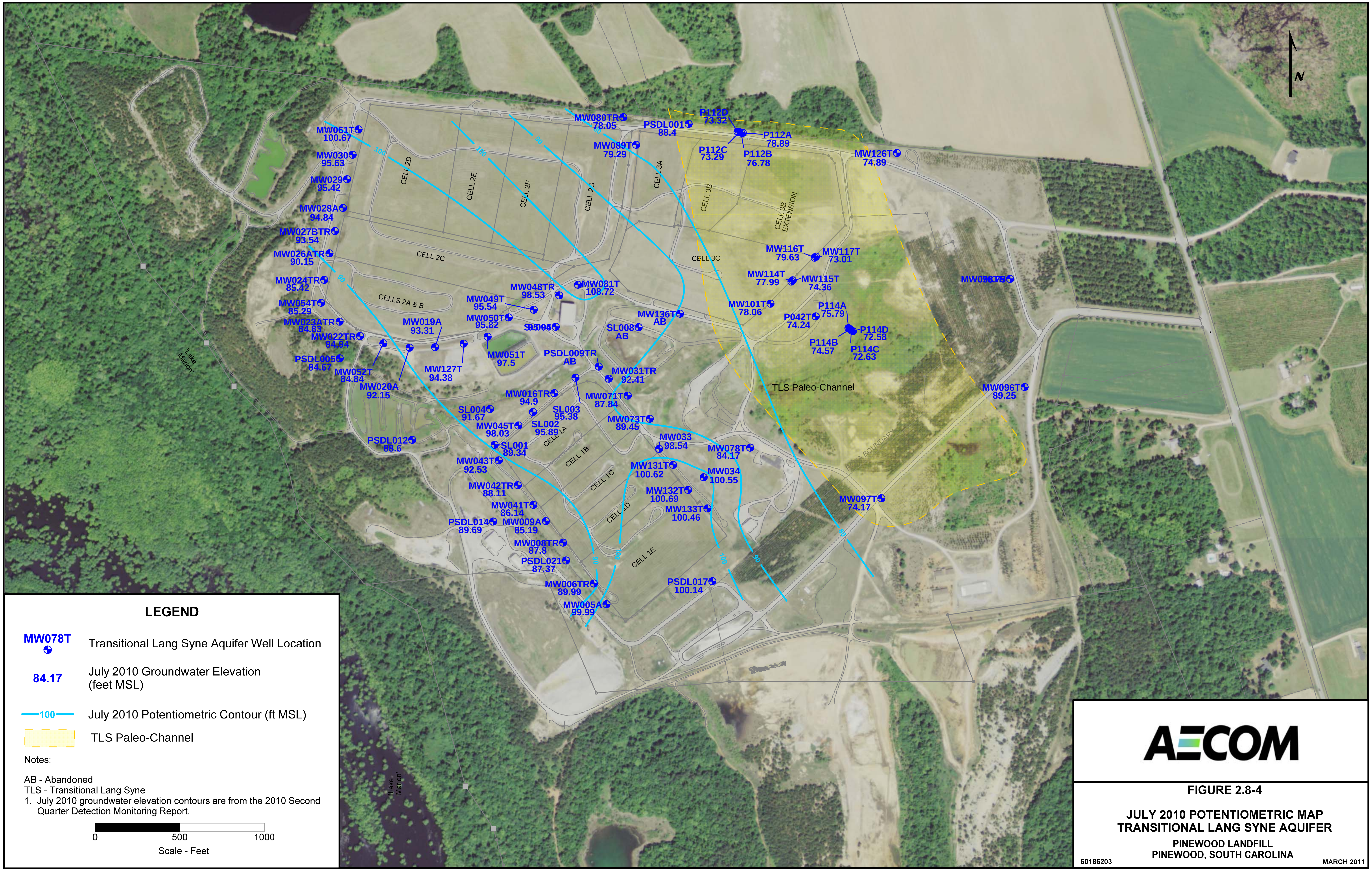

LEGEND

MW078T ●	Transitional Lang Syne Aquifer Well Location
84.17	July 2010 Groundwater Elevation (feet MSL)
—100—	July 2010 Potentiometric Contour (ft MSL)
▨	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. July 2010 groundwater elevation contours are from the 2010 Second Quarter Detection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-4

JULY 2010 POTENTIOMETRIC MAP
TRANSITIONAL LANG SYNE AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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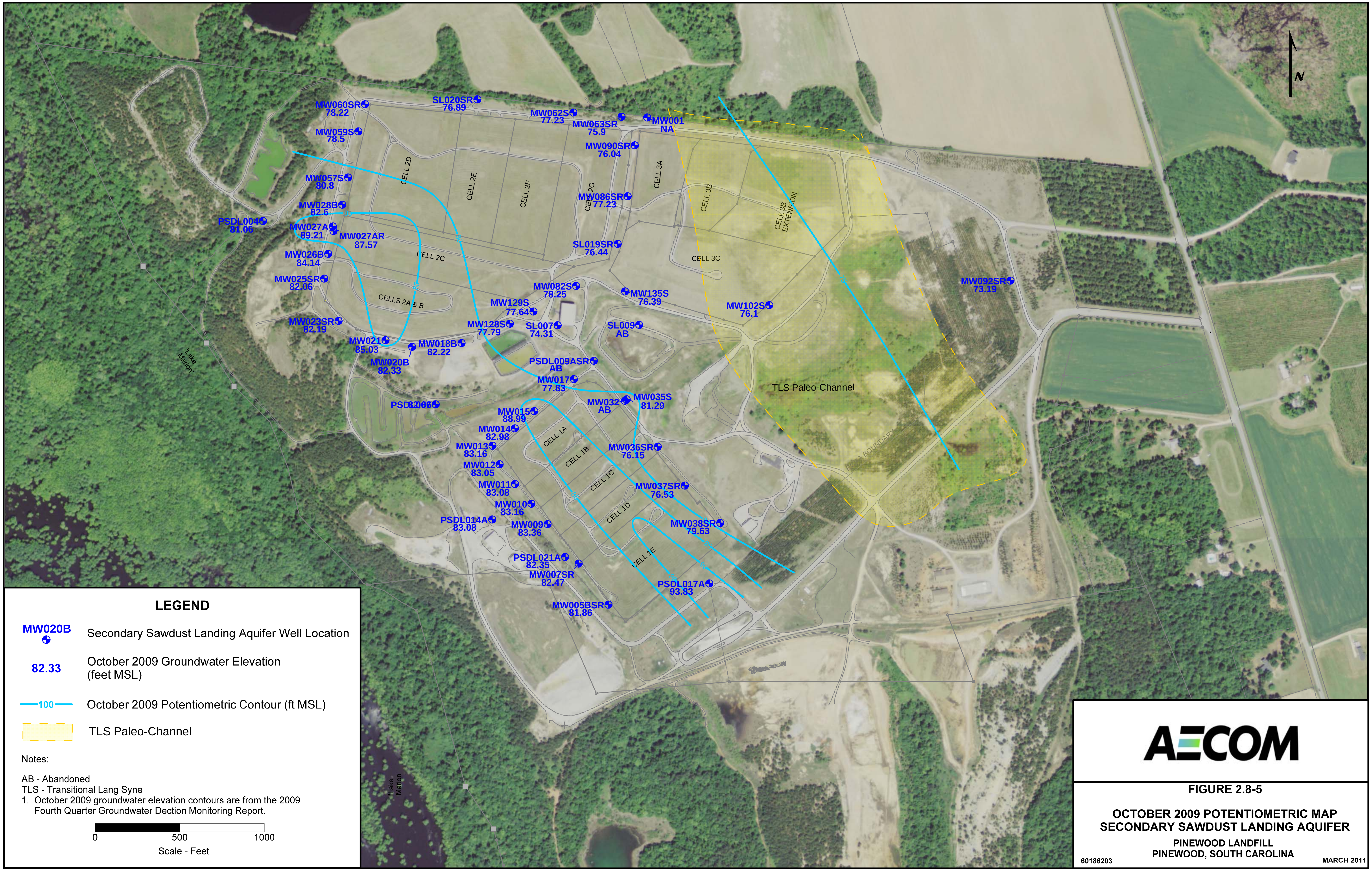

LEGEND

MW020B ⊕	Secondary Sawdust Landing Aquifer Well Location
82.33	October 2009 Groundwater Elevation (feet MSL)
—100—	October 2009 Potentiometric Contour (ft MSL)
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. October 2009 groundwater elevation contours are from the 2009 Fourth Quarter Groundwater Dection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-5

OCTOBER 2009 POTENTIOMETRIC MAP SECONDARY SAWDUST LANDING AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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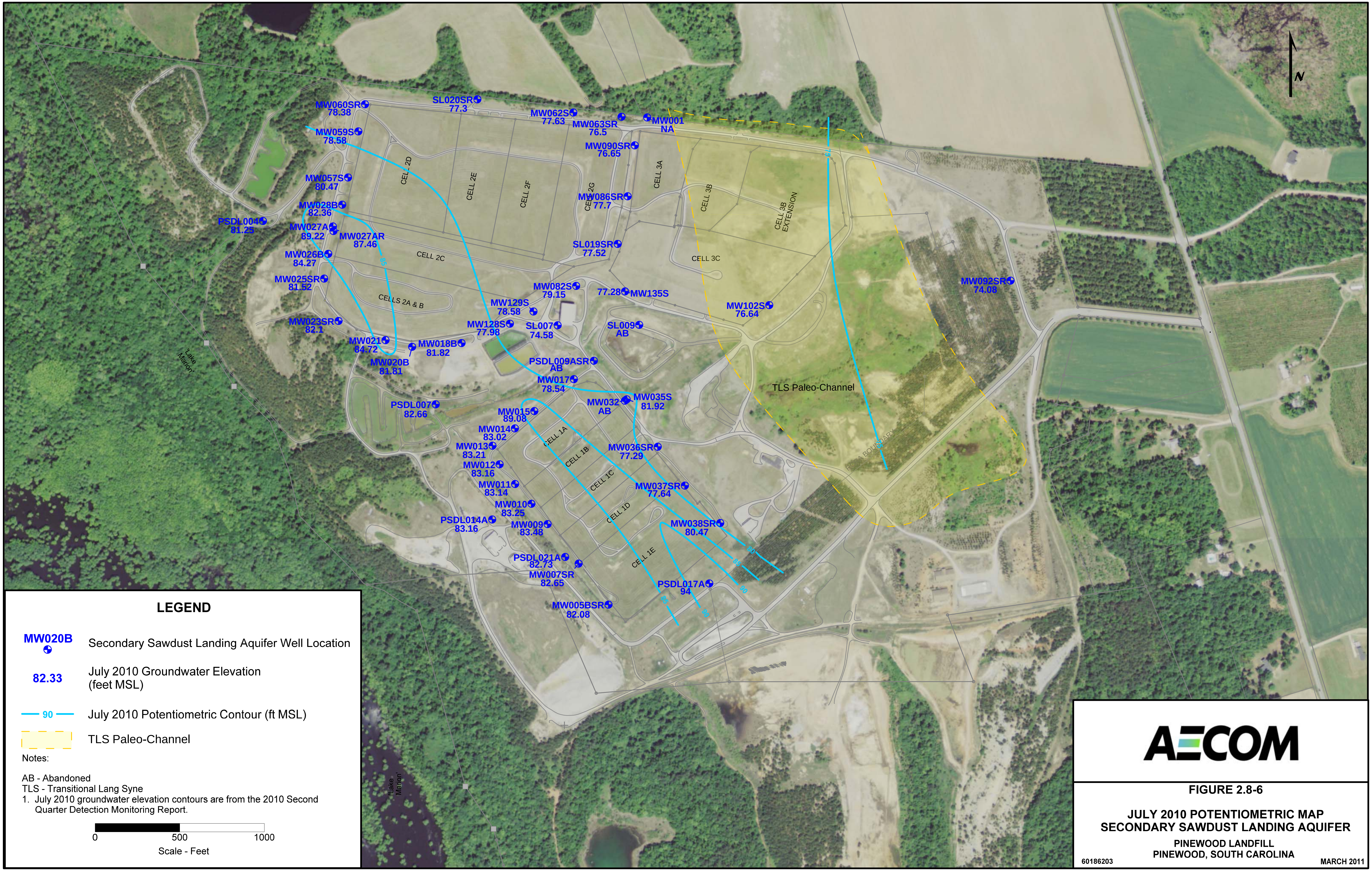

LEGEND

MW020B ●	Secondary Sawdust Landing Aquifer Well Location
82.33	July 2010 Groundwater Elevation (feet MSL)
— 90 —	July 2010 Potentiometric Contour (ft MSL)
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. July 2010 groundwater elevation contours are from the 2010 Second Quarter Detection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-6

JULY 2010 POTENTIOMETRIC MAP
SECONDARY SAWDUST LANDING AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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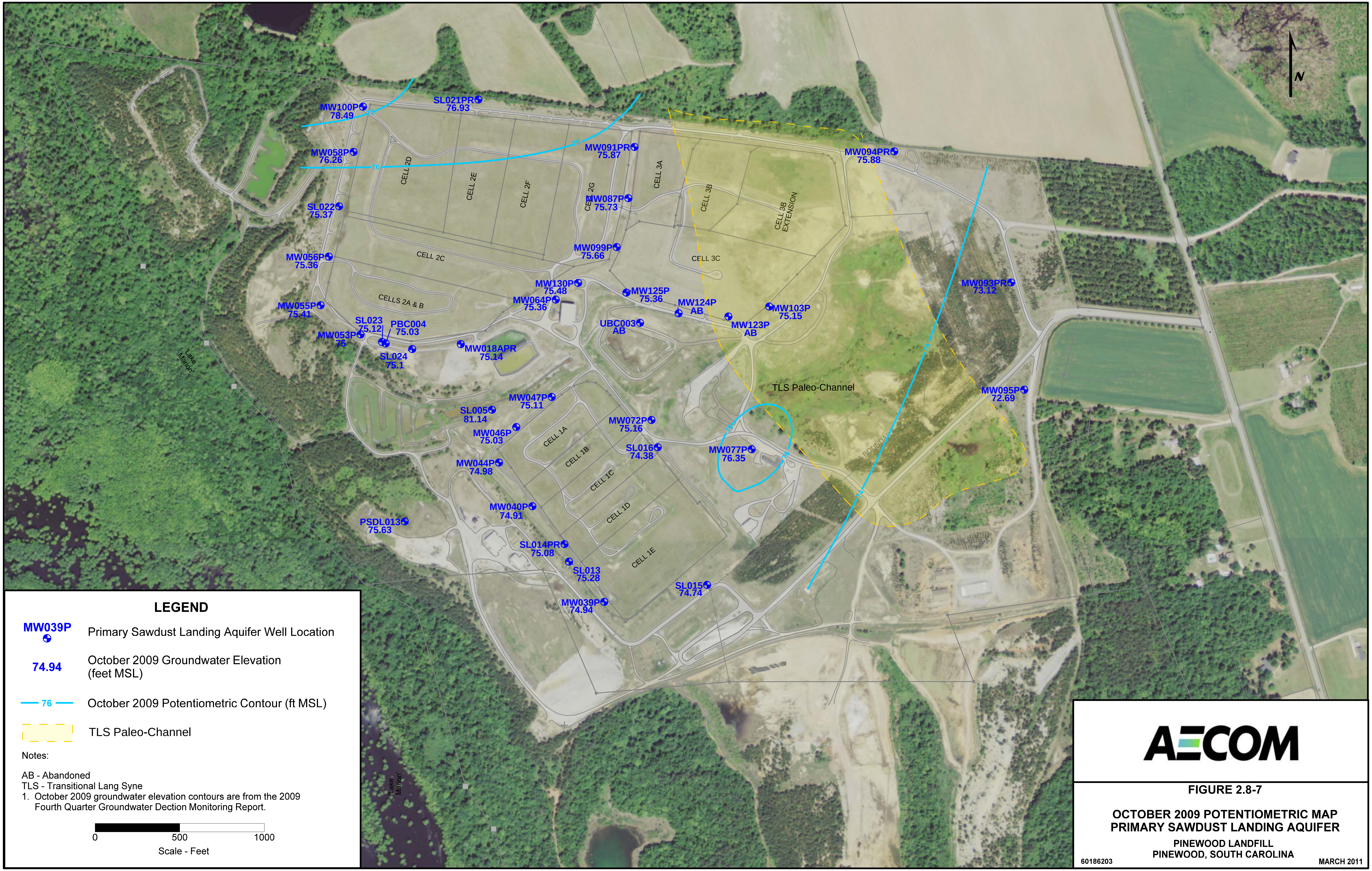

LEGEND

MW039P ●	Primary Sawdust Landing Aquifer Well Location
74.94	October 2009 Groundwater Elevation (feet MSL)
— 76 —	October 2009 Potentiometric Contour (ft MSL)
▨	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. October 2009 groundwater elevation contours are from the 2009 Fourth Quarter Groundwater Dection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-7

OCTOBER 2009 POTENTIOMETRIC MAP
PRIMARY SAWDUST LANDING AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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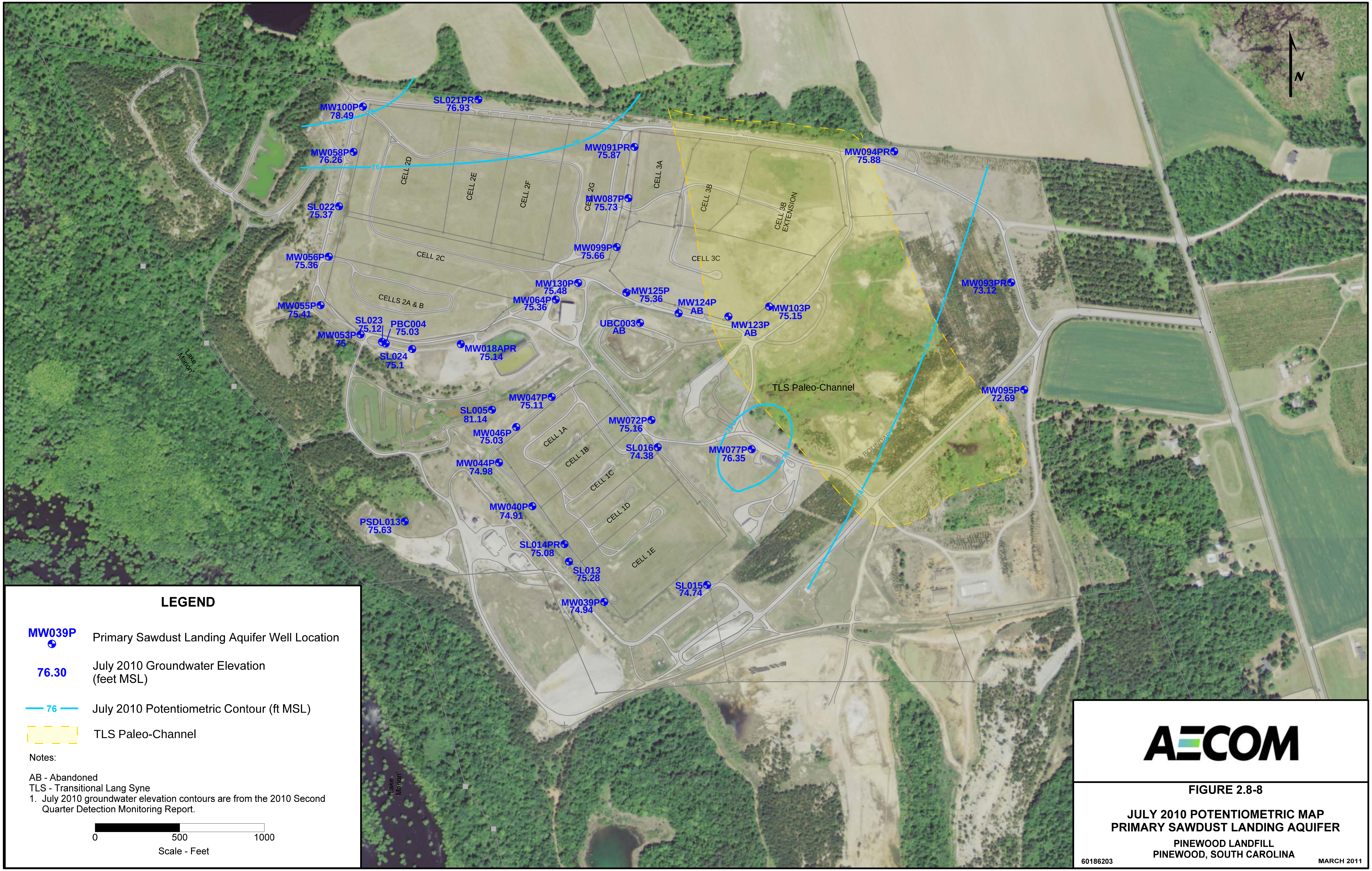
60186203/400 - TECHNICAL INFORMATION AND TECHNICAL DISCIPLINE FILES/480 - Project 3 Element 2 Environmental Mon Systems/2009 Water Table Surface Recreation/2009 4Q Potentiometric Maps.srf; F2.8-7_4Q 2009 PSDL Pot Map.pdf



LEGEND

MW039P ●	Primary Sawdust Landing Aquifer Well Location
76.30	July 2010 Groundwater Elevation (feet MSL)
— 76 —	July 2010 Potentiometric Contour (ft MSL)
▨	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. July 2010 groundwater elevation contours are from the 2010 Second Quarter Detection Monitoring Report.

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FIGURE 2.8-8

JULY 2010 POTENTIOMETRIC MAP
PRIMARY SAWDUST LANDING AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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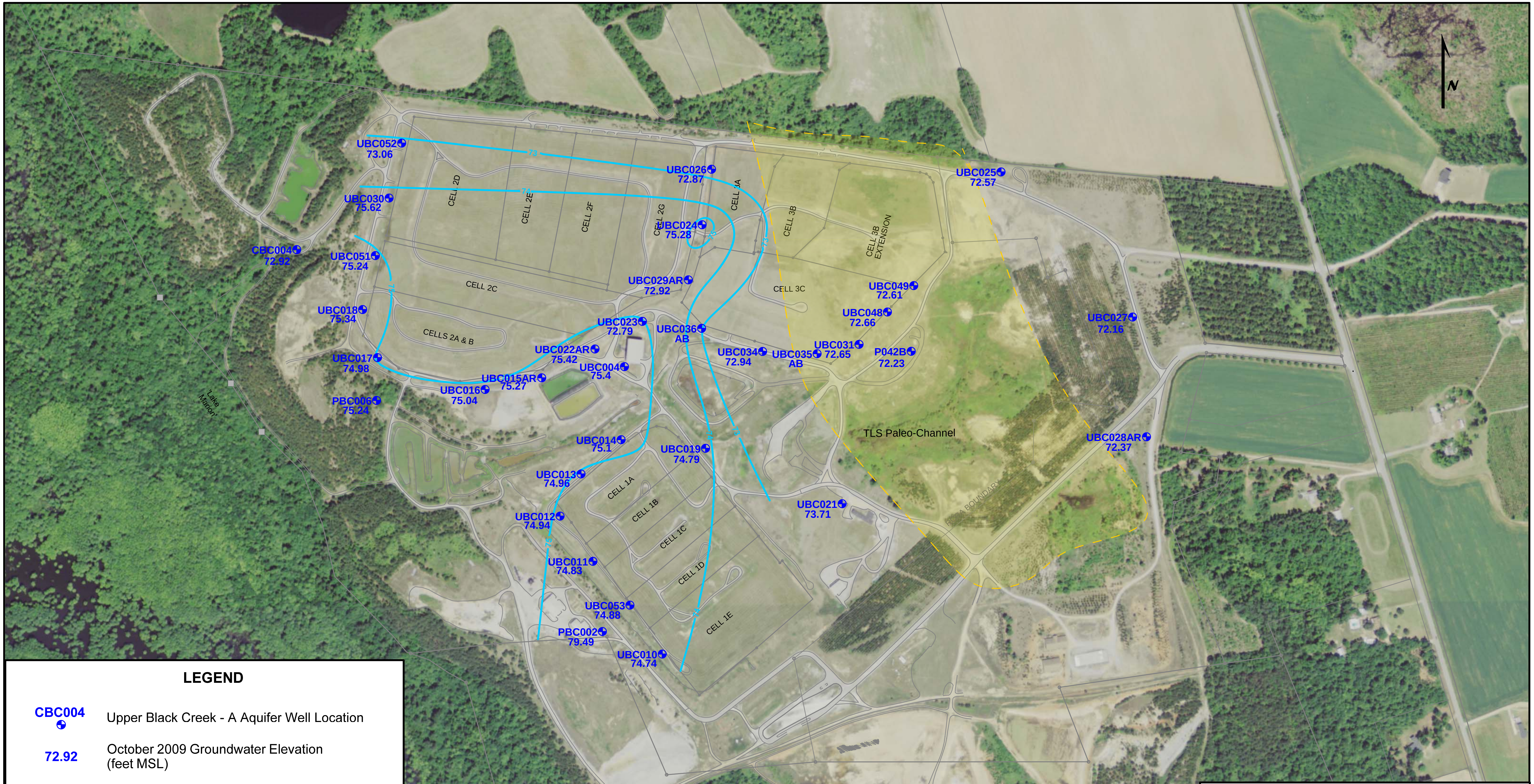

LEGEND

CBC004 ●	Upper Black Creek - A Aquifer Well Location
72.92	October 2009 Groundwater Elevation (feet MSL)
— 75 —	October 2009 Potentiometric Contour (ft MSL)
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Transitional Lang Syne
1. October 2009 groundwater elevation contours are the UBC-A1 aquifer contours from the 2009 Fourth Quarter Detection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-9

OCTOBER 2009 POTENTIOMETRIC MAP
UPPER BLACK CREEK - A AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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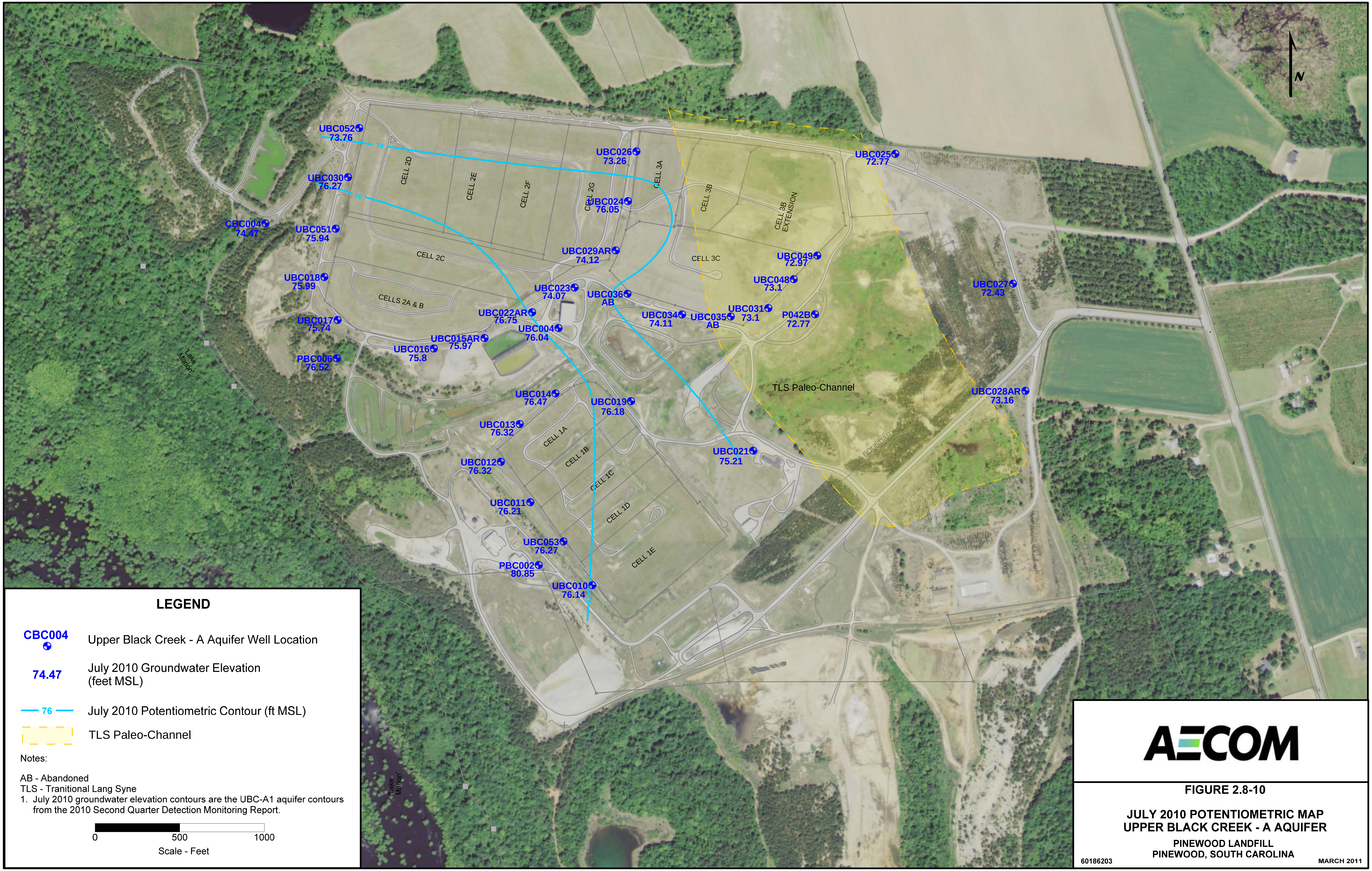

LEGEND

CBC004 ●	Upper Black Creek - A Aquifer Well Location
74.47	July 2010 Groundwater Elevation (feet MSL)
— 76 —	July 2010 Potentiometric Contour (ft MSL)
▨	TLS Paleo-Channel

Notes:

AB - Abandoned
TLS - Tranitional Lang Syne
1. July 2010 groundwater elevation contours are the UBC-A1 aquifer contours from the 2010 Second Quarter Detection Monitoring Report.

0 500 1000
Scale - Feet

AECOM

FIGURE 2.8-10

JULY 2010 POTENTIOMETRIC MAP
UPPER BLACK CREEK - A AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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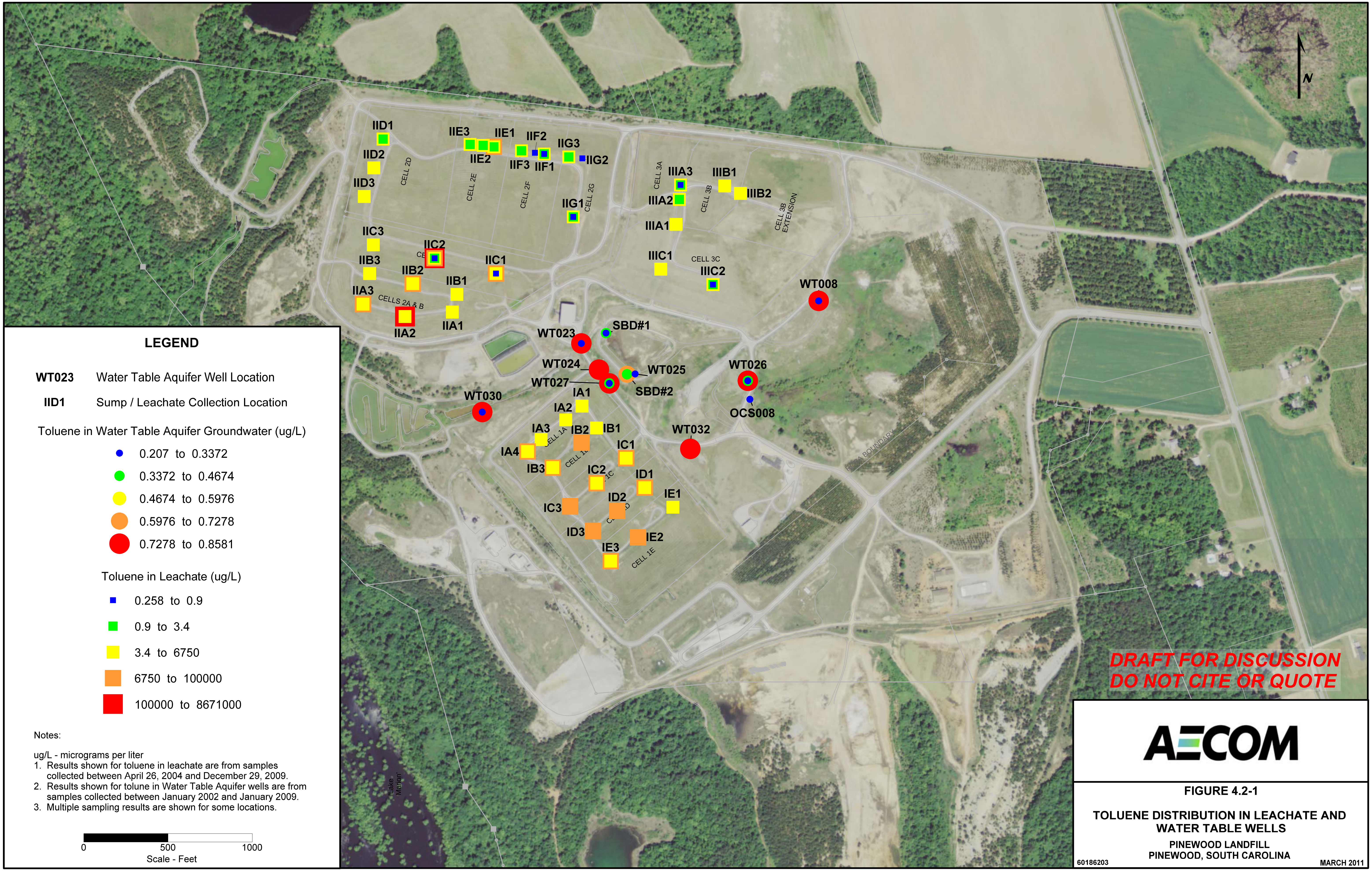

LEGEND

WT023	Water Table Aquifer Well Location
IID1	Sump / Leachate Collection Location

Toluene in Water Table Aquifer Groundwater (ug/L)

●	0.207 to 0.3372
●	0.3372 to 0.4674
●	0.4674 to 0.5976
●	0.5976 to 0.7278
●	0.7278 to 0.8581

Toluene in Leachate (ug/L)

■	0.258 to 0.9
■	0.9 to 3.4
■	3.4 to 6750
■	6750 to 100000
■	100000 to 8671000

Notes:

ug/L - micrograms per liter

1. Results shown for toluene in leachate are from samples collected between April 26, 2004 and December 29, 2009.
2. Results shown for tolune in Water Table Aquifer wells are from samples collected between January 2002 and January 2009.
3. Multiple sampling results are shown for some locations.

0 500 1000

Scale - Feet

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FIGURE 4.2-1

TOLUENE DISTRIBUTION IN LEACHATE AND WATER TABLE WELLS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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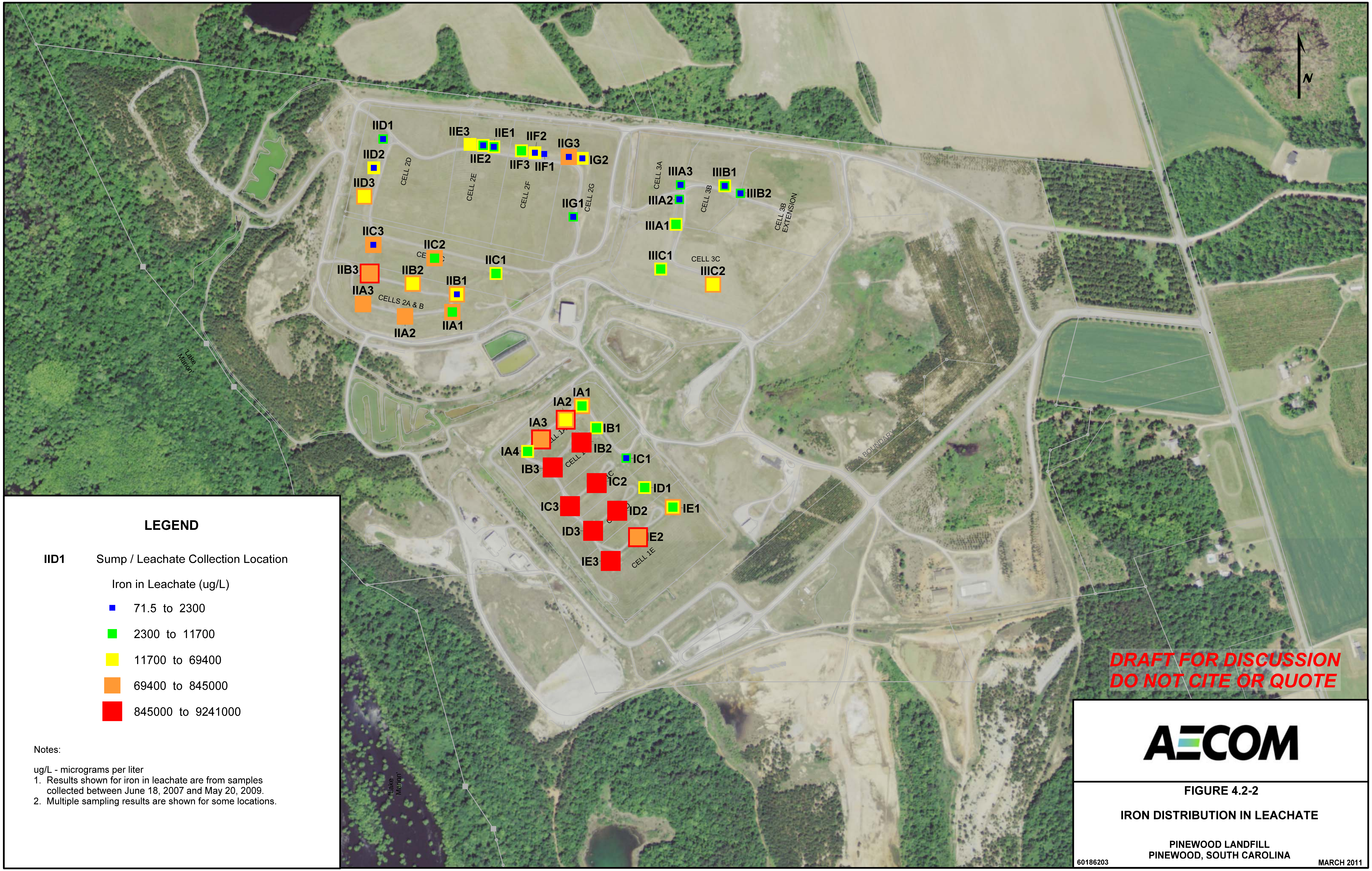

LEGEND

IID1 Sump / Leachate Collection Location

Iron in Leachate (ug/L)

- 🟦 71.5 to 2300
- 🟩 2300 to 11700
- 🟨 11700 to 69400
- 🟧 69400 to 845000
- 🟥 845000 to 9241000

Notes:

ug/L - micrograms per liter
1. Results shown for iron in leachate are from samples collected between June 18, 2007 and May 20, 2009.
2. Multiple sampling results are shown for some locations.

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FIGURE 4.2-2

IRON DISTRIBUTION IN LEACHATE

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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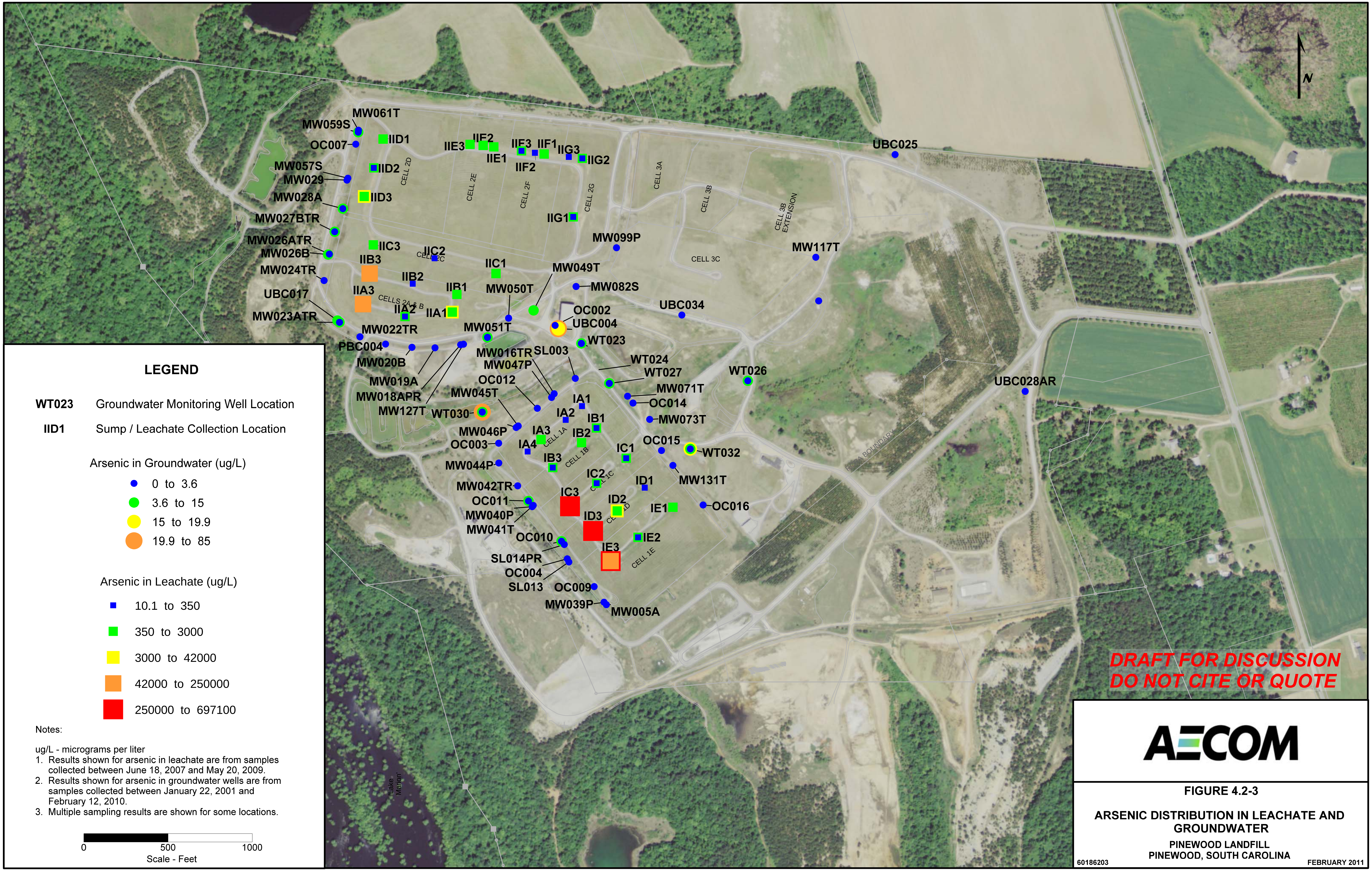

LEGEND

WT023 Groundwater Monitoring Well Location

IID1 Sump / Leachate Collection Location

Arsenic in Groundwater (ug/L)

- 🔵 0 to 3.6
- 🟢 3.6 to 15
- 🟡 15 to 19.9
- 🟠 19.9 to 85

Arsenic in Leachate (ug/L)

- 🟦 10.1 to 350
- 🟩 350 to 3000
- 🟨 3000 to 42000
- 🟧 42000 to 250000
- 🟥 250000 to 697100

Notes:

ug/L - micrograms per liter

1. Results shown for arsenic in leachate are from samples collected between June 18, 2007 and May 20, 2009.
2. Results shown for arsenic in groundwater wells are from samples collected between January 22, 2001 and February 12, 2010.
3. Multiple sampling results are shown for some locations.

0 500 1000

Scale - Feet

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FIGURE 4.2-3

ARSENIC DISTRIBUTION IN LEACHATE AND GROUNDWATER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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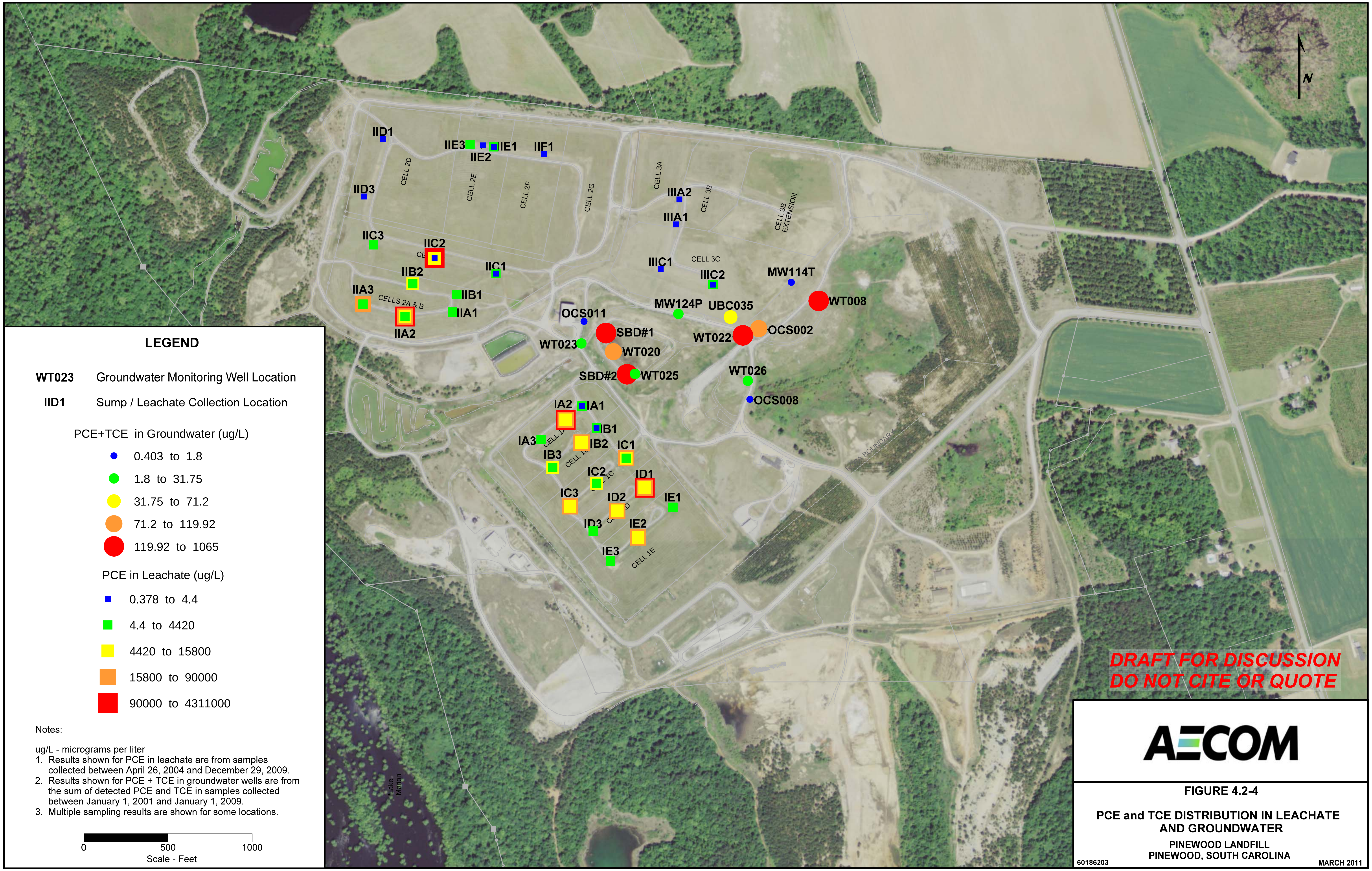

LEGEND

WT023 Groundwater Monitoring Well Location

IID1 Sump / Leachate Collection Location

PCE+TCE in Groundwater (ug/L)

- ● 0.403 to 1.8
- ● 1.8 to 31.75
- ● 31.75 to 71.2
- ● 71.2 to 119.92
- ● 119.92 to 1065

PCE in Leachate (ug/L)

- ■ 0.378 to 4.4
- ■ 4.4 to 4420
- ■ 4420 to 15800
- ■ 15800 to 90000
- ■ 90000 to 4311000

Notes:

ug/L - micrograms per liter

1. Results shown for PCE in leachate are from samples collected between April 26, 2004 and December 29, 2009.
2. Results shown for PCE + TCE in groundwater wells are from the sum of detected PCE and TCE in samples collected between January 1, 2001 and January 1, 2009.
3. Multiple sampling results are shown for some locations.

0 500 1000
Scale - Feet

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FIGURE 4.2-4

PCE and TCE DISTRIBUTION IN LEACHATE AND GROUNDWATER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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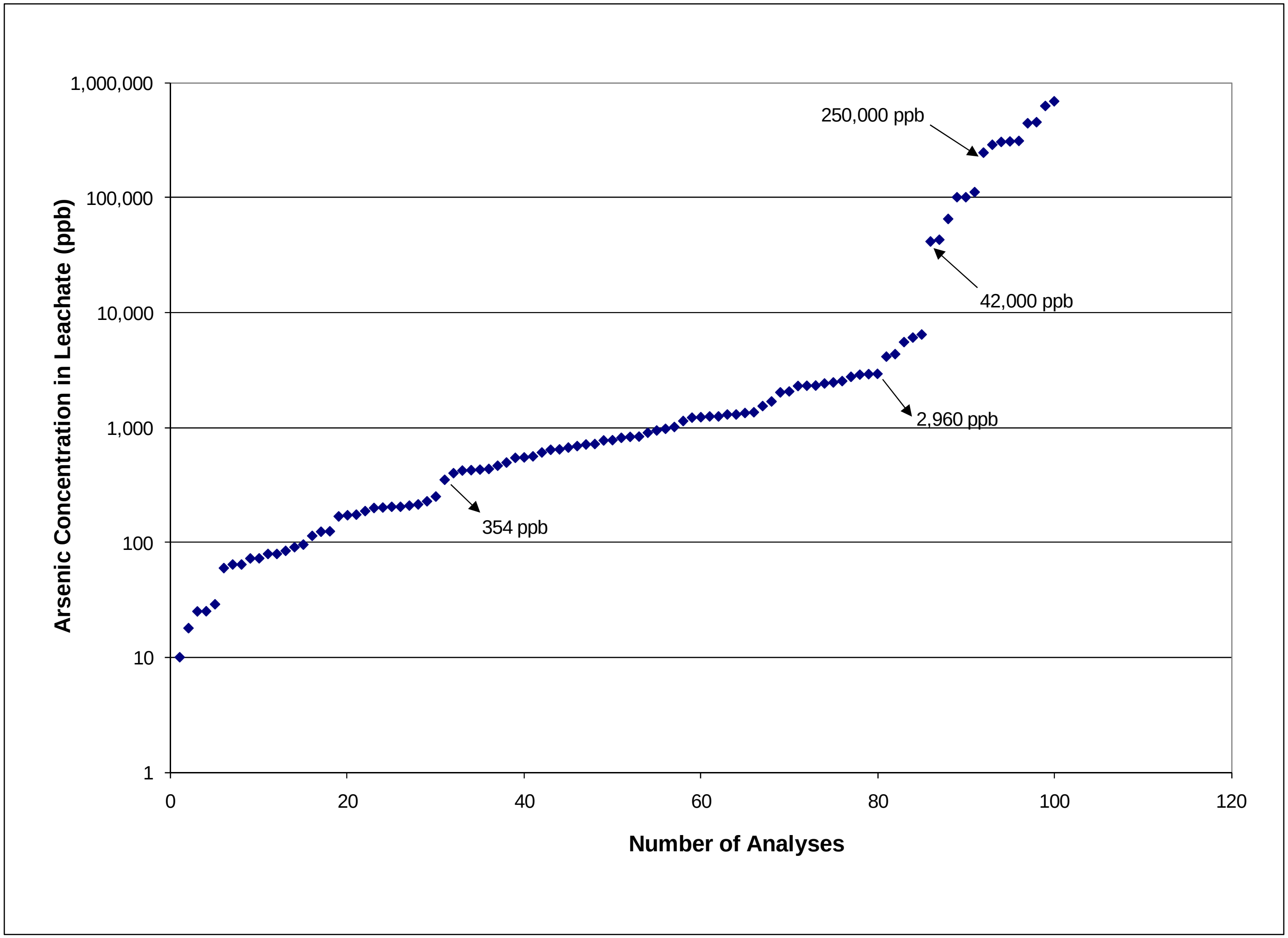

Notes:
1) Data from June 2007 through May 2009

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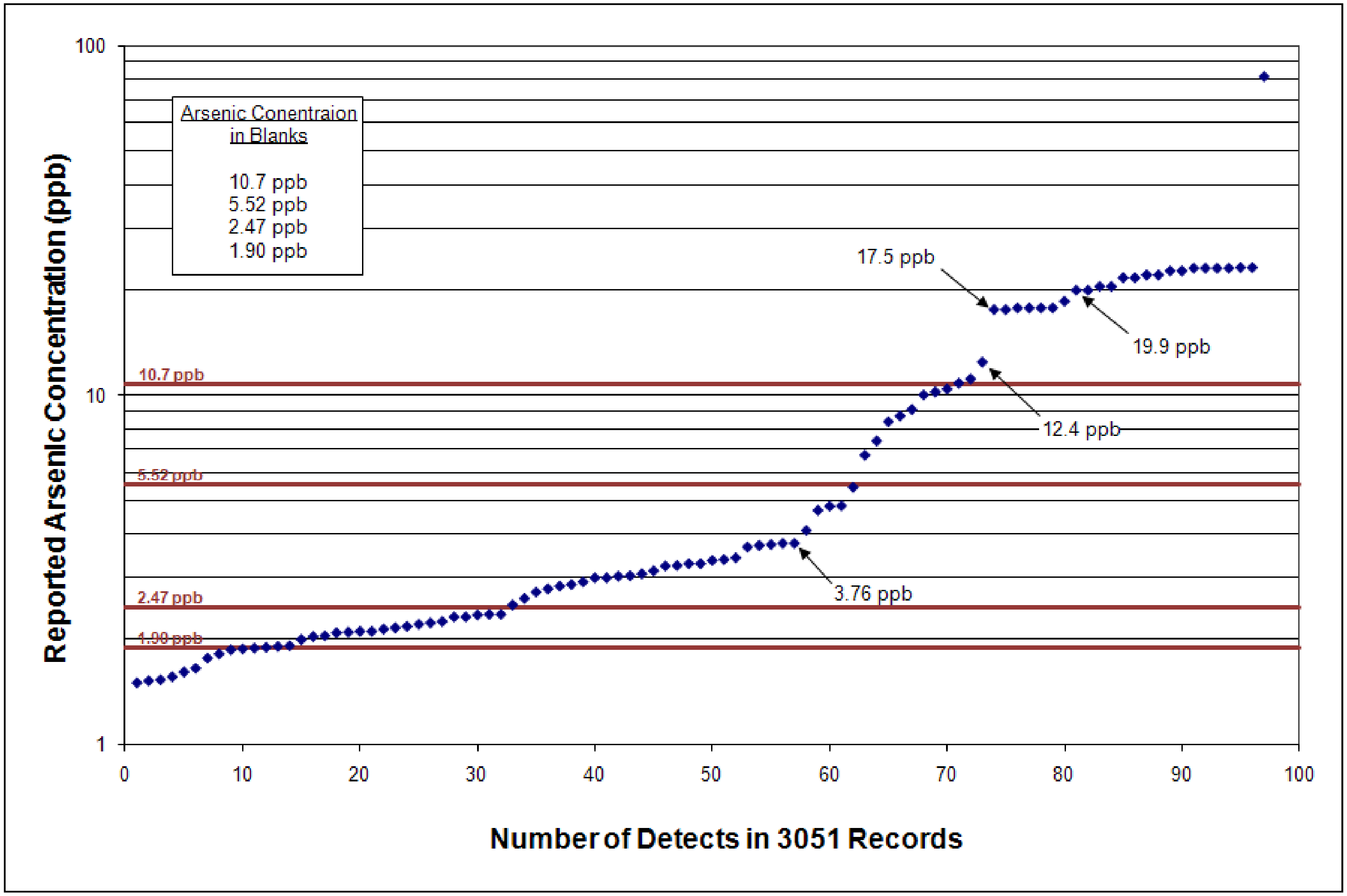
FIGURE 4.2-5
ARSENIC DETECTIONS IN LEACHATE

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



Notes:

1) Data from January 2001 through February 2010

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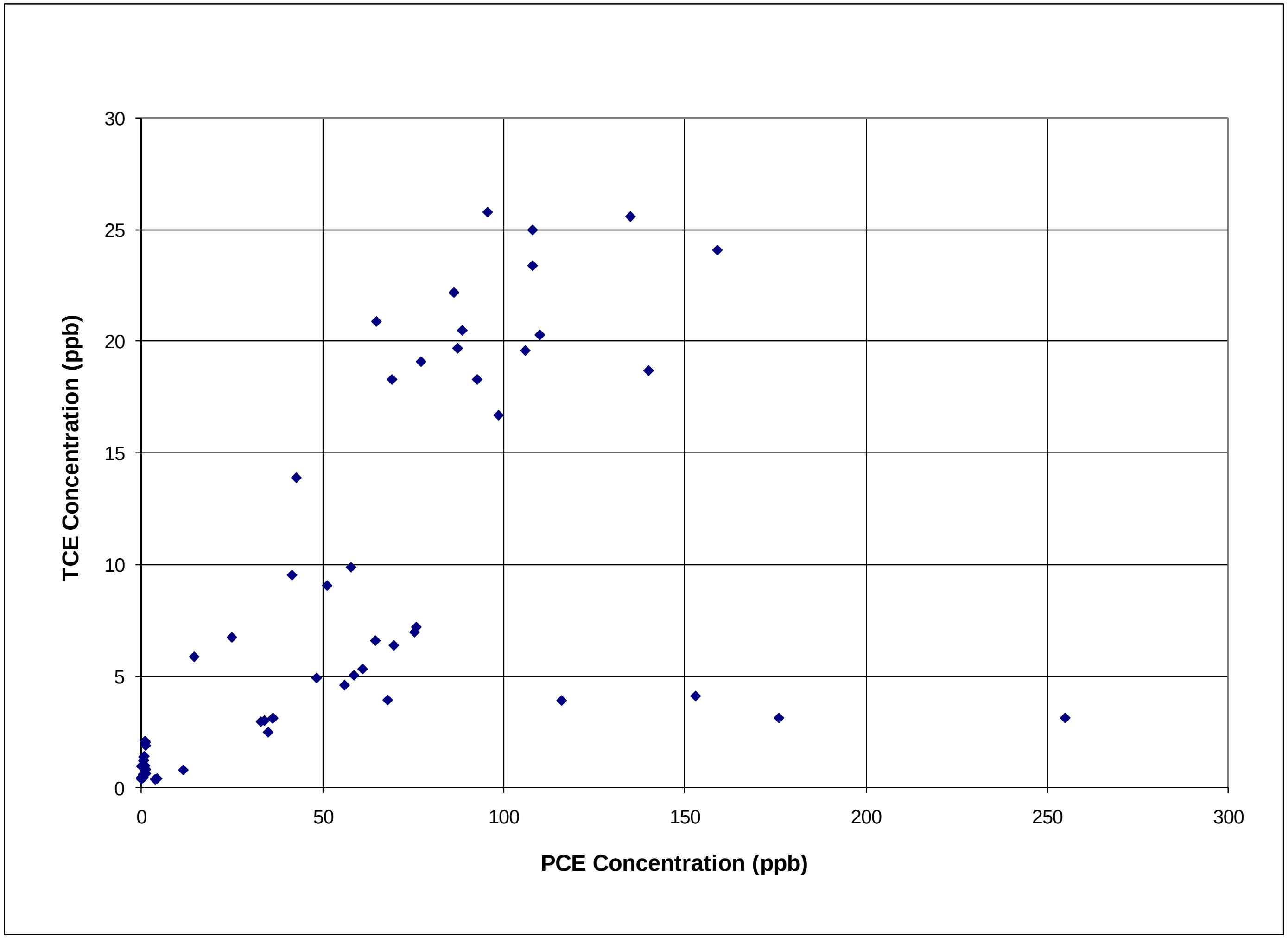
FIGURE 4.2-6

ARSENIC DETECTIONS IN GROUNDWATER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



Notes:

1) Data from 2001 through 2009

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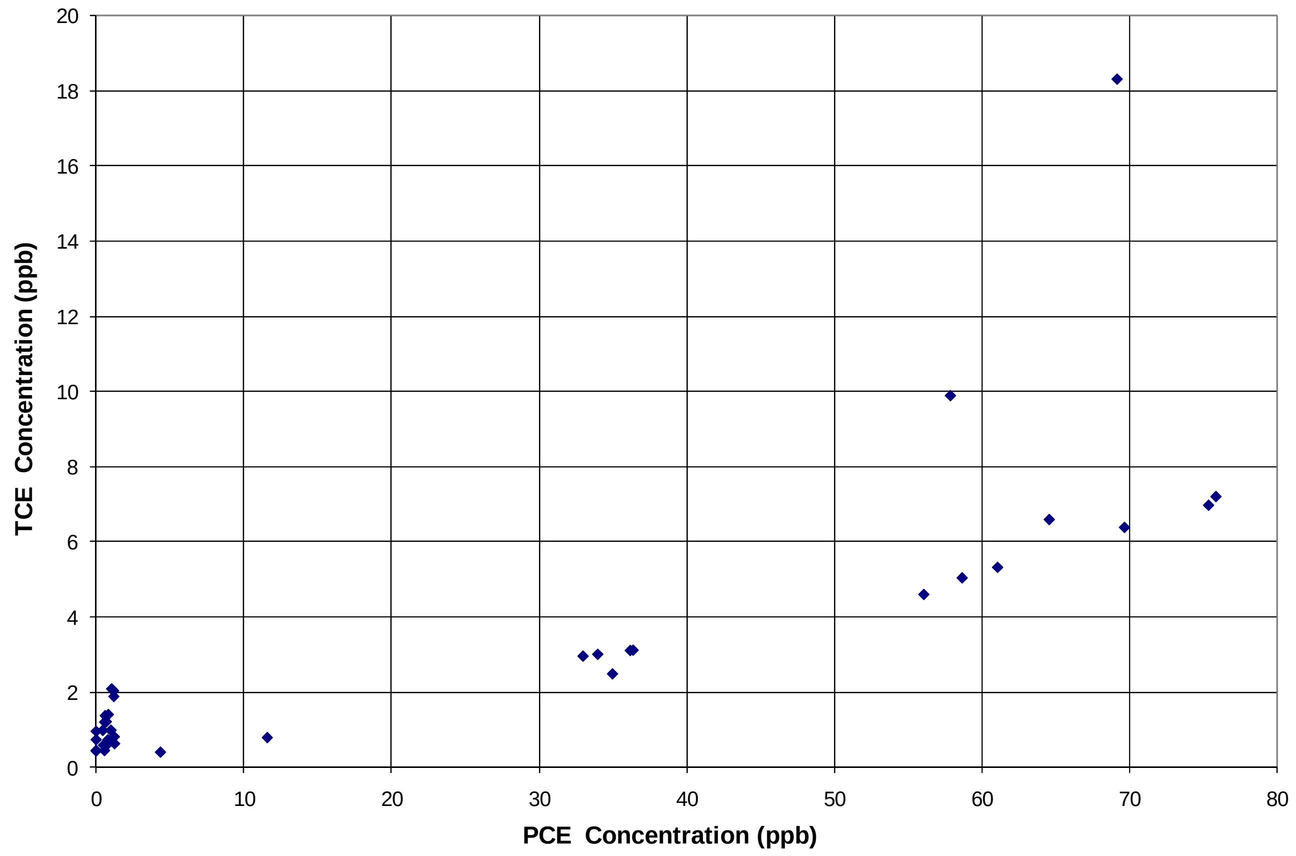
FIGURE 4.2-7
CROSS-PILOT OF PCE AND-TCE
IN GROUNDWATER
PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



Notes:

1) Data from 2001 through 2009

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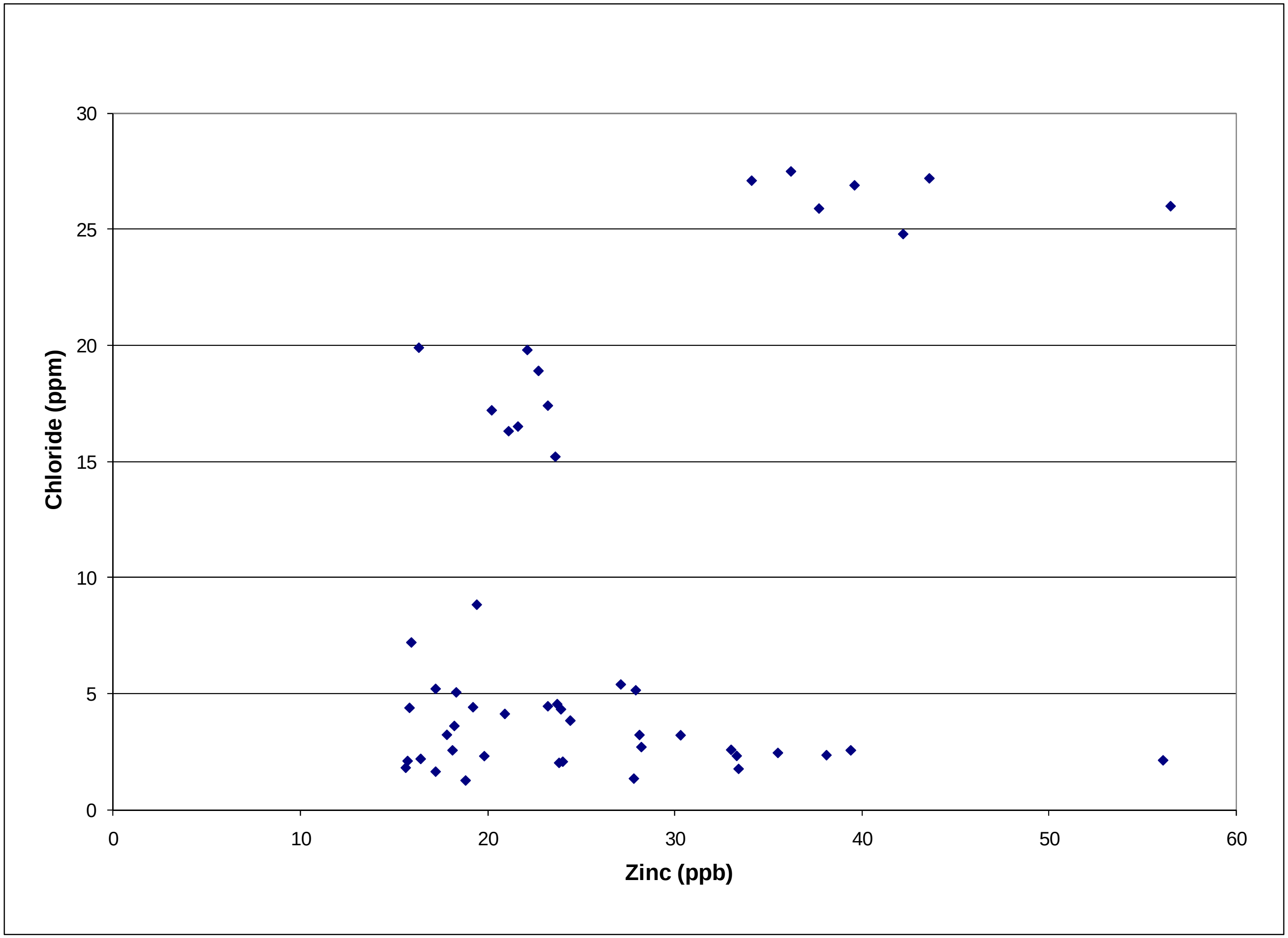
FIGURE 4.2-8
CROSS-PLOT OF PCE AND TCE IN GROUNDWATER EXCEPT WT022, SBD1 AND SBD2

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



Notes:

1) Zinc concentrations are >15 ppb
2) Data from 2001 through 2009

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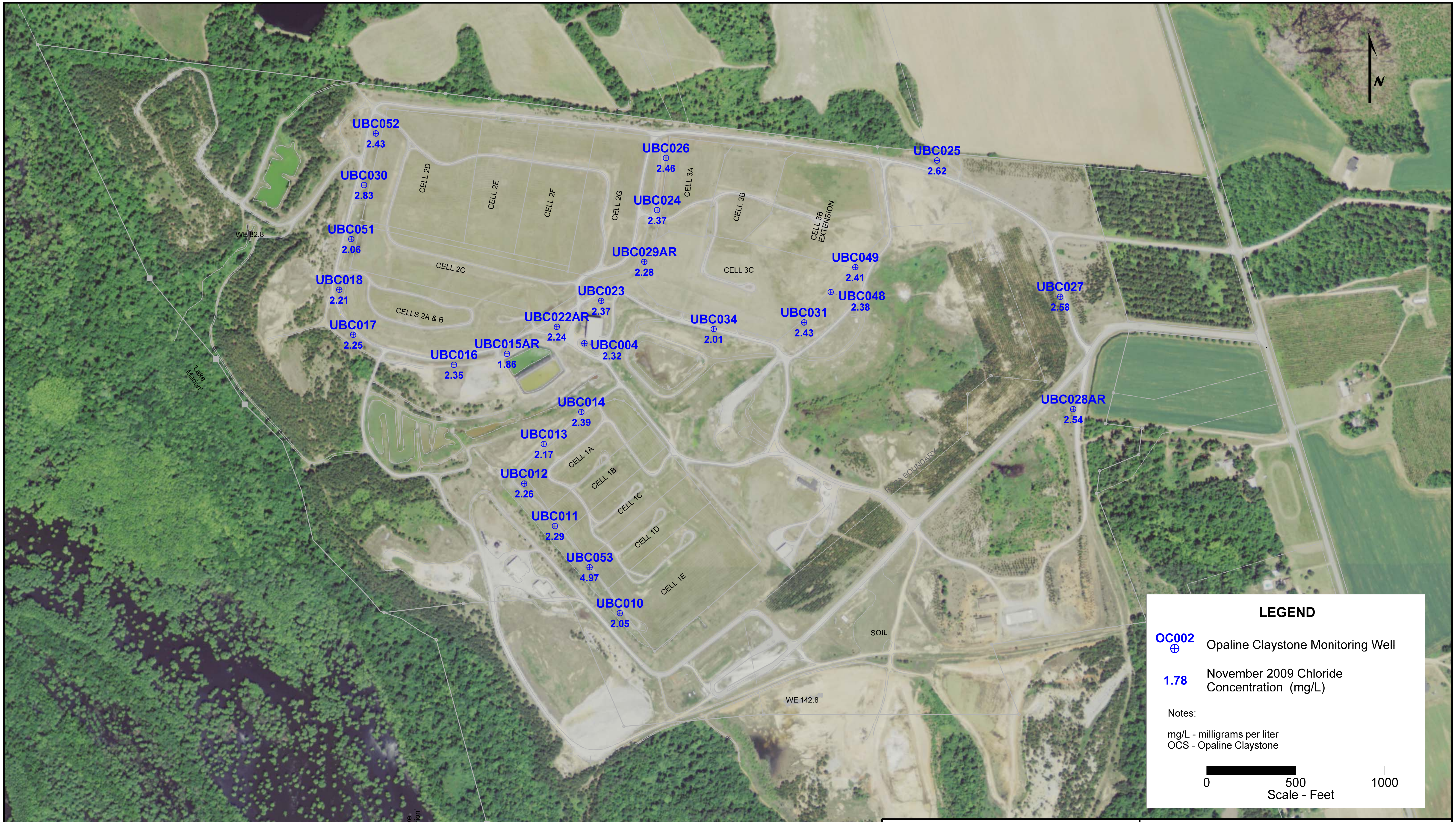
FIGURE 4.2-9

CROSS-PLOT OF ZINC VERSUS CHLORIDE IN GROUNDWATER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA



LEGEND

OC002 ⊕	Opaline Claystone Monitoring Well
1.78	November 2009 Chloride Concentration (mg/L)

Notes:

mg/L - milligrams per liter
OCS - Opaline Claystone

0 500 1000
Scale - Feet

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FIGURE 4.3-1

SPATIAL DISTRIBUTION OF CHLORIDE IN GROUNDWATER - OCS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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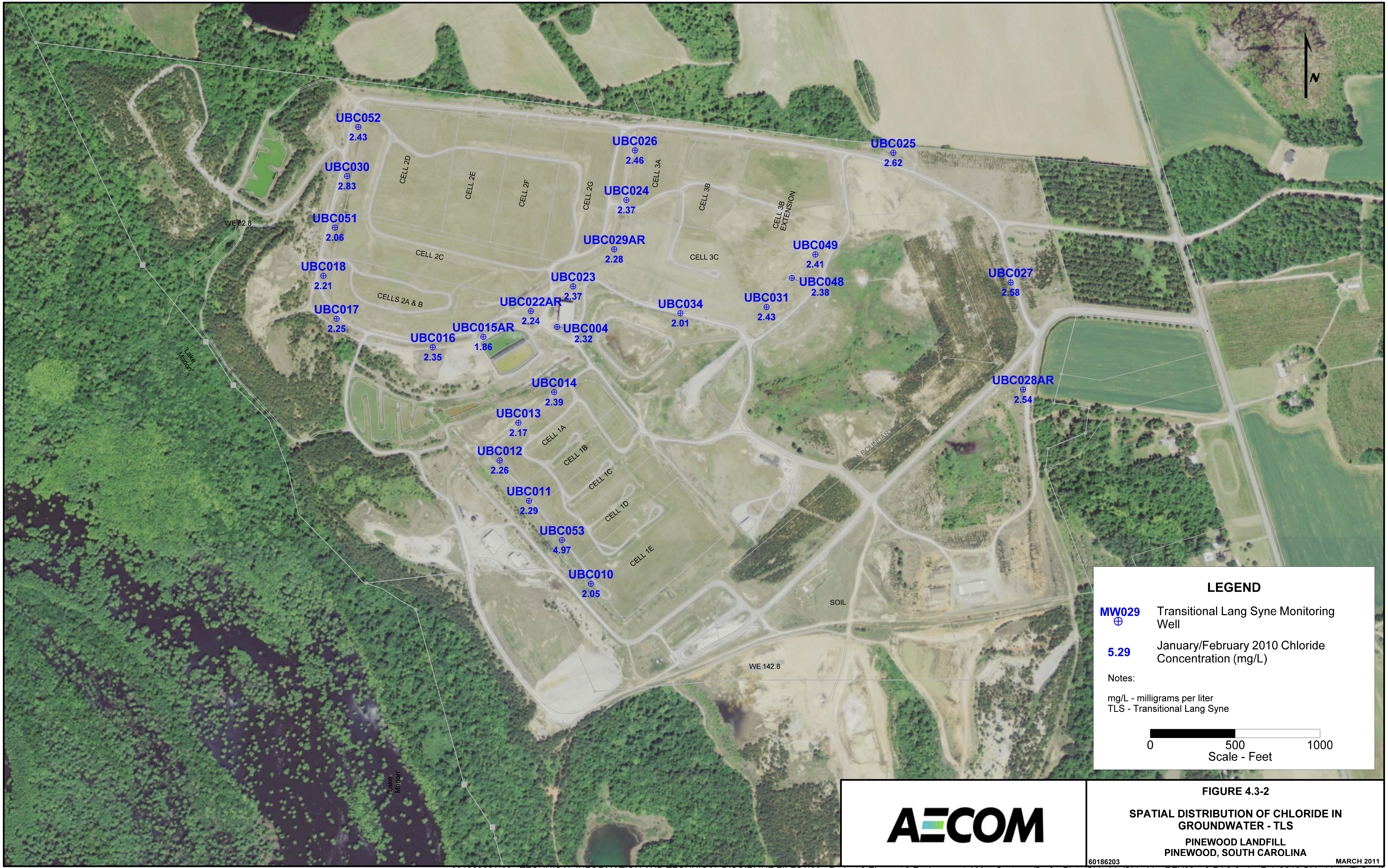

LEGEND

MW029 ⊕	Transitional Lang Syne Monitoring Well
5.29	January/February 2010 Chloride Concentration (mg/L)

Notes:

mg/L - milligrams per liter
TLS - Transitional Lang Syne

0 500 1000
Scale - Feet

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FIGURE 4.3-2

SPATIAL DISTRIBUTION OF CHLORIDE IN GROUNDWATER - TLS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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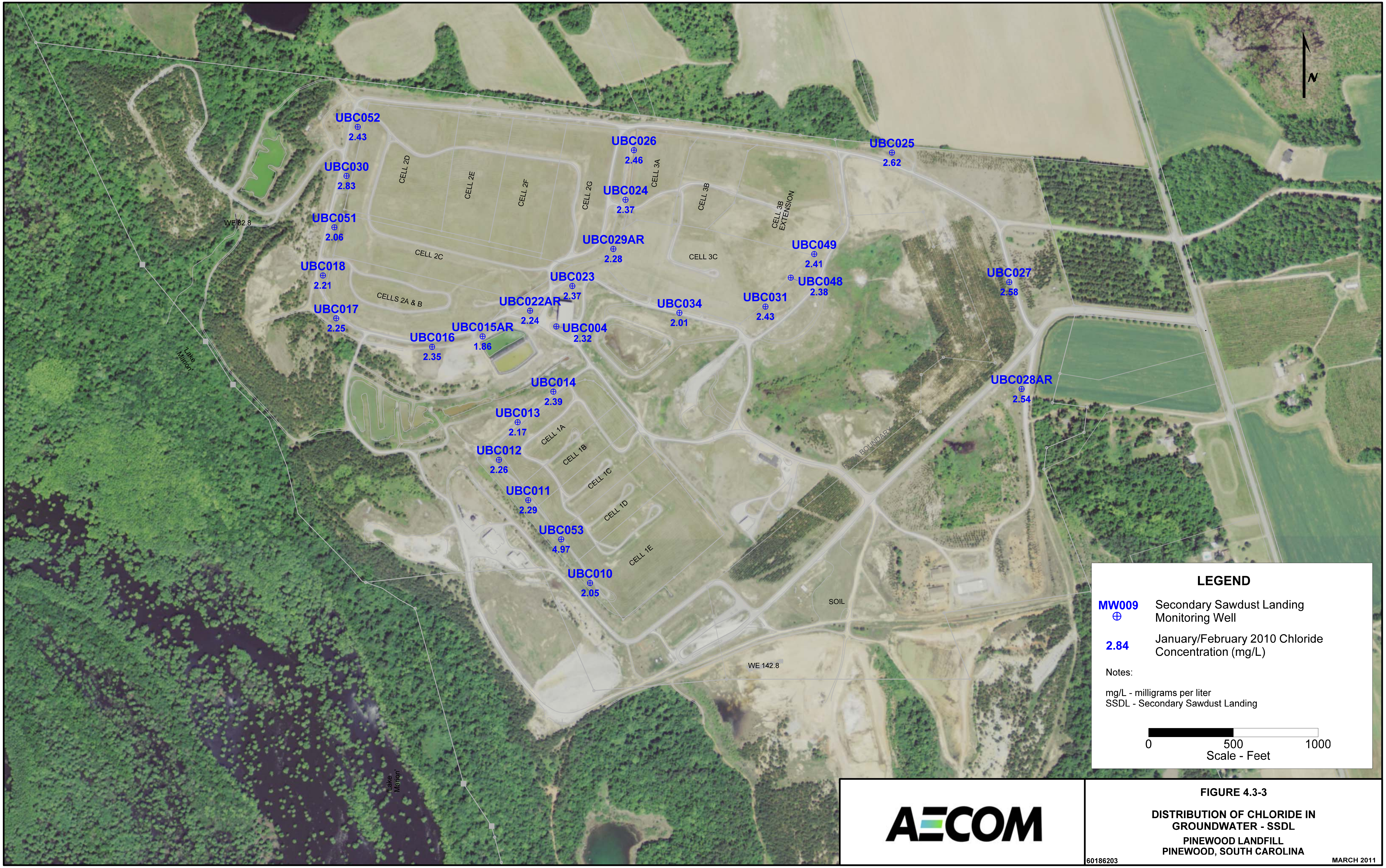

LEGEND

MW009 ⊕	Secondary Sawdust Landing Monitoring Well
2.84	January/February 2010 Chloride Concentration (mg/L)

Notes:

mg/L - milligrams per liter
SSDL - Secondary Sawdust Landing

0 500 1000
Scale - Feet

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FIGURE 4.3-3

DISTRIBUTION OF CHLORIDE IN GROUNDWATER - SSDL

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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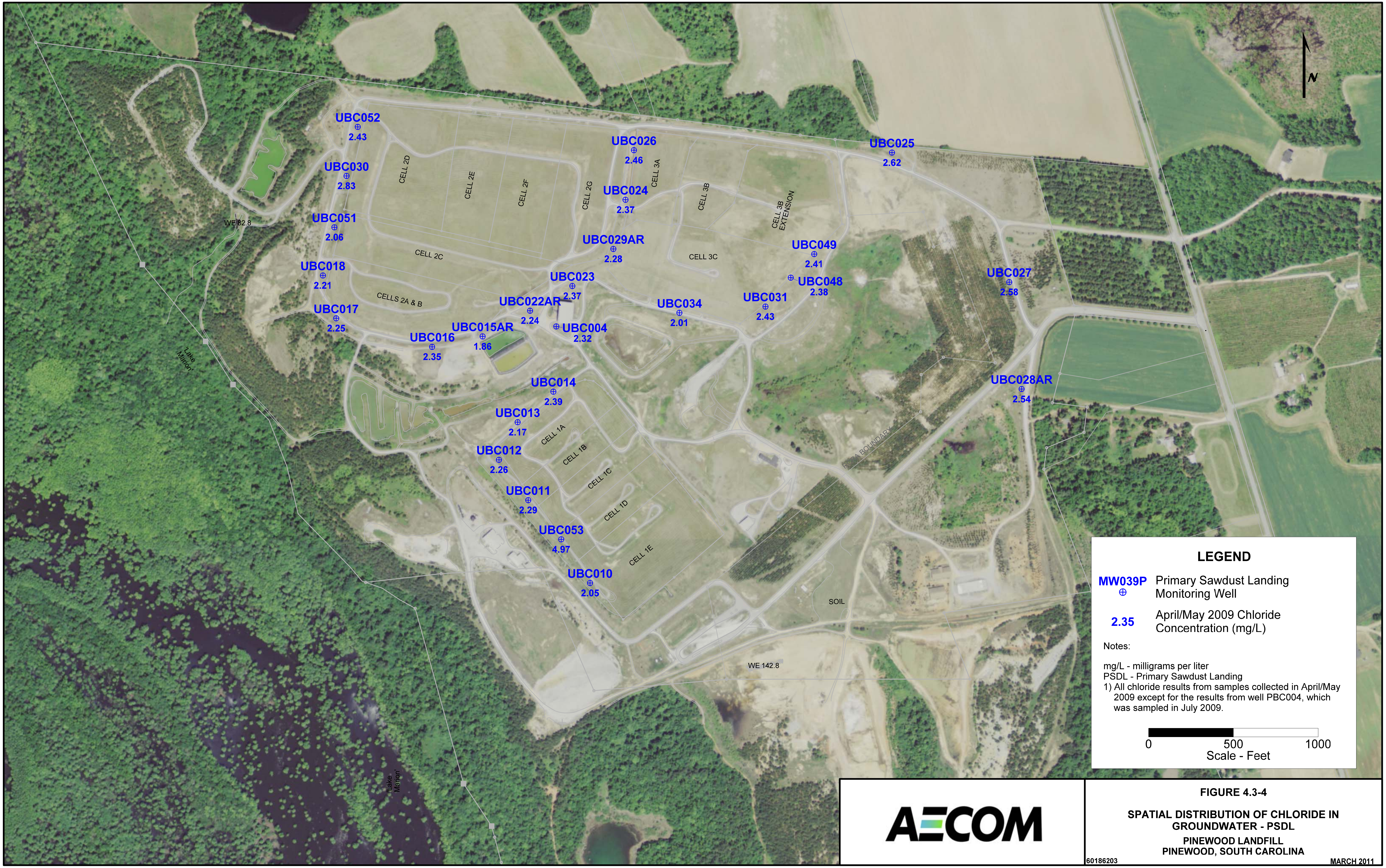

LEGEND

MW039P ⊕ Primary Sawdust Landing Monitoring Well

2.35 April/May 2009 Chloride Concentration (mg/L)

Notes:

mg/L - milligrams per liter
PSDL - Primary Sawdust Landing
1) All chloride results from samples collected in April/May 2009 except for the results from well PBC004, which was sampled in July 2009.

0 500 1000
Scale - Feet

AECOM

FIGURE 4.3-4

SPATIAL DISTRIBUTION OF CHLORIDE IN GROUNDWATER - PSDL
PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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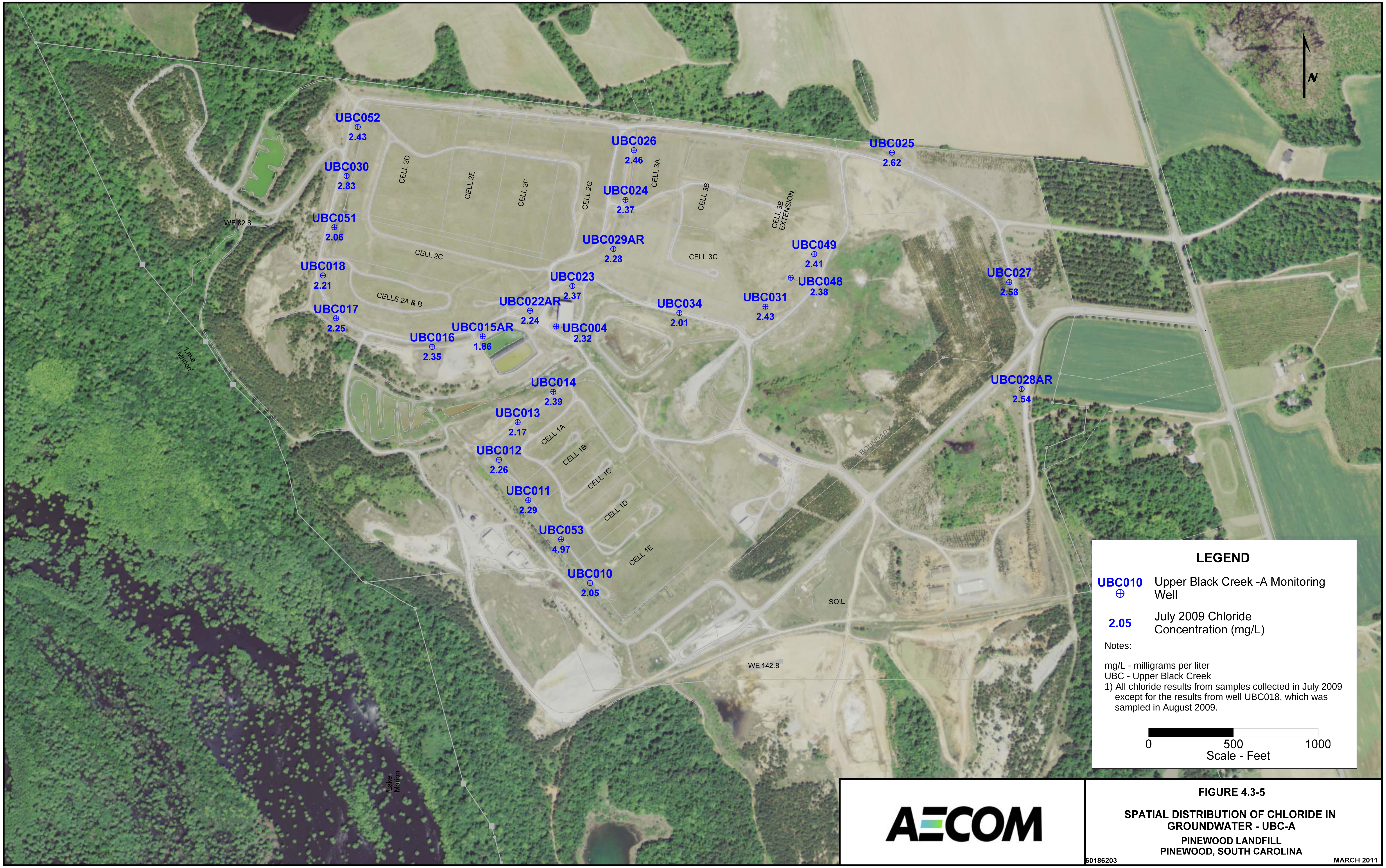

LEGEND

UBC010 ⊕	Upper Black Creek -A Monitoring Well
2.05	July 2009 Chloride Concentration (mg/L)

Notes:

mg/L - milligrams per liter
UBC - Upper Black Creek
1) All chloride results from samples collected in July 2009 except for the results from well UBC018, which was sampled in August 2009.

0 500 1000
Scale - Feet

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FIGURE 4.3-5

SPATIAL DISTRIBUTION OF CHLORIDE IN GROUNDWATER - UBC-A

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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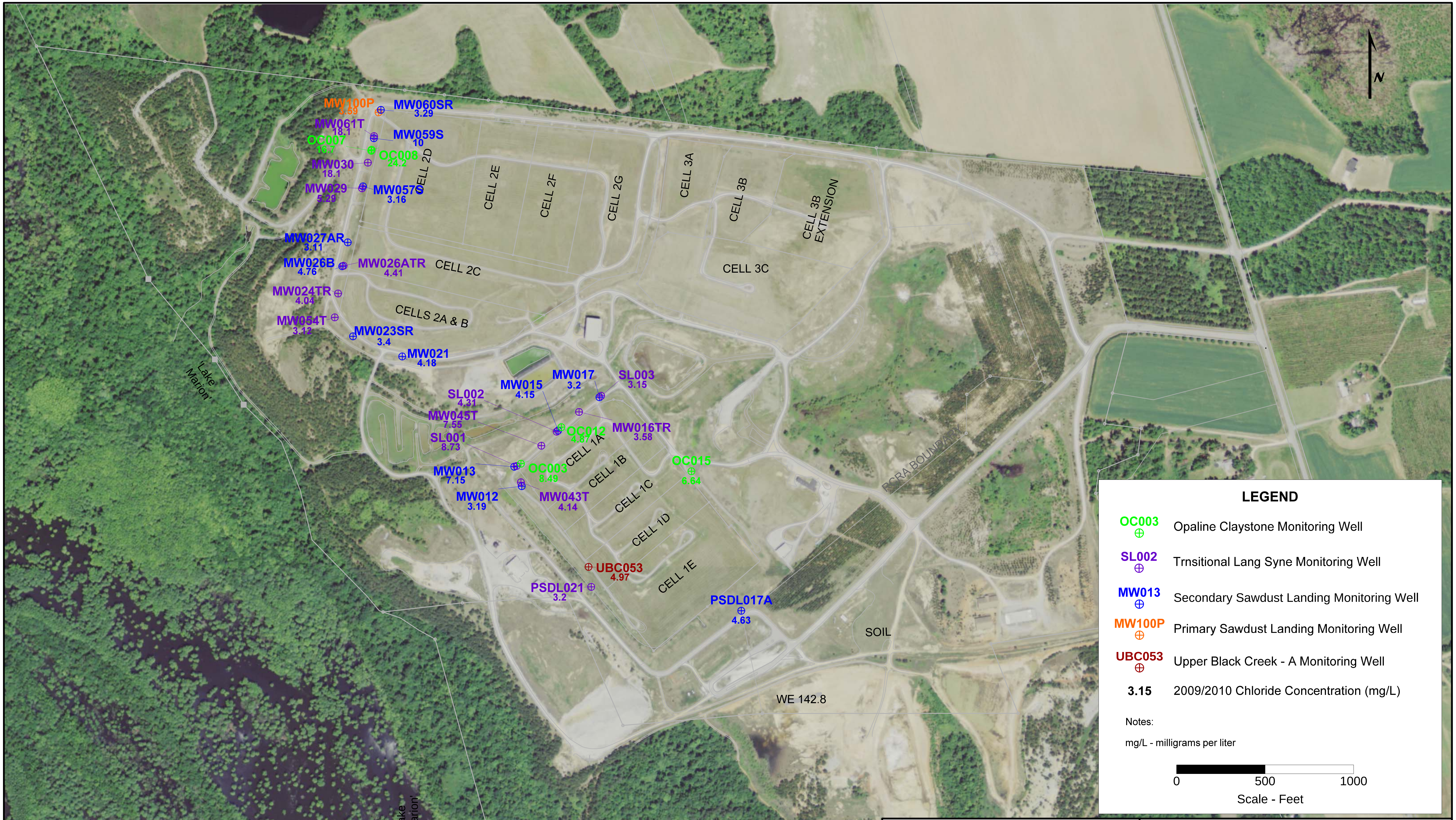

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FIGURE 4.3-6

SPATIAL DISTRIBUTION OF 2009 AND 2010
CHLORIDE CONCENTRATIONS > 3 MG/L

2010 PINEWOOD SITE IMPROVEMENT PROJECTS
PINEWOOD, SOUTH CAROLINA

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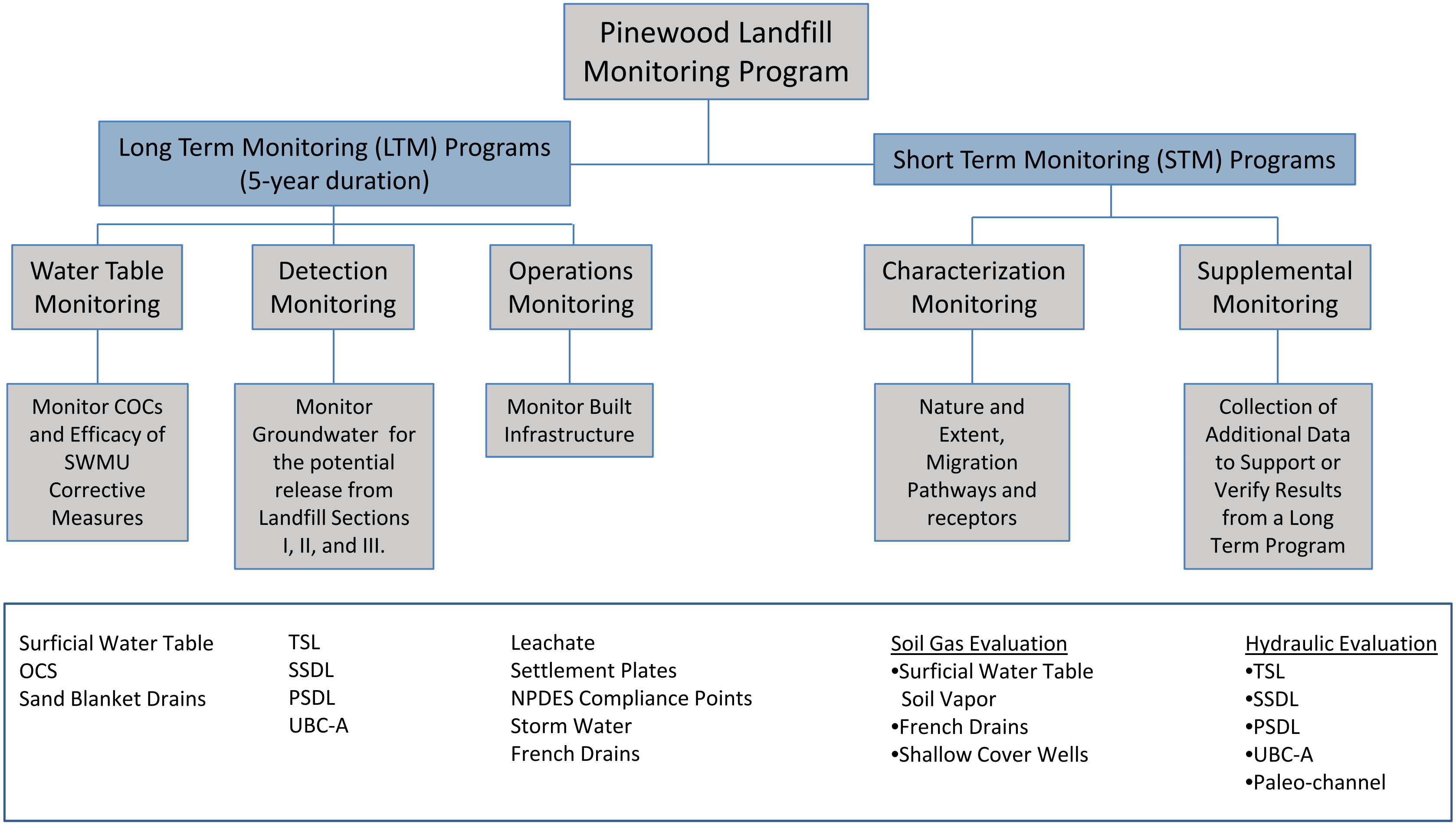

Pinewood Landfill Monitoring Program

Long Term Monitoring (LTM) Programs (5-year duration)

Water Table Monitoring

Monitor COCs and Efficacy of SWMU Corrective Measures

Detection Monitoring

Monitor Groundwater for the potential release from Landfill Sections I, II, and III.

Operations Monitoring

Monitor Built Infrastructure

Short Term Monitoring (STM) Programs

Characterization Monitoring

Nature and Extent, Migration Pathways and receptors

Supplemental Monitoring

Collection of Additional Data to Support or Verify Results from a Long Term Program

Surficial Water Table
OCS
Sand Blanket Drains

TSL
SSDL
PSDL
UBC-A

Leachate
Settlement Plates
NPDES Compliance Points
Storm Water
French Drains

<u>Soil Gas Evaluation</u>
- Surficial Water Table Soil Vapor
- French Drains
- Shallow Cover Wells

<u>Hydraulic Evaluation</u>
- TSL
- SSDL
- PSDL
- UBC-A
- Paleo-channel

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FIGURE 6.1-1
ENVIRONMENTAL MONITORING PROGRAM

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

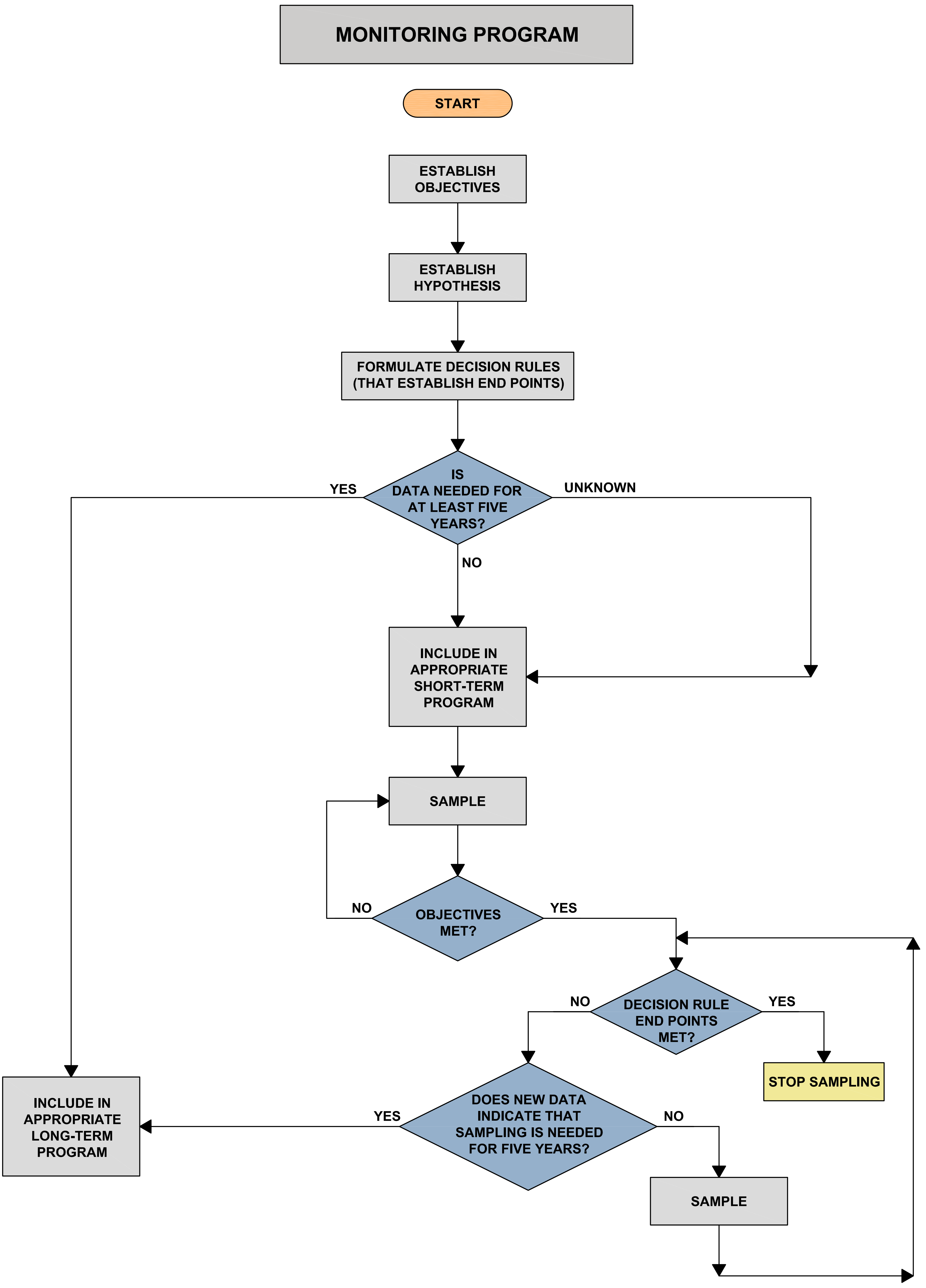

FIGURE 6.1-2
MONITORING PROGRAM LOGIC
FLOW CHART

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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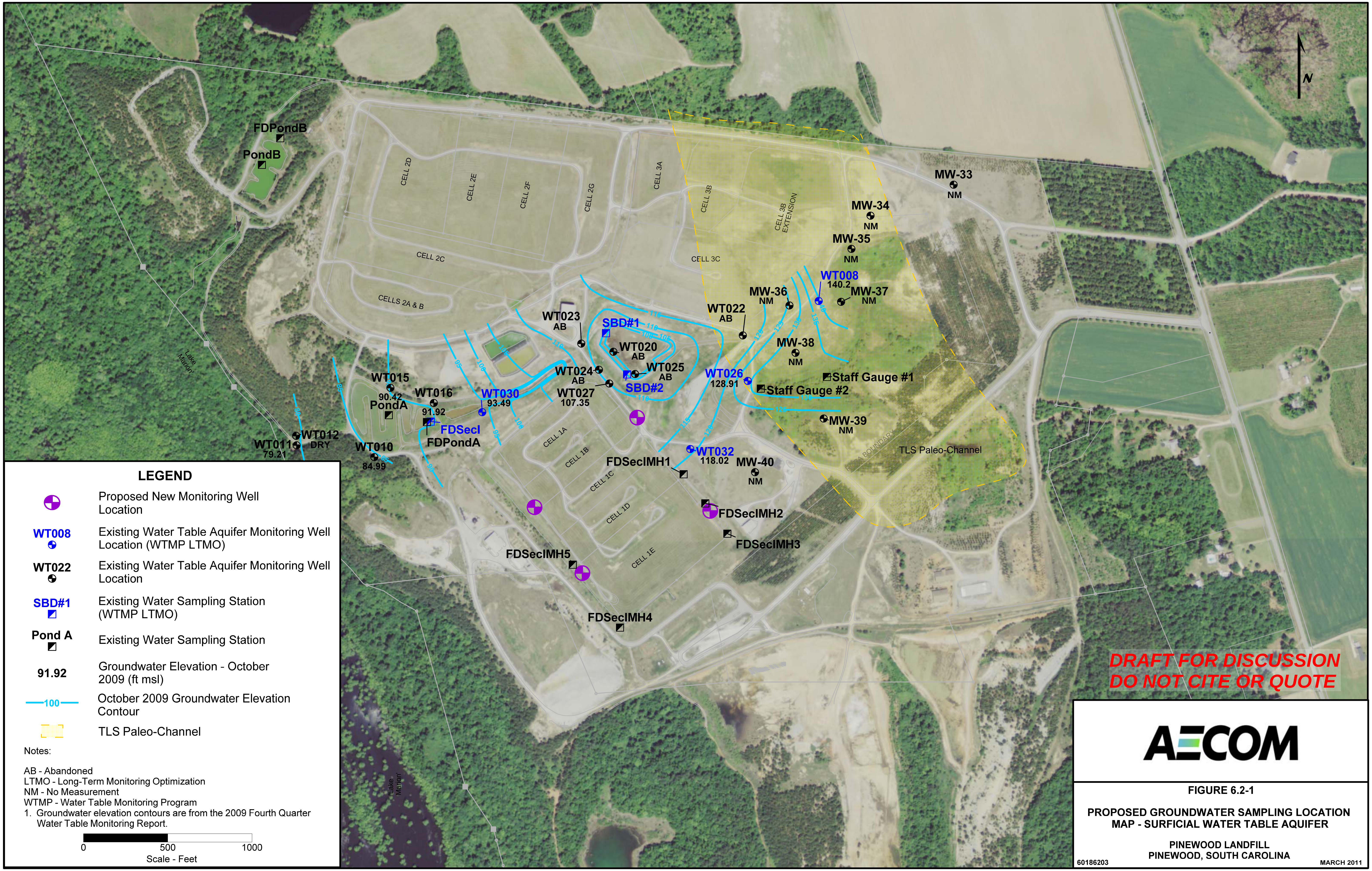


LEGEND

⊕	Proposed New Monitoring Well Location
WT008 ⊕	Existing Water Table Aquifer Monitoring Well Location (WTMP LTMO)
WT022 ⊕	Existing Water Table Aquifer Monitoring Well Location
SBD#1 ◪	Existing Water Sampling Station (WTMP LTMO)
Pond A ◪	Existing Water Sampling Station
91.92	Groundwater Elevation - October 2009 (ft msl)
—100—	October 2009 Groundwater Elevation Contour
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
LTMO - Long-Term Monitoring Optimization
NM - No Measurement
WTMP - Water Table Monitoring Program

1. Groundwater elevation contours are from the 2009 Fourth Quarter Water Table Monitoring Report.

0 500 1000
Scale - Feet

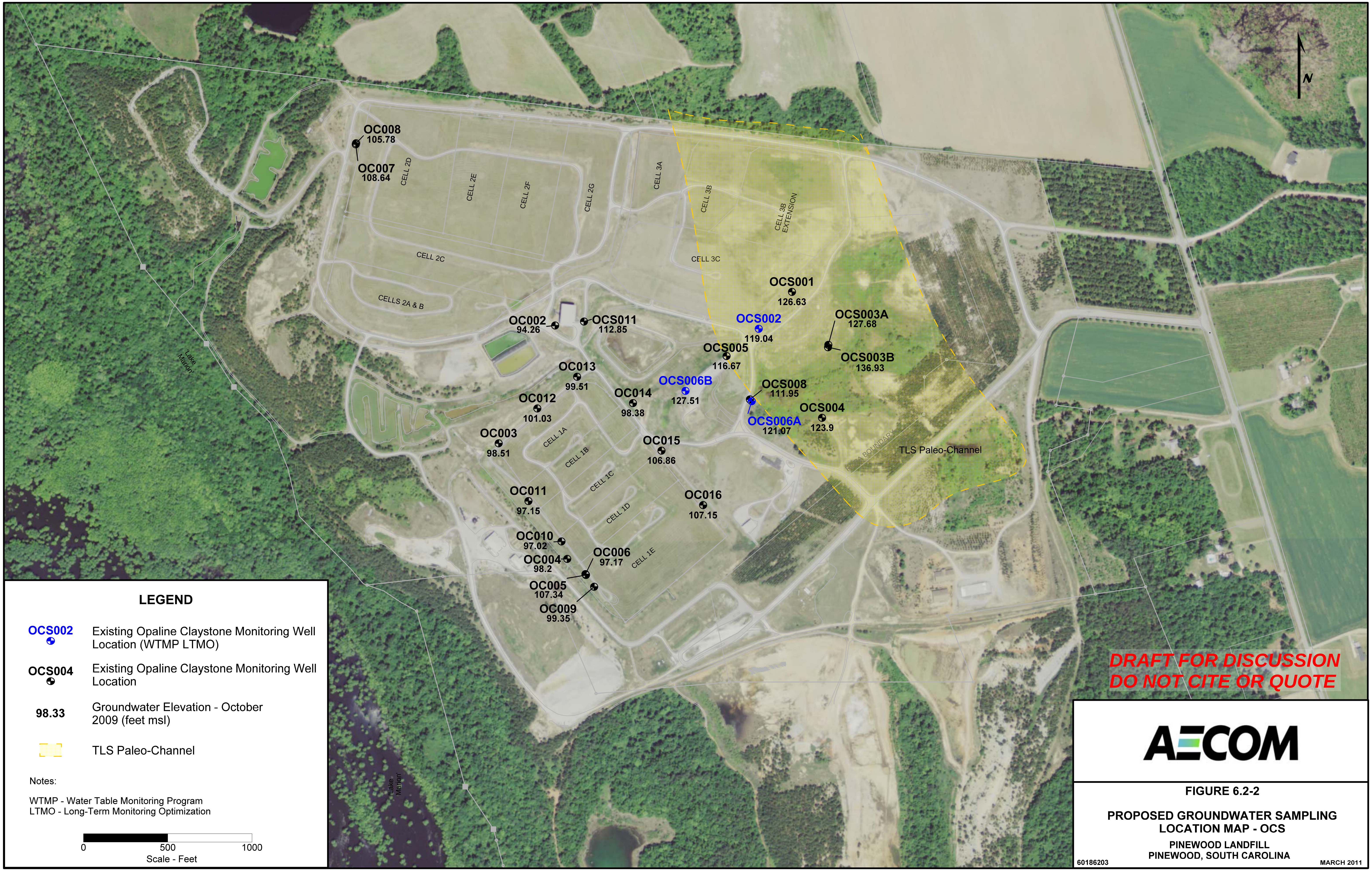
AECOM

FIGURE 6.2-1

PROPOSED GROUNDWATER SAMPLING LOCATION MAP - SURFICIAL WATER TABLE AQUIFER

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

60186203
MARCH 2011



LEGEND

OCS002 ●	Existing Opaline Claystone Monitoring Well Location (WTMP LTMO)
OCS004 ●	Existing Opaline Claystone Monitoring Well Location
98.33	Groundwater Elevation - October 2009 (feet msl)
▨	TLS Paleo-Channel

Notes:

WTMP - Water Table Monitoring Program
LTMO - Long-Term Monitoring Optimization

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FIGURE 6.2-2

PROPOSED GROUNDWATER SAMPLING
LOCATION MAP - OCS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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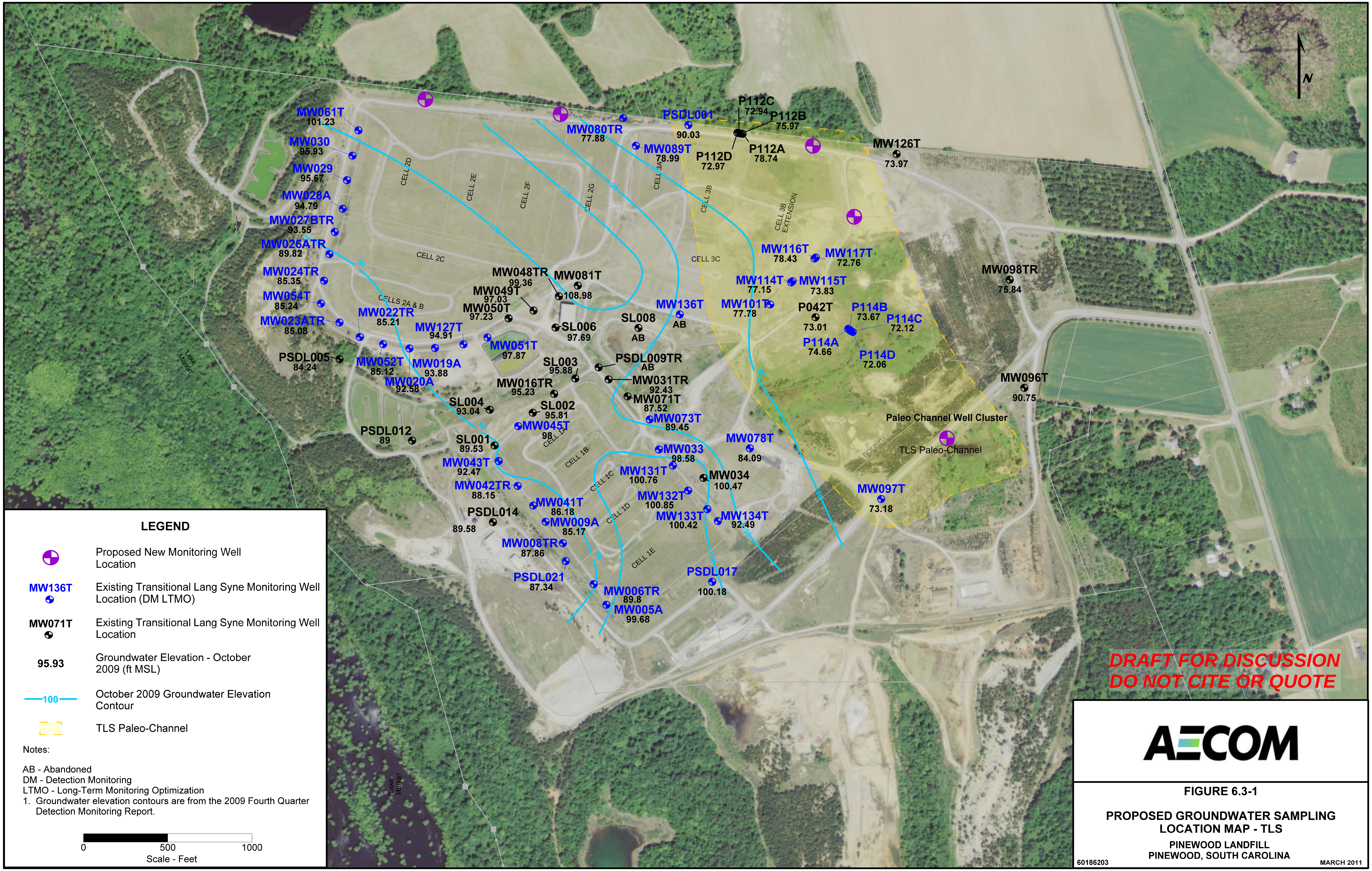

Notes:

AB - Abandoned
DM - Detection Monitoring
LTMO - Long-Term Monitoring Optimization
1. Groundwater elevation contours are from the 2009 Fourth Quarter Detection Monitoring Report.

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FIGURE 6.3-1

PROPOSED GROUNDWATER SAMPLING LOCATION MAP - TLS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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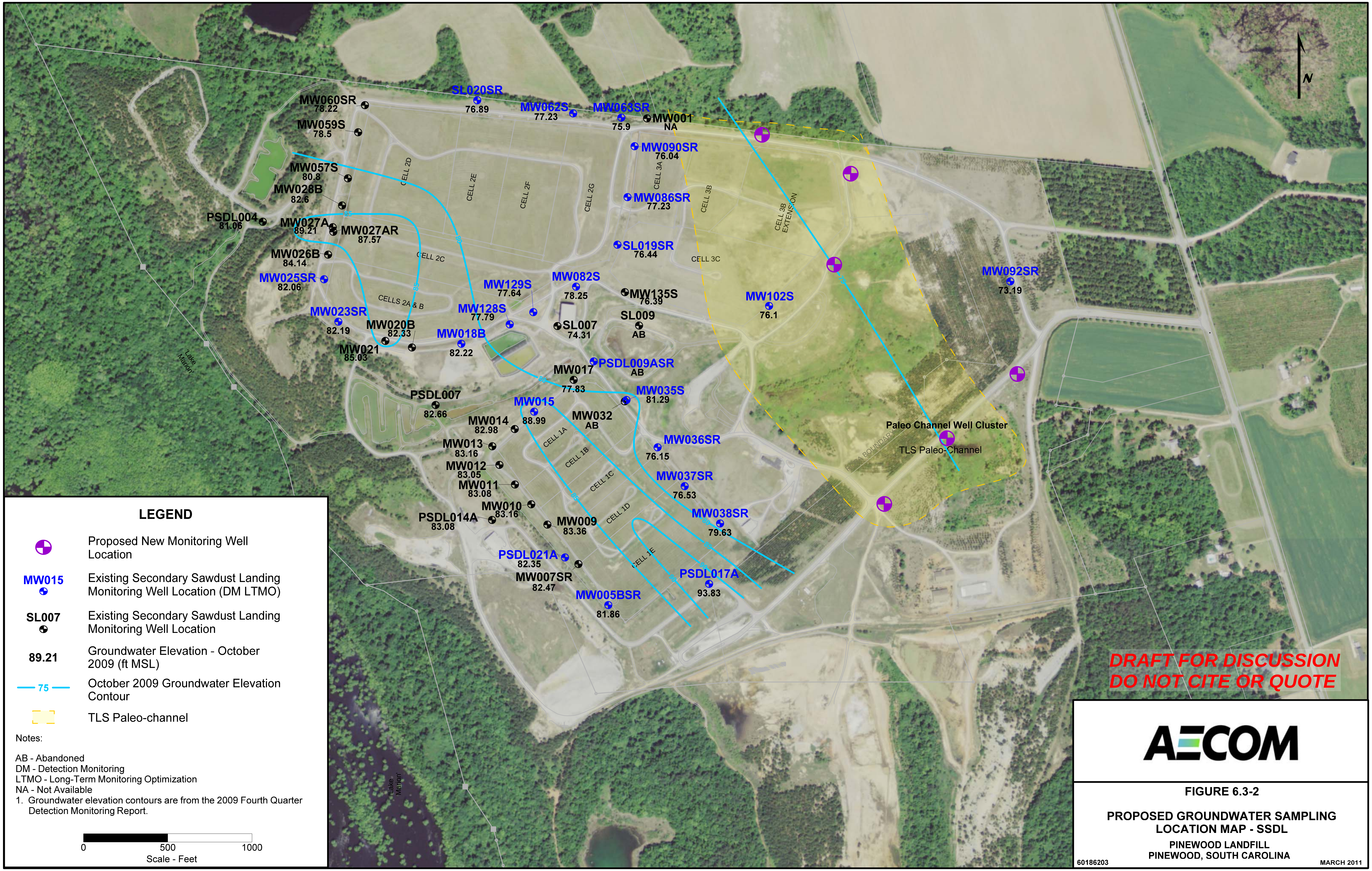

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LEGEND

⊕	Proposed New Monitoring Well Location
MW015 ⊕	Existing Secondary Sawdust Landing Monitoring Well Location (DM LTMO)
SL007 ⊕	Existing Secondary Sawdust Landing Monitoring Well Location
89.21	Groundwater Elevation - October 2009 (ft MSL)
— 75 —	October 2009 Groundwater Elevation Contour
▨	TLS Paleo-channel

Notes:

AB - Abandoned
DM - Detection Monitoring
LTMO - Long-Term Monitoring Optimization
NA - Not Available

1. Groundwater elevation contours are from the 2009 Fourth Quarter Detection Monitoring Report.

0 500 1000
Scale - Feet

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FIGURE 6.3-2

PROPOSED GROUNDWATER SAMPLING LOCATION MAP - SSDL

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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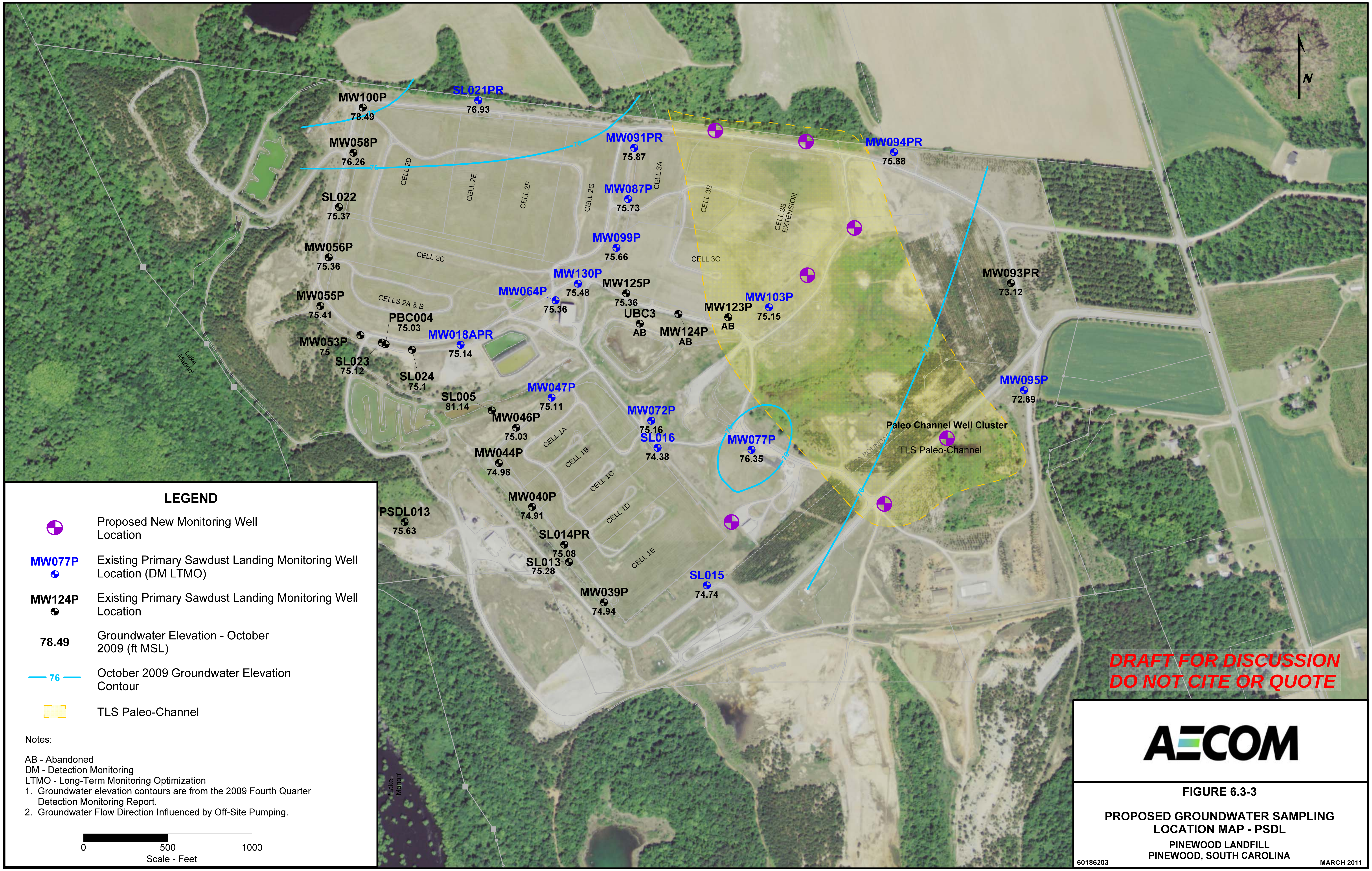

LEGEND

⊕	Proposed New Monitoring Well Location
MW077P ⊕	Existing Primary Sawdust Landing Monitoring Well Location (DM LTMO)
MW124P ⊕	Existing Primary Sawdust Landing Monitoring Well Location
78.49	Groundwater Elevation - October 2009 (ft MSL)
— 76 —	October 2009 Groundwater Elevation Contour
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
DM - Detection Monitoring
LTMO - Long-Term Monitoring Optimization

1. Groundwater elevation contours are from the 2009 Fourth Quarter Detection Monitoring Report.
2. Groundwater Flow Direction Influenced by Off-Site Pumping.

0 500 1000
Scale - Feet

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FIGURE 6.3-3

PROPOSED GROUNDWATER SAMPLING LOCATION MAP - PSDL

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

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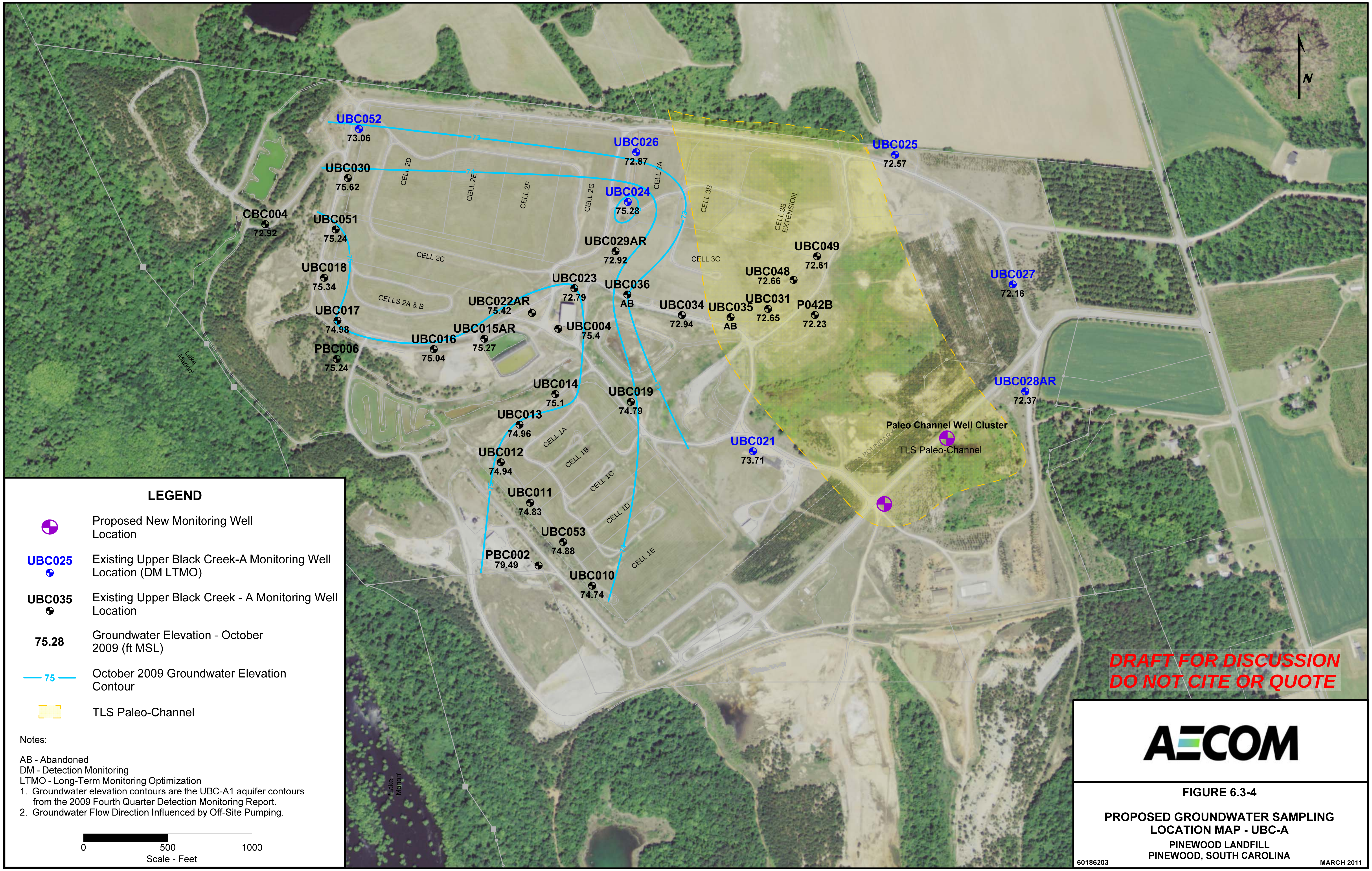
MARCH 2011

60186203/400 - TECHNICAL INFORMATION AND TECHNICAL DISCIPLINE FILES/480 - Project 3 Element 2 Environmental Mon Systems/Surfer Plots/Sampling Plan Analysis Maps/Proposed Sampling Plan Maps.srf



LEGEND

⊕	Proposed New Monitoring Well Location
UBC025 ⊕	Existing Upper Black Creek-A Monitoring Well Location (DM LTMO)
UBC035 ⊕	Existing Upper Black Creek - A Monitoring Well Location
75.28	Groundwater Elevation - October 2009 (ft MSL)
— 75 —	October 2009 Groundwater Elevation Contour
▭	TLS Paleo-Channel

Notes:

AB - Abandoned
DM - Detection Monitoring
LTMO - Long-Term Monitoring Optimization

1. Groundwater elevation contours are the UBC-A1 aquifer contours from the 2009 Fourth Quarter Detection Monitoring Report.
2. Groundwater Flow Direction Influenced by Off-Site Pumping.

0 500 1000
Scale - Feet

DRAFT FOR DISCUSSION
DO NOT CITE OR QUOTE

AECOM

FIGURE 6.3-4

PROPOSED GROUNDWATER SAMPLING LOCATION MAP - UBC-A

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

60186203

MARCH 2011

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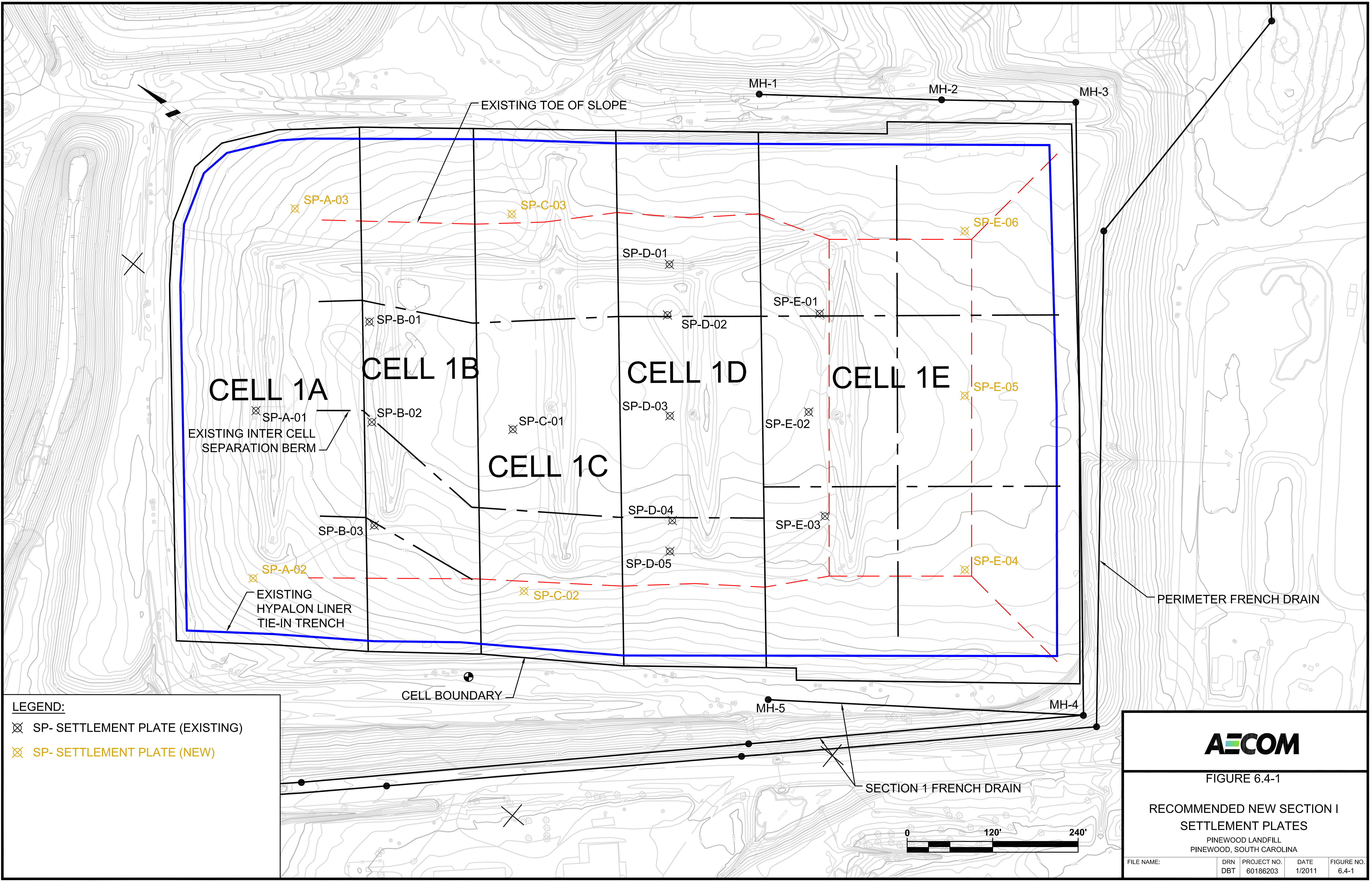


LEGEND:

⊠ SP- SETTLEMENT PLATE (EXISTING)

⊠ SP- SETTLEMENT PLATE (NEW)

AECOM

FIGURE 6.4-1

RECOMMENDED NEW SECTION I
SETTLEMENT PLATES

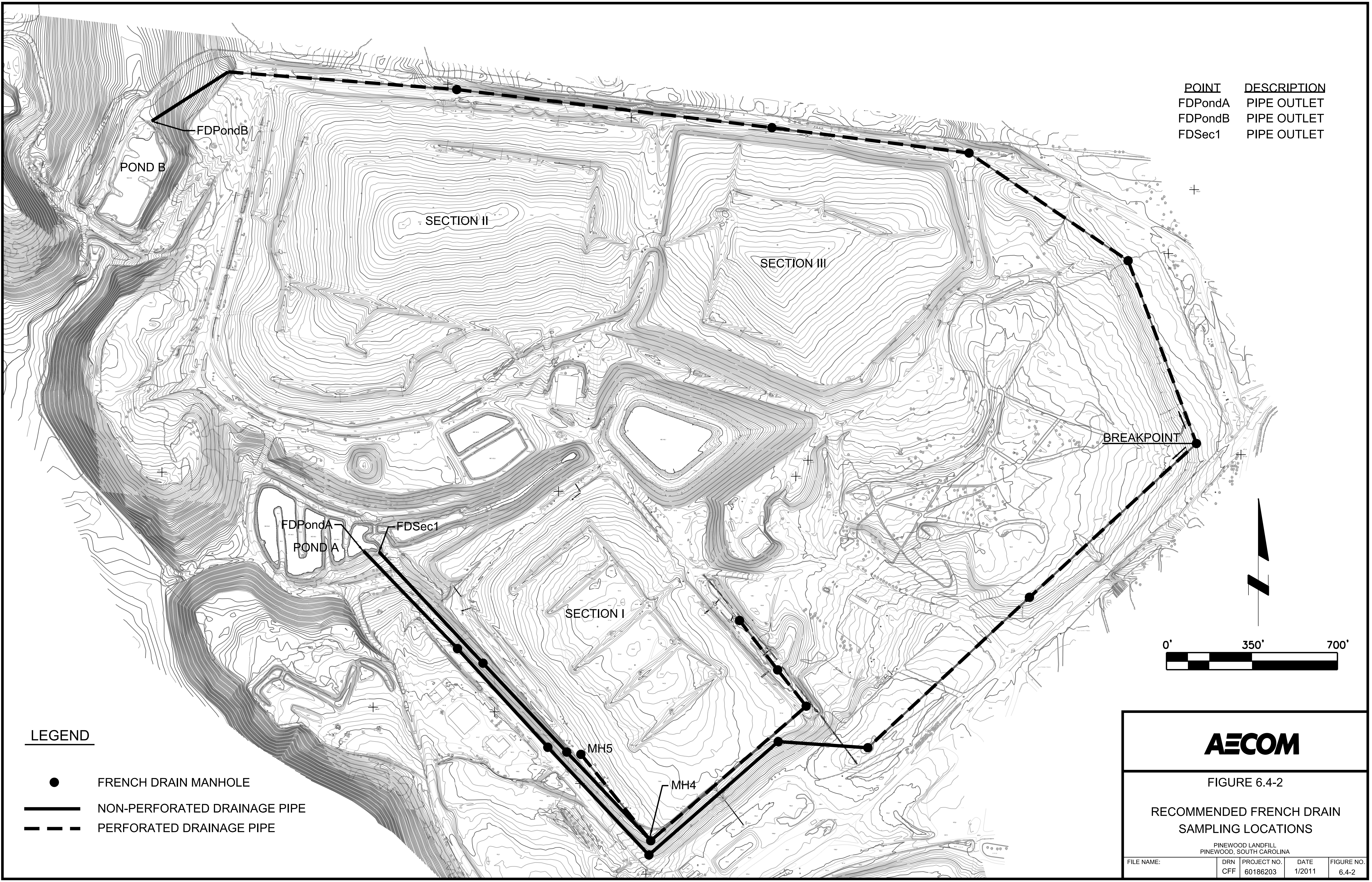
PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
	DBT	60186203	1/2011	6.4-1

Plotted By: TICED
Layout-Sheet Name: FIGURE 4.4-1
Plot File Date Created: Mar/11/2011 10:24 AM

Filename: L:\PROJECTS\60186203\400 – TECHNICAL INFORMATION AND TECHNICAL DISCIPLINE FILES\450 – CADD\SECTION I\PROJECT DRAWINGS\SECTION 1 – F

POINT	DESCRIPTION
FDPondA	PIPE OUTLET
FDPondB	PIPE OUTLET
FDSec1	PIPE OUTLET



LEGEND

●	FRENCH DRAIN MANHOLE
━━	NON-PERFORATED DRAINAGE PIPE
━ ━ ━	PERFORATED DRAINAGE PIPE

AECOM

FIGURE 6.4-2

RECOMMENDED FRENCH DRAIN
SAMPLING LOCATIONS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
	CFF	60186203	1/2011	6.4-2

Plotted By: furmanskic
Layout-Sheet Name: MODEL
Plot File Date Created: Feb/03/2011 12:37 PM

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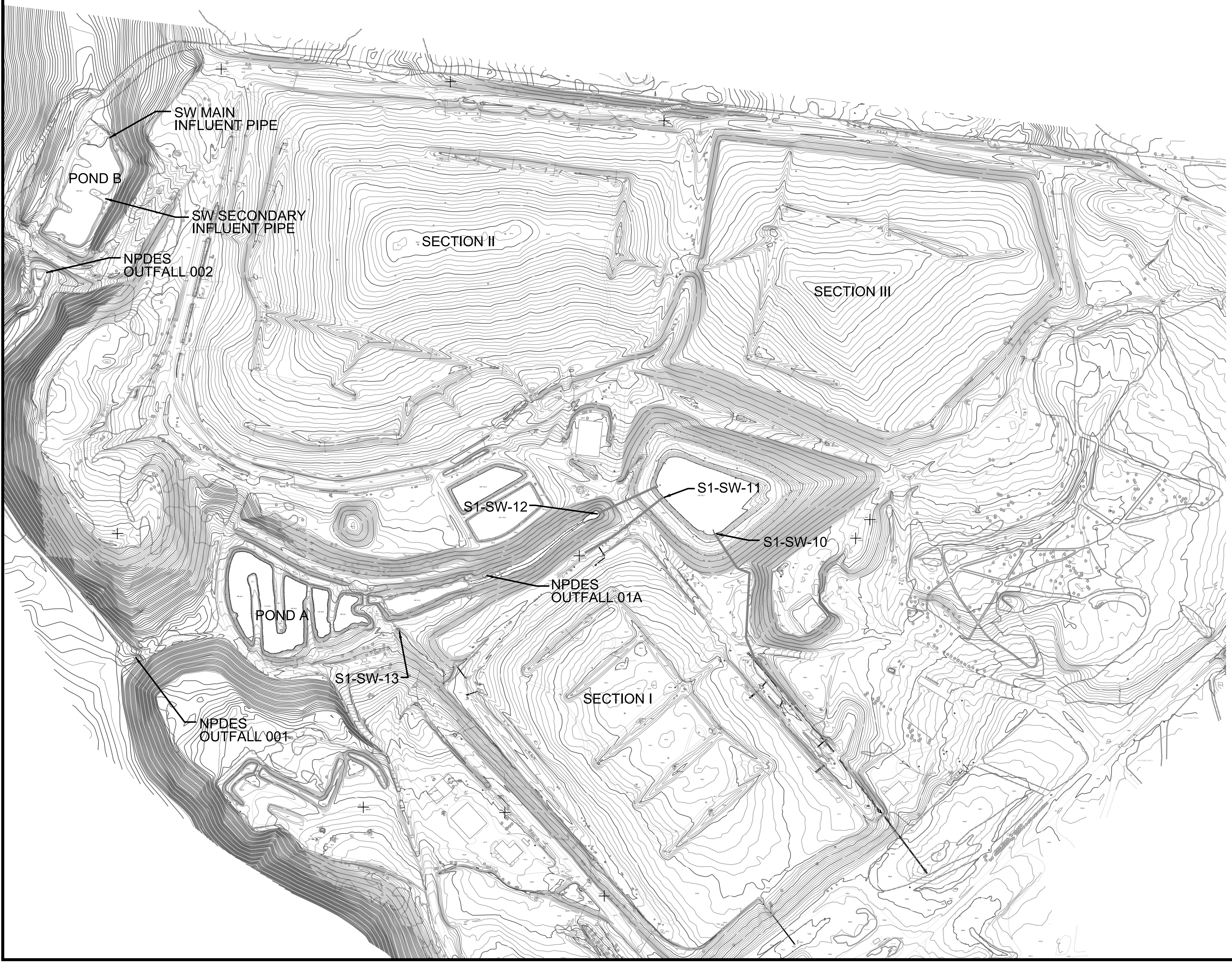

SECTION I

POINT	DESCRIPTION
S1-SW-10	PIPE OUTLET
S1-SW-11	PIPE OUTLET
S1-SW-12	PIPE OUTLET
S1-SW-13	PIPE INLET

SECTION II & III

POINT	DESCRIPTION
SW MAIN INFLUENT PIPE	INLET PIPE
SW SECONDARY INFLUENT PIPE	INLET PIPE

NPDES OUTFALLS

POINT	DESCRIPTION
OUTFALL 001	OUTFALL STRUCTURE
OUTFALL 002	OUTFALL STRUCTURE
OUTFALL 01A	OUTFALL STRUCTURE

0' 350' 700'

AECOM

FIGURE 6.4-3
RECOMMENDED SECTION I, II & III
STORM WATER SAMPLING LOCATIONS
AND NPDES PERMIT
SAMPLING LOCATIONS
PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
	CFF	60186203	1/2011	6.4-3

Plotted By: furmanskic
Layout-Sheet Name: MODEL
Plot File Date Created: Feb/03/2011 12:37 PM

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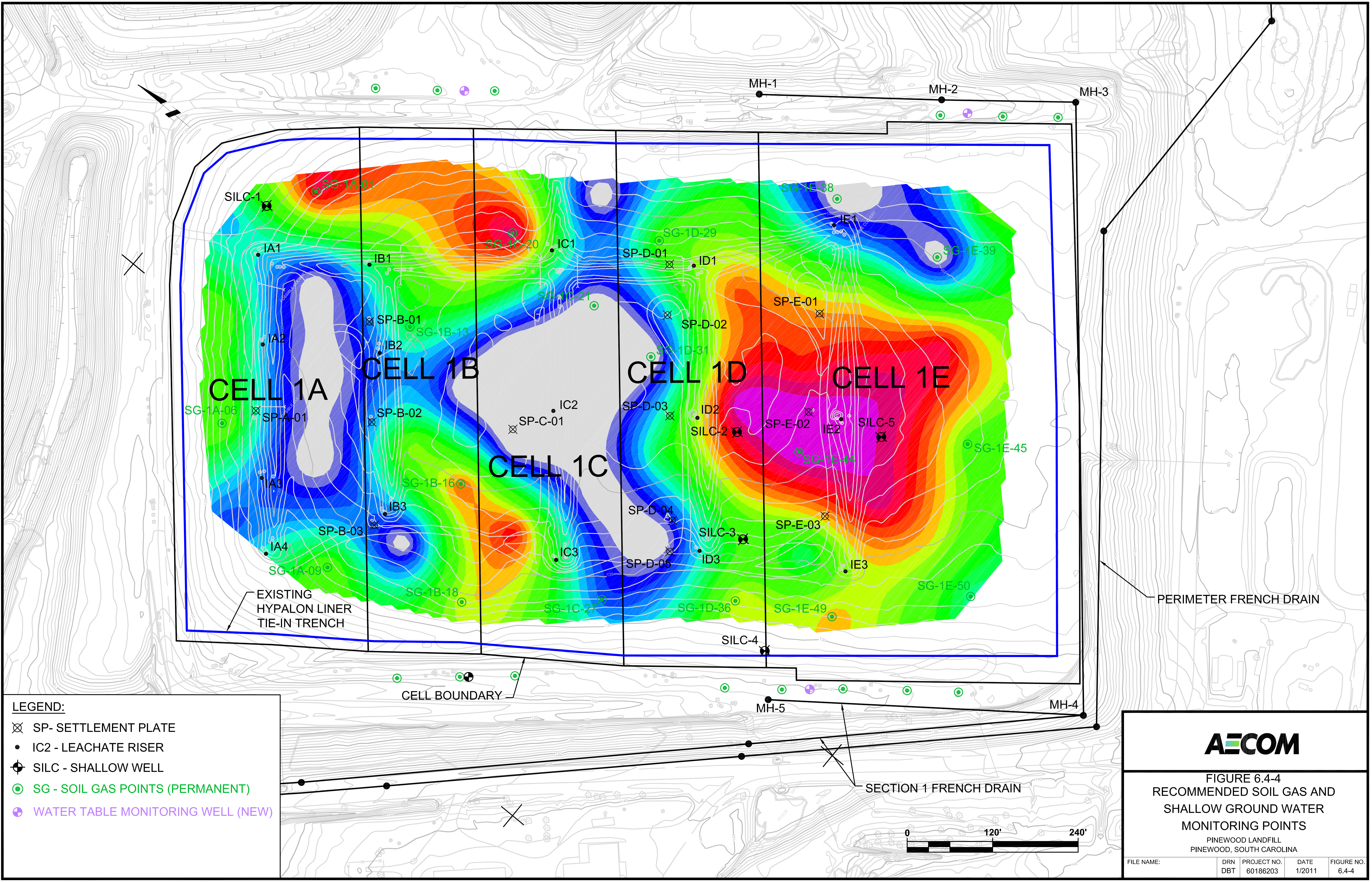

LEGEND:

⊠ SP- SETTLEMENT PLATE

• IC2 - LEACHATE RISER

⊕ SILC - SHALLOW WELL

◉ SG - SOIL GAS POINTS (PERMANENT)

◉ WATER TABLE MONITORING WELL (NEW)

AECOM

FIGURE 6.4-4
RECOMMENDED SOIL GAS AND
SHALLOW GROUND WATER
MONITORING POINTS

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
	DBT	60186203	1/2011	6.4-4

Plotted By: TICED
Layout-Sheet Name: FIGURE 6.4-5
Plot File Date Created: Mar/11/2011 1:02 PM

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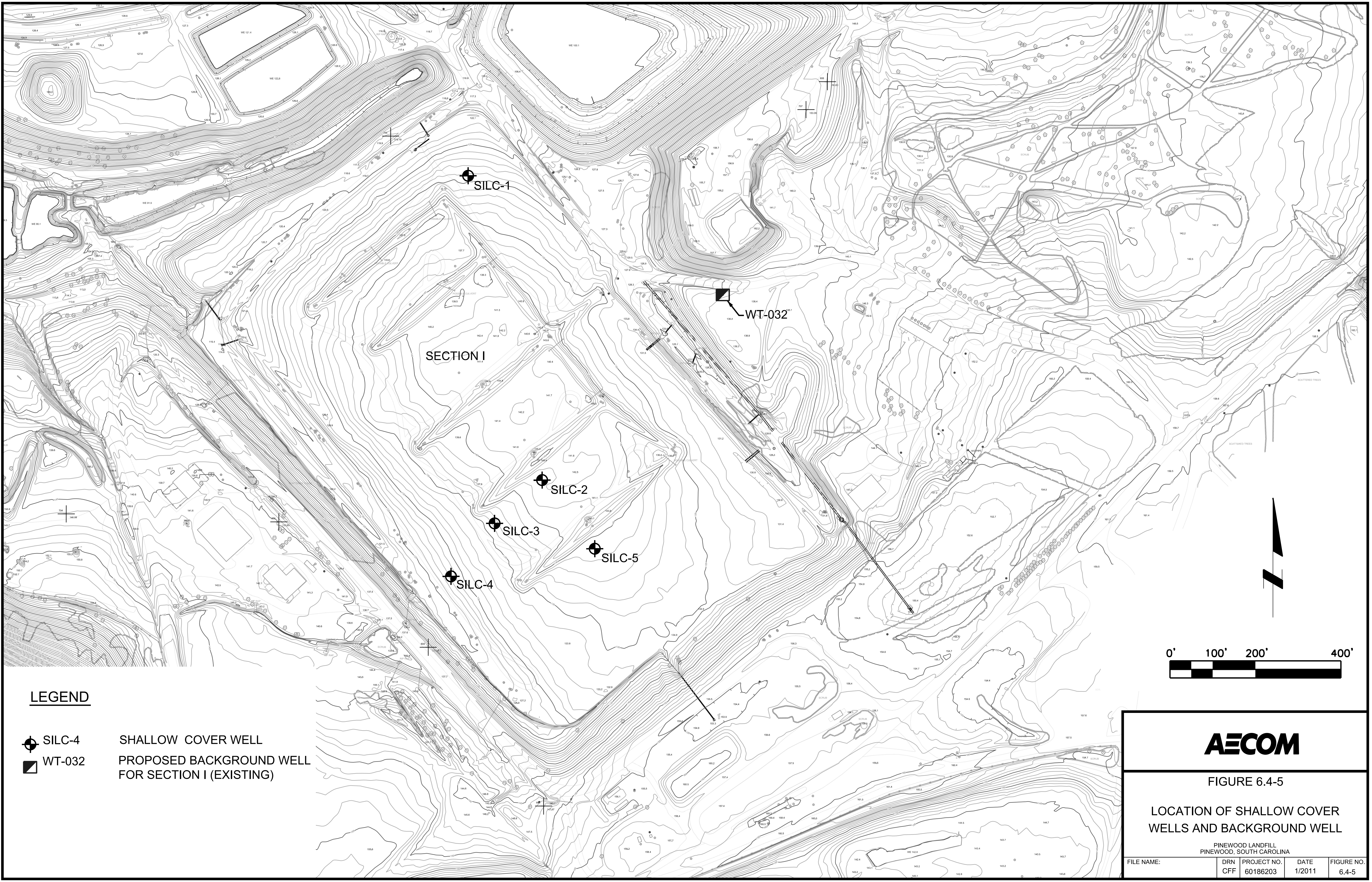

AECOM

FIGURE 6.4-5

LOCATION OF SHALLOW COVER WELLS AND BACKGROUND WELL

PINEWOOD LANDFILL
PINEWOOD, SOUTH CAROLINA

FILE NAME:	DRN	PROJECT NO.	DATE	FIGURE NO.
	CFF	60186203	1/2011	6.4-5

Plotted By: furmanskic
Layout-Sheet Name: MODEL
Plot File Date Created: Feb/03/2011 12:37 PM

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APPENDICES

APPENDIX A

GROUNDWATER SAMPLING AND ANALYSIS PLAN – INTERIM STATUS MONITORING

Ground Water Sampling and Analysis Plan
Interim Status Monitoring

Pinewood Secure Landfill (SCD 070375985)
Pinewood SC

October 15, 2003

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1 Introduction

The following Sampling and Analysis Plan (SAP) has been written specifically for the collection and analysis of groundwater samples taken from point of compliance (POC) monitoring wells at the Pinewood South Carolina Secure Landfill Facility, located in Pinewood South Carolina. The facility began operation in 1979, and was operated by Safety-Kleen (Pinewood), Inc. and it's predecessors as a hazardous waste treatment, storage and disposal facility. The SAP has been written and modified in accordance with conditions set in Part VIII Groundwater Protection of the Hazardous Waste Permit #SCD 070 375 985.

The purpose of this SAP is to provide protocol for sample collection, analytical methodology, quality assurance/quality control (QAQC), and documentation measures sufficient to conclude representative samples of aquifer conditions have been collected and transported to the contract laboratory. Upon receipt at the laboratory, this document provides that the samples are analyzed according to United States Environmental Protection Agency and South Carolina Department of Health and Environmental Control (SC DHEC) approved methodology. This SAP supersedes other plans devised for detection monitoring. It is the intention of the Pinewood Landfill facility that this plan replaces the existing plan submitted to SC DHEC on September 5, 1995.

Date generation and acquisition, as discussed below, is defined by site specific purging requirements, documentation of field parameters, sampling protocol, analytical protocol, and reporting requirements. It emphasizes the importance of sample collection being completed in the same manner during each sampling event, including: the usage of instruments, sample collection method, sample storage, preservation, document control, and the use of chain-of-custody and transport procedures. The submittal of the QAQC document ensures the usage of proper laboratory protocol. Copies of this SAP will be provided to field personnel. Field personnel will be required to review and initial the document quarterly prior to the initiation of routine monitoring. This will expedite sampling, reduce the possibility of error, and provide continuity of technique if a number of personnel are involved in sample collection.

2 Sampling Requirements

2.1 Water Levels

Static water levels will be measured monthly for one year following installation. Static water levels will be measured quarterly every year following the first year of installation. Water levels will be collected at all monitoring wells within a 48-hour time period. Water level measurements will be used for the preparation of potentiometric maps. All water levels will be measured to the nearest 0.01 feet.

2.2 Purge Requirements

Monitoring wells at the Pinewood facility will be purged prior to sampling to ensure collection of "representative" samples. The purging effort will ideally result in the removal of all stagnant water stored in the casing and artificial sand pack surrounding the well screen. If purging is successful, the sample will represent water introduced directly from the formation to the well thereby constituting a sample typifying aquifer characteristics.

The volume of water purged from a given well is dependent on: the volume of the water column in the well, the volume of water stored in the sand pack, and the permeability of the formation opposite the well screen and sand pack. For most wells, removal of three to five volumes of water is considered standard practice. For wells installed in low permeability formations, however, practical limitations regarding the rate of recovery after purging may supersede the de-facto standard of three to five well volumes.

Indicator parameters will be recorded at each well immediately prior to initiation of purging activities. For wells that are not purged dry, indicator parameters will be checked after each well volume removed. If the final two consecutive measurements of pH, temperature, and specific conductance exhibit greater than 15% variability, or in the case of pH, a change greater than 0.2 standard pH units, purging will continue until these indicators stabilize, or until five well volumes have been removed from the well. Not all wells at the Pinewood facility are capable of producing five well volumes. In cases where the nature and permeability of water bearing strata does not allow for instantaneous or rapid recovery, wells must be completely evacuated. In such cases (e.g., where recovery times are greater than four hours), complete well evacuation followed by sampling as soon as practical, is acceptable (Gibb, et al., 1981). Therefore, wells which will not yield multiple purge volumes will be completely evacuated and sampled as soon as a sufficient volume of groundwater has recovered. For wells that are purged dry, the indicator parameters will be collected prior to purging and when the groundwater recovers and groundwater samples are being collected.

So that the exact volume of groundwater withdrawn from individual wells can be determined, the following formulas for calculating the volume of a liquid in a two or four-inch well are utilized:

$$V = (TD - SWL)*0.163$$

$$V = (TD - SWL)*0.653$$

where:

V = volume of water in the well (gals.)
TD = total depth of the well (ft.)
SWL = depth to the static water level (ft.)
.163 = gallons of water in a one foot section of two-inch diameter pipe (gals./ft.)
.653 = gallons of water in a one foot section of four-inch diameter pipe (gals./ft.)

Table 1 shows well specific purge volumes and recovery periods for wells currently involved in routine monitoring. As other wells are incorporated into the monitoring network, Table 1 will be modified to include purging and recovery requirements for additional sampling locations. Actual purge volumes well vary depending on conditions at the time of sampling.

Purged water will be managed in one of two ways. Purged water from the wells will be managed as leachate whereby the water is collected and transported to the leachate collection system or a temporary storage area will be created for the purged water until receipt of analyses demonstrates the water is not contaminated at which time the purged water will be discharged as storm water.

2.3 Sampling Protocol

In this section, the sampling protocol is described. The recommended protocol is predicated upon implementation of methods that will minimize the potential for sampling induced bias, interference, or cross contamination. Above all else, it is imperative that the sampling procedure be consistent in all aspects each time the wells are sampled. To the extent possible (and practical) the personnel assigned to the sampling effort will be the same each time the wells are sampled.

Proper container selection, sample preservation, and documentation in groundwater monitoring are essential to the integrity of any sampling program. Improper selection of containers, for example, can destroy the validity of the sample. All samples will be collected and packaged for shipment or transport to the laboratory in a manner which will protect the integrity of the sample and ensure that all protocols for sample handling are met. Proper sample identification and chain-of-custody procedures will be carefully followed. Samples will be traceable from the time they are collected and submitted to the laboratory until all analyses are completed and the derived data are submitted to the regulatory agency. Proper document and sample control, as well as, chain-of-custody procedures are as important as the technical considerations which go into maintaining the validity of the sample.

2.3.1 Equipment and Instrumentation

All monitoring wells will be equipped with positive displacement (bladder type), non-gas contact submersible pumps (QED Corp.'s Well Wizard, or equivalent) for sample collection. The sampling pumps will be constructed of stainless steel and Teflon. Tubing used for sample delivery and water level measurement devices will also be constructed of Teflon. Well wizard sampling pumps arrive from the manufacturer pre-assemble, decontaminated, and identified by well number. The protective packaging will be removed at the well location at the time of installation.

Four-inch diameter monitoring wells will be equipped with submersible sampling pumps (for groundwater sample collection), and may also be equipped with purge pumps (due to large well volumes and extended purging times). All pumps will be decontaminated at the factory prior to delivery to the site. Purge pump tubing is pre-cut, however, not assembled. Purge pumps will be assembled in the field and installed. If field decontamination procedures are determined to be necessary, the following steps will be completed. The pumps (inside and outside) will be washed with Liquinox and triple rinsed with distilled water. A solution of Liquinox and distilled water will be run through the pumps. After which, a sufficient volume of distilled water will be run through the pumps to assure that all detergent (and potential contaminants) are removed.

A dedicated or disposable Teflon bailer or pump equivalent may be substituted as the backup system in the event a bladder type pump malfunctions.

Field measurements of pH, specific conductance, and temperature will be required for groundwater at all sampled wells during each sampling episode. Accordingly, the following instruments will be utilized in the field:

- pH meter (Hydac Model PCT/PH COMP or equivalent),
- conductance meter (Hydac Model PCT/PH COMP or equivalent),
- thermometer (C/F),
- water level indicator (Model QED 6000 or equivalent),
- turbidity meter (HF Scientific Model DRT15CE or equivalent).

2.3.2 Equipment Calibration

Each day of sampling, the field meters will be examined to ensure they are in good working order. The pH and specific conductance meter information will be recorded on the form located in Appendix A. The field pH and conductance meter will be calibrated at the beginning of each use and in accordance with the frequency suggested by the manufacturer. The pH meter will initially be calibrated using at least two standards spanning the range of results anticipated during the sampling event. The field conductance meter will be verified using a calibration solution and adjusted as necessary. The manufacturer's calibration instructions will be kept in the facility's groundwater file. Calibration records will be located in the sampling log book. Each instrument is decontaminated by triple rinsing with distilled water prior to use. Calibration of the turbidity meter will be conducted in accordance with the Standard Operating Procedures for Turbidity Analysis Using the HF Scientific DRT-15CE prepared by Safety-Kleen in August 2002. If a similar instrument is utilized, an equivalent calibration will be conducted at the manufacturer's recommendations. A calibration log is included in Appendix A. A thermometer will be kept on site so that the air temperature is accurately measured. Air temperature will be recorded at a minimum of twice daily in the sampling log book.

2.3.3 Sample Collection Methods

All field personnel involved with collection of groundwater samples will wear disposable latex gloves (or equivalent). The gloves will properly be discarded after use at each well. Pump controllers and drive engines will be located at each well, downwind of the sampling area (to minimize air-borne sample contamination).

The order of sample collection is determined by volatility of the parameter/analysis to be completed. Volatile organics will be collected first during which the flow rate of the submersible pump will be slowed so as not to de-gas the sample. Semi-volatile samples will be collected next followed by all other parameters. The sample will be collected directly from the Teflon tubing into the appropriate container discussed in the next section. The sample will also be collected so that there is no air in the vial for VOCs after the Teflon coated cap is tightened.

During sample collection, field pH, specific conductance, and temperature measurements will be recorded. At well locations where the well does not purge dry, the field measurements reported to the State and EPA will be collected prior to the last volume purged and prior to groundwater sample collection. At well locations where wells are purged dry, the field parameters reported will be collected at the time the samples are collected. Appendix C includes the monitoring well sampling schedule which may be revised upon approval by SC DHEC due to evaluation of the monitoring network.

During sample collection, the sampling tube will not be allowed to become immersed into the purge water. If for any reason the sampling tube and the purge water do come in contact, the tube will either be replaced or properly decontaminated prior to initiating sampling procedures.

2.3.4 Sample Containers and Preservation

The primary types of sample containers are glass and plastic. The choice of proper sample containers is dependent upon several factors, including:

- The type of analysis to be performed (this dictates the minimum volume required and the container material to be employed to minimize potential interference);
- The type of preservation employed (if chemical addition is necessary, the container must be compatible with the additive as well as the sample; if the sample is light sensitive, the container must be a light inhibiting bottle);

The size of the container is dependent on the analysis and methodology. The containers used for sample collection at the Pinewood facility will be shipped to the site from the contract laboratory pre-cleaned and ready for use.

The purpose of sample preservation is to maintain the validity of the sample from the time of collection until the sample is prepared for laboratory analysis. Specifically, preservation is geared to retarding biological action and hydrolysis, and reducing volatility (ASTM, 1981). Standard preservation methods include :

- pH control (usually less than pH 2, using acid specific to the analysis required or raising the pH using sodium hydroxide),
- Freezing,
- Refrigeration (<4 degrees C) using wet ice
- Light inhibiting bottles.

Sample containers will be provided pre-preserved by the contract laboratory. Standard preservation methods and laboratory holding times for the analytical determinations are included in the laboratory QAQC manual. 2-Chloroethyl vinyl ether will be collected unpreserved in 40-ml vials used for volatile organic sample collection. All other volatiles will be collected unpreserved and analyzed within 7 days or collected pre-preserved with hydrochloric acid. In filling the vials, care will be taken to ensure the water does not overflow the vial and dilute the acid preservative. In addition head space in the VOC samples will be minimized by ensuring the vials are free of bubbles. All other sample containers will be filled and capped immediately pre-preserved with the appropriate preservative for it's respective analysis.

At least 10% of the samples collected for metals analysis will be verified that the sample is appropriately preserved for pH. The samples will be checked by pouring a small amount of the mixed preserved sample in a separate container and then using a pH indicator strip (Baxter Scientific Products, S/P pH Indicator Strips or equivalent). The strip will be inserted into the separate container and then compared to the pH chart provided on the pH strip indicator container. If the sample is incorrectly preserved, more nitric acid will be added and the sample retested until the correct pH is achieved. The indicator strips will not directly be inserted into the sample containers in order to minimize the potential for cross contamination. Results will be recorded on the well sampling log.

Sample containers will be placed on wet ice in the field immediately after collection and transported to the on-site refrigerator immediately following sampling. To reduce the potential for cross contamination of the samples within the transport cooler, either the wet ice or the samples containers will be contained in clean plastic bags. The temperature of the refrigerator will be maintained at or below 4 degrees Celsius.

The table below summarizes preservatives, hold times and type of containers.

Analysis	Hold Time	Preservative	Container Type
VOCs	14 days or 7 days	HCL or unpreserved	40 ml VOA viles with Teflon lined septas
2-Chloroethyl vinyl ether	7 days	unpreserved	40 ml VOA viles with Teflon lined septas
Chloride	28 days	-	HDPE Plastic
RCRA Metals	6 months	Nitric acid	HDPE Plastic
Mercury	28 days	Nitric acid	HDPE Plastic
SVOCs	7 days extraction, 40 days analysis	-	Amber Glass
Herbicides	7 days extraction, 40 days analysis	-	Amber Glass
PCBs	7 days extraction, 40 days analysis	-	Amber Glass
Pesticides	7 days extraction, 40 days analysis	-	Amber Glass
Sulfide, Total	7 days	Zinc acetate and NaOH	HDPE Plastic
Cyanide – Total	14 days	NAOH	HDPE Plastic
Dioxins/Furans	30 days extraction, 45 days analysis	Sodium thiosulfate	Amber Glass

2.3.5 Quality Assurance/Quality Control Samples

Field and trip blank samples are performed to assess the potential interference from the sampling procedure and the analysis, respectively.

The field blank consists of laboratory prepared "organic-free" water that is obtained from the contract laboratory and transported to the site. Appropriate sample container or containers are filled on-site using this water and returned to the contract laboratory for analysis. The field blank serves to assess the potential interference introduced as a result of field sampling and conditions during sample transfer, storage, preservation, and transport to the laboratory.

The trip blank consists of the laboratory prepared "organic free" water and is designed to assess any interference introduced during storage and transportation.

The criteria for the collection of field and trip blanks during groundwater sampling are as follows:

- one full trip blank per sampling episode (i.e. samples collected within a period of a month) for laboratory analysis identical to that of the groundwater analysis.
- one trip blank per cooler (of groundwater sampling) for volatile organic compound analysis
- one full field blank per sampling episode (i.e. samples collected within a period of a month) for laboratory analysis identical to that of the groundwater analysis.
- one field blank per day (of groundwater sampling) for volatile organic compound analysis.

The collection of additional field blanks during a sampling episode will be at the discretion of the field sampling technician. These additional samples would be collected at locations or instances where a high potential for extrinsic influence on the sample quality has possibly occurred. It should be noted that all field blank samples will be collected in the region of the site, which at the time of sample collection, appear to have the greatest potential for extrinsic influences on sample quality.

Duplicate samples may also be collected to assess laboratory accuracy and sample collection methods.

2.4 Sample Control and Handling

The validity of information submitted to the regulatory agency must be documentable. Sample control is provided via proper sample identification and proper chain-of-custody documentation.

2.4.1 Sample Labels

Identifying labels will be affixed to the samples. The labels will include the following information:

- facility name
- well location name
- sample collectors name
- date of sample collection
- time of sample collection
- the analyses to be performed
- the preservation method
- any special information relating to the nature of the sample (e.g., split, duplicate, blanks).

Samples will be identified with an alpha-numeric code consistent with the assigned monitoring well numbering system. All samples will be labeled with indelible ink to prevent confusion due to label illegibility. It is the responsibility of the field crew chief to ensure that sampling is conducted properly and representative of the total environment under investigation.

Samples will be transported to the laboratory via courier service or equivalent transporter accompanied by a chain-of-custody form. Samples will be maintained at 4 degrees Celsius or less during transport. The field crew chief must keep a written log of field activities and pertinent sampling data as described below.

2.4.2 Field Records

A log book shall be maintained as a permanent record of all activities relating to sample collection. Information included in the log book for a given sampling trip and a particular sample shall include the following: the date, well identification, weather conditions, purging requirement information, time of purging, time of sampling, pH meter calibration information, indicator parameter readings, sample preservation information, problems encountered, and general remarks (see Appendix D, Wells Sample Logs). The log book will be legible with indelible ink, accurate, objective, numbered pages and signed.

2.4.3 Chain-of-Custody and Transport of Samples

The purpose of chain-of-custody record-keeping is to ensure that the sample can be traced from the time it is collected until the analyses are completed and the data is submitted to the regulatory agency. It is recommended that the number of people handling the sample be minimized. This reduces the possibility for error, confusion, and damage.

When transferring and/or shipping from the field, samples must be accompanied by the chain-of-custody record. The chain-of-custody record must include the identity of all samples being relinquished to the laboratory, the requested analyses, time and date of sample collection, signatures of the relinquisher and the receiver as well as the date and time of the exchange, and any pertinent remarks. A sample chain-of-custody is presented in Appendix E. The overall shipping container should also be padlocked or provided with a tamper-proof seal, and shipped courier service or equivalent transporter for next day delivery. In addition, the sample containers will be adequately packaged to prevent breakage and ensure a temperature of less than 4 degrees Celsius is maintained during transport. Maximum time of transport from the Pinewood facility to the laboratory should not exceed 48 hours.

A sample custodian will receive the samples. Upon sample receipt, the custodian will inspect the condition of the samples and the cooler in which the samples were shipped, reconcile the samples received against the chain of custody record, enter the samples in the laboratory logbook, and store the samples in a secured sample storage room or cabinet until analysis.

Discrepancies observed between the samples received and information on the chain of custody form will be resolved before analysis. The Laboratory Coordinator will be informed of any such discrepancy and resolve the conflict with the laboratory. The laboratory will also notify the appropriate party immediately if any problems are noted with the samples (i.e. breakage, high temperature, chain of custody discrepancies, etc.). The data manager shall ensure that samples are properly stored and maintained through analysis and until results are reviewed and approved.

3 Analytical Protocol

In this section the required analytical parameters, approved laboratory methods, and laboratory quality assurance/ quality control procedures are described.

Sample analyses will be conducted by a SC DHEC certified laboratory in accordance with US EPA and SC DHEC approved methodology. All laboratory procedures for the analysis of groundwater samples at the Pinewood facility follow those as specified by SW-846 or methods approved by SC DHEC. Information concerning laboratory QA/QC procedures are provided in the laboratory QA/QC plan included in Appendix B. For parameter reporting limits, background levels and prediction limits refer to Appendix F.

3.1 Analytical Methods

Parameter selection is a key component of an effective monitoring plan. Parameters which have relatively little probability of migration are often routinely included, as are parameters which may be redundant. The recommendations provided herein describe a suite of parameters that will permit detection of an impact from the facility, should such an impact occur.

For the purposes of detection monitoring activities, the Pinewood Landfill will perform:

- quarterly analysis on monitoring wells located downgradient in the Transitional Lang Syne
- annual analysis will be performed on monitoring wells located in the upgradient Transitional Lang Syne
- annual analysis will also be performed in the Opaline Claystone, Secondary Sawdust Landing, Primary Sawdust Landing, and the Upper Black Creek A aquifers.
- Monitoring wells in the Opaline Claystone will initially be analyzed for four consecutive quarters, to establish background data, before being scheduled for annual analysis.
- Monitoring wells located in the Upper Black Creek B aquifer will be analyzed for four quarters only, to establish baseline data. In the event of a confirmed statistical failure, wells located in both the vicinity of the detection and the next lower zone will be analyzed more frequently (semi-annual or quarterly).

Analysis will include the following compounds: volatile organics compounds, 8 RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, nickel, zinc), chloride, and field parameters (pH, specific conductance, temperature, field turbidity, and groundwater elevation). Samples will be collected from specific wells locations according to schedules in Appendix C (which correspond to Tables 3, 4, 5 and 6 of Attachment H of the site Permit). The foundation for this analytical scheme is an extensive review of the entire Pinewood groundwater quality data base.

On an annual basis, groundwater samples from five wells must be collected for Appendix IX analysis (VIII.A.9.c). At least thirty days prior to the collection of the Appendix IX samples, the Facility will submit a specific proposal and rationale to SC DHEC for review and approval detailing which five wells will be sampled. The sampling protocol described herein will be employed for sample collection as will laboratory QA/QC procedures detailed within Appendix B.

Results of the sampling event will be reported to SC DHEC and US EPA as described in Reporting Requirements of this plan.

3.2 Quality Assurance/Quality Control Samples

Field, trip, and laboratory blank samples are performed to assess the potential interference from the sampling procedure and the analysis, respectively.

The laboratory blanks are prepared in the laboratory at the time of sample analysis and are designed to assess the potential level of interference introduced during analysis. In addition to the laboratory blank, matrix spikes, matrix spike duplicates, laboratory control samples for precision, accuracy and completeness will be conducted and reported.

Organic parameters that are detected at levels below the parameter specific PQL but above the method detection limit will be reported and "J" flagged to indicate the result is an estimated value.

4 Data Quality Objectives

The DQO process ensures that the needed data is available to the data users once the fieldwork phase is complete. The following objectives have been identified:

- Determine the presence or absence of parameters in the ground water. This process requires definitive data and knowledge of action levels and statistical approaches for media classifications.
- Determine the horizontal and vertical limits of ground water with concentrations of constituents above appropriate maximum contaminant levels (MCLs). This process requires definitive data and knowledge of MCLs.
- Quantify the concentration of the constituent in groundwater. This also requires definitive data.

Screening data will be used for field-measured parameters (e.g., pH, specific conductance and temperature) and are data generated by less precise analytical methods and with less rigorous sample preparation. Definitive data includes volatile organic compounds (VOCs), chloride, and metals analyzed using USEPA SW-846 methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data.

Both screening and definitive data will be collected. Both types of data will be used in making comparisons as follows:

- Comparison to Background Concentrations - Samples will be collected in the project area to establish background concentrations against which the on-site data can be compared.
- Comparison to Environmental Quality Standards or Appropriate Risk Levels - Parameters that have environmental quality standards or risk levels for ground water will be evaluated in terms of their respective standards in determining if constituents are found at elevated concentrations. The detection limits in which the samples will be analyzed will be at or below action levels predetermined by SC DHEC or US EPA to ensure that the appropriate level of precision is analyzed. Method specific DQOs have also been established for precision and accuracy and are updated on a regular basis by the laboratory.

5 Well Maintenance

Monitoring wells and piezometers will be inspected at a minimum of once per year. Wells and piezometers without pumps will be measured for total depths annually to ensure the wells are free of sediment build-up. For monitoring wells with dedicated pumps, total depth of the monitoring well will be measured if a pump is removed for repair. Maintenance (i.e. pad replacement, casing replacement, redevelopment, etc.) will be completed as necessary for monitoring wells and piezometers, and summarized in the Annual Report. The well inspection form in Appendix G will be provided in the Annual Report

6 Reporting Requirements

All groundwater quality data will be reported to both SC DHEC and US EPA. Groundwater quality data will be submitted within thirty days of the end of each quarter. Fourth quarter data will be submitted with the Annual Report which is due by March 1 of the following year. One full paper copy will be supplied to the Department while supplement transmittals of the reports will be submitted electronically. In addition, the data generated will be supplied in an electronic version in a spreadsheet or database format.

At a minimum, the following items will be discussed or included within the groundwater quality reports:

- groundwater quality analytical data and elevation data in tabular form
- evaluation and discussion of all water quality and water elevation data
- potentiometric maps depicting all hydrologic units at a scale of 1"=200 feet
- brief evaluation of ground water elevation data
- determination of ground-water flow rates and direction for each hydrologic unit based on gradients from the quarter; evaluation of any changes
- hydrographs for each well (clustered wells to appear on a single hydrograph)
- field log sheets for each well
- laboratory data reports
- laboratory and field QA/QC documentation
- statistical evaluation of water quality data (metals, pH and conductivity)
- description of implemented or proposed modifications to the system
- detailed narrative evaluation and discussion of the detection monitoring systems effectiveness (annual report only)
- summary of well inspections (annual report only) and maintenance.

REFERENCES CITED

ASTM, 1981. Draft Standard Guide for Sampling Groundwater Monitoring Wells, American Society of Testing Materials, 24 pp.

Gibb, J.P., R.M. Schuller, and R.A. Griffin, 1981. Procedures for the Collection of Representative Water Quality Data from Monitoring Wells. Illinois State Water Survey, Cooperative Groundwater Report No.7, 61 pp.

APPENDIX A

LOG FORMS - pH, SPECIFIC CONDUCTANCE, TURBIDITY METERS

pH Meter QA/QC Log Sheet
Model #HYDAC 015235

Date	Time	Buffer Readings B/A			Temperature	Tech I.D.	Comments
		4.00	7.00	10.00			

Specific Conductivity QA/QC Log Sheet
Model #HYDAC 015235

Date	Time	Standard Calibration	Range	Reading	Temperature	Tech I.D.	Comments

Turbidity Meter Log Sheet
HF Scientific DRT-15

Date	Time	Formazin Standard	Meter Before	Meter After	Secondary Reading	Percent Difference	Tech I.D.	Comments

APPENDIX B

LABORATORY QA/QC PLANS

VERIFY THE VALIDITY OF THIS SOP EACH DAY IN USE

GENERAL ENGINEERING LABORATORIES, LLC

QUALITY ASSURANCE PLAN

(GL-QS-B-001 REVISION 15)

PROPRIETARY INFORMATION

This document contains proprietary information that is the exclusive property of General Engineering Laboratories, LLC (GEL). No contents of this document may be reproduced or otherwise used for the benefit of others except by express written permission of GEL.

Quality Assurance Plan Approval Signatures:

James M. Stelling
President and CEO

GEL's Document Control Officer certifies this document to be a true copy of the fully executed original.
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(Date)
fficer

Robert L. Pullano (Date)
Director, Quality Systems

James B. Westmoreland (Date)
Director, Radiochemistry Division

Prepared by:
General Engineering Laboratories, LLC

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SECTION 1
INTRODUCTION

Section 1 - Introduction

General Engineering Laboratories, LLC (GEL) is a privately owned environmental laboratory dedicated to providing personalized client services of the highest quality. Our mission is to be the "Analytical Firm of First Choice."

GEL was established as an analytical testing laboratory in 1981. Now a full service lab, our analytical divisions use state of the art equipment and methods to provide a comprehensive array of organic, inorganic, radiochemical and bioassay analyses and related support services to meet the needs of our clients.

This Quality Assurance Plan provides an overview of our quality assurance program for analytical services. Outlined in this plan are the responsibilities, policies and processes essential to maintaining client satisfaction and our high quality of performance.

Everyone on our staff is expected to understand the policies, objectives and procedures that are described in this plan and to fully appreciate our commitment to quality and their respective roles and responsibilities with regard to quality. We also expect any analytical subcontractors we employ to perform in accordance with the quality assurance requirements delineated in this plan. All GEL employees are required to participate in Annual Quality Systems.

This Quality Assurance Plan (QAP) has been prepared according to the standards and requirements of the US Environmental Protection Agency (EPA) and the National Environmental Laboratory Accreditation Program (NELAP) Quality Systems Standards June 2000.

1.1 Quality Policy

GEL's policy is "to provide high quality, personalized analytical services that enable our clients to meet their environmental needs cost effectively."

We define quality as "…consistently meeting the needs and exceeding the expectations of our clients." As such, we consistently strive to:

meet or exceed client and regulatory requirements
be technically correct and accurate
be defensible within contract specifications
provide services in a cost-effective, timely and efficient manner

At GEL, quality is emphasized at every level—from the Chairman, CEO, CFO and COO to the newest of employees. Management's ongoing commitment to quality is demonstrated by their dedication of personnel and resources to develop, implement, assess, and improve our technical and management operations.

Our quality assurance program is designed to comply with the guidelines and specifications outlined in the following:

NELAC 2001
ASME/NQA-1
ISO/IEC Guide 17025
QAPPs, U.S. EPA QA/R5
Department of Energy Order 414.1
Current U.S. EPA CLP statements of work for inorganic and organic analyses
ANSI N42.23 Quality Assurance for Bioassay Laboratories 1995

1.2 Quality Goals

GEL's primary goals are to:

Ensure that all measurement data generated is scientifically and legally defensible, of known and acceptable quality per the data quality objectives (DQOs), and thoroughly documented to provide sound support for environmental decisions
Ensure compliance with all contractual requirements, environmental standards, and regulations established by local, state and federal authorities.

Additional goals include:

A comprehensive quality assurance program to ensure the timely and effective completion of each measurement effort.
A commitment to excellence at all levels of the organization.
Early detection of deficiencies that might adversely affect data quality.
Adequate document control.
Effective quality assurance objectives for measurement systems and for quality data in terms of accuracy, precision, completeness, and comparability through the use of proven methods.
The establishment of procedures that demonstrate that the analytical systems are in a state of statistical control.
The implementation of corrective actions to ensure the integrity of data.

Reduction of data entry errors through comprehensive automated data handling procedures.

The development and implementation of good laboratory and standard operating procedures (SOPs).

Ability to customize quality assurance procedures to meet a client's specific requirements for data quality.

Good control of instruments, services, and chemical procurement.

A continuously evolving laboratory information management system (ALPHALIMS).

Validated and documented computer hardware and software.

1.3 Key Quality Elements

A sound quality assurance program is essential to our ability to provide data and services that consistently meet our high standards of integrity. The key features of our program are:

An independent quality assurance (QA) validation and Quality Systems Department.
A formal quality policy and QAP.
Management Review
Stated data quality objectives.
A comprehensive employee training program.
Ethics policy and education program.
Internal audits and self-evaluations.
A closed-loop corrective action program.
State-of-the-art facilities and instruments.
Adherence to standard operating procedures.
EPA/NIST traceable reference materials.
Electronically based document control.
Chain of custody and electronic sample tracking.
Inter-laboratory comparison programs.
Formal laboratory accreditations.
The evaluation of subcontractor laboratories.
Statistical controls for analytical precision and accuracy.
Replicate, method blank, matrix spike, tracer yield, internal standards, and surrogate measurements.
The preventive maintenance of instrumentation and equipment.
Independently prepared blind standard reference materials.
Multi-level review processes.
Focus on client satisfaction.
Electronic tracking of client commitments, nonconformances and corrective actions.
Trend analysis of nonconforming items.

1.4 Management Reviews

The effectiveness of the Quality System is reviewed at least annually by Senior Management. These reviews address issues that impact quality, and the results of the reviews are used to develop and implement improvements to the system. Records of the review meetings are maintained as quality documents.

1.5 Disposition of Client Records

In the even that the laboratory should change ownership, the responsibility for the maintenance and disposition of client records shall transfer to the new owners. In the unlikely event that the laboratory ceases to conduct business, clients shall be notified and asked to provide instructions as to how their records should be returned or disposed. If a client does not provide instructions, those records will be maintained and disposed in a manner consistent with regulations and good laboratory practices for quality records.

1.5 Supporting Documents

Our laboratory operations and the quality of our analytical data comply with the specifications described in the documents listed in Appendix A.

1.6 Definitions

Applicable definitions are listed in Appendix B.

SECTION 2
ORGANIZATION, MANAGEMENT, AND PERSONNEL

Section 2 - Organization, Management, and Personnel

The chart found in Appendix C depicts our corporate organization, chain of command and flow of responsibility. The illustration in this appendix is designed to ensure the overall quality and cost efficiency of our company's analytical products and services.

Our structure is based on customer-focused divisions that follow a project from the point of initial contact to the final invoicing of work. These divisions include expertise in project management, sample receipt and custody, sample preparation and analysis, data review and data packaging. An independent Quality Systems Management Department monitors the adherence of these divisions to the Quality Assurance Program.

The general responsibilities associated with the following position levels are discussed in this section:

Chairman
Chief Executive Officer (CEO) and President
Chief Financial Officer (CFO)
Chief Operating Officer (COO)
Quality Systems Director
Laboratory Directors
Project Managers
Group Leaders
Laboratory and Technical Staff
Information Systems Manager
Environmental Manager

An overview of GEL's employee training protocol is also provided at Section 2.11.

2.1 Chairman, CEO/President, Chief Financial Officer and Chief Operating Officer

Operational responsibility rests with GEL's three owners and COO. Kathleen H. Stelling, James M. Stelling, and Douglas E. Earnst are GEL's owners and serve respectively as Chairman, CEO/President, and CFO. Carey J. Bocklet occupies the position of COO. As the highest level executives, their philosophical approach to quality, technology and customer service keeps GEL unique.

The Stellings, Mr. Earnst and Ms. Bocklet comprise our Executive Committee. They are also part of a Leadership Team that works to create a workplace environment that attracts and retains highly qualified professionals.

As Chairman, Ms. Stelling oversees the Executive Committee and leads management in implementing total quality initiatives that ensure quality services that meet stringent criteria of excellence. She has responsibility for public relations efforts and community affairs. Ms. Stelling holds a Bachelor of Arts in Education from the University of South Carolina.

As CEO and President, Mr. Stelling has overall operational responsibility for GEL. He operates the laboratory according to corporate policies and applicable licenses and regulations.

Mr. Stelling also has primary responsibility for the development and administration of our analytical testing and environmental consulting services. He holds a Bachelor of Science in Commerce from the University of Virginia.

Douglas E. Earnst is GEL's Chief Financial Officer and oversees our financial management. He is responsible for contracts administration, invoicing, purchasing, payroll, accounts payable and receivable, inventory control, property control, and financial forecasting. Mr. Earnst holds a Bachelor of Science in Business Administration from the Citadel.

The Chief Operating Officer is Carey J. Bocklet. Ms. Bocklet is responsible for the daily operations of the laboratories and client services.

Together, the Chairman, CEO/President, CFO and COO form GEL's Executive Committee. Their responsibilities include the following:

Ensuring that the individuals who staff our technical and quality positions have the necessary education, training and experience to competently perform their jobs.
Ensuring that all staff members receive ancillary training, as needed, to enhance performance in assigned positions.
Budgeting, staffing, managing and equipping the laboratory to meet current and future analytical program requirements.
Overseeing the implementation and overall effectiveness of our Quality Assurance Plan, health and safety initiatives, and environmental programs.
Managing production and cost control activities.

Ensuring development of capabilities in response to new or revised regulations, instrumentation and procedures, and quality assurance initiatives.

2.2 Technical Laboratory Co-Directors

To enhance our responsiveness to clients through dedicated expertise and teamwork, our laboratory is divided into two major divisions, Chemistry and Radiochemistry, each with its own Technical Laboratory Director.

The Technical Directors report to the Executive Committee and are ultimately responsible for the technical content and quality of work performed within each division. They are also responsible for strategic planning, profitability and growth, personnel management and business development. Other responsibilities include:

Monitoring and meeting profitability and growth objectives of the division.

Establishing and implementing short and long range objectives and policies that support GEL's goals.

Defining the minimum level of qualification, experience, and skills necessary for positions in their divisions.

Establishing and implementing policies and procedures that support our quality standards.

Ensuring that technical laboratory staff demonstrate initial and continuing proficiency in the activities for which they are responsible.

Documenting all analytical and operational activities of the laboratory.

Supervising all personnel employed in the division.

Ensuring that all sample acceptance criteria is verified and that samples are logged into the sample tracking system, properly labeled and stored.

Documenting the quality of all data reported by the division.

Developing internal mechanisms and measurements to improve efficiency.

Overseeing activities designed to ensure compliance with laboratory health and safety requirements.

Allocating the resources necessary to support an effective and ongoing quality assurance program.

Representing the company to the public and to clients.

Ensuring the appropriate delegation of authorities during periods of absence.

Due to high volume and variety of analytical tests performed in the Chemistry Laboratory, the Technical Director for the Chemistry Laboratory has the daily assistance of a Production Manager.

2.3 Quality Systems Director

Our Quality Systems Director (QSD) reports directly to the CEO. The QSD manages the design, implementation and maintenance of our quality systems in a timely, accurate, and consistent manner.

In addition to having responsibility for the initiation and recommendation of corrective and preventative actions, the QSD is responsible for:

Establishing, documenting and maintaining comprehensive and effective quality systems.

Developing and evaluating quality assurance policies and procedures pertinent to our laboratory functions, and communicating these with the division directors and managers.

Ensuring that the operations of the lab are in conformance with the Quality Assurance Plan and meet the quality requirements specific to each analytical method.

Ensuring that laboratory activities are in compliance with local, state and federal environmental laws and regulations.

Reviewing project-specific quality assurance plans.

Ensuring that quality control limits are established and followed for critical points in all measurement processes.

Initiating internal performance evaluation studies using commercially purchased certified, high-purity standard reference materials.

Performing independent quality reviews of randomly selected data reports.

Conducting periodic audits to ensure method compliance.

Conducting or arranging periodic technical system evaluations of facilities, instruments and operations.

Overseeing and monitoring the progress of nonconformances and corrective actions.

Communicating system deficiencies, recommending corrective action to improve the system, and defining the validity of data generated during out of control situations.

Preparing and updating quality assurance documents and reports to management.

Coordinating inter-laboratory reviews and comparison studies.

Overseeing Stop Work Orders in out of control situations.

Administering accreditation and licensing.

Administering our document control system.

Providing guidance and training to laboratory staff as requested.

Evaluating subcontractors and vendors that provide analytical and calibration services.

Designating quality systems authorities in times of absence to one or more appropriately knowledgeable individuals.

2.4 Quality Systems Review

The effectiveness of the Quality System is reviewed on a regular basis during meetings of the Leadership Team, which may be as often as weekly, but not less than quarterly. These meetings address issues that impact quality and the subsequent discussions are used to design and implement improvements to the system. At least annually, a management assessment of GEL's Quality System is conducted and reported. The QSD maintains records of these assessments.

2.5 Manager of Client and Support Services

Project Managers (PMs) serve as primary liaisons to our clients. PMs, under the guidance of the Manager of Client and Support Services, manage the company's interaction with clients. They are the client's fist point of contact and have responsibility for client satisfaction and for communicating project specifications and changes to the appropriate laboratory areas.

Additional responsibilities include:

Retaining clients and soliciting new work.

Managing multiple sample delivery orders and preparing quotes.

Working with clients to define analytical methodologies, quality assurance requirements, reports, deliverables, and pricing.

Overseeing sample management and informing laboratory staff of the anticipated arrival of samples for analysis.

Conducting a final technical review of all client documents (quotes, hard copy deliverables, invoices, routine and specialized reports).

Working with the accounting team on invoicing and collection issues.

Working with the Laboratory Directors and Production Manager to project workloads and determine schedules.

2.6 Production Manager and Group Leaders

Group Leaders are a critical link between project management, lab personnel and support staff. They report to the Technical Directors and have the following responsibilities:

Planning and coordinating the operations of their groups to meet client expectations.

Scheduling sample preparation and analyses according to holding times, quality criteria, and client due dates.

Ensuring a multi-level review of 100% of data generated by their groups.

Coordinating nonconformances and corrective actions in conjunction with the Quality Systems Management team.

Serving as technical resources to their groups, including data review.

Managing special projects, reviewing new work proposals, and overseeing the successful implementation of new methods.

Monitoring and controlling expenses incurred within their groups such as overtime and consumables.

Providing performance and career development feedback to their group members.

2.7 Laboratory and Technical Staff - General Requirements

At GEL, every effort is made to ensure that the laboratory is sufficiently staffed with personnel who have the training, education and skills to perform their assigned jobs competently.

Depending upon the specific position, laboratory personnel are responsible for:

Complying with quality assurance and quality control requirements that pertain to their group and/or technical function.

Demonstrating a specific knowledge of their particular function and a general knowledge of laboratory operations.

Understanding analytical test methods and standard operating procedures that are applicable to their job function.

Documenting their activities and sample interactions in accordance with analytical methods and standard operating procedures.

Implementing the quality assurance program as it pertains to their respective job functions.

Identifying potential sources of error and reporting any observed substandard conditions or practices.

Identifying and correcting any problems affecting the quality of analytical data.

2.8 Information Systems Manager

The Information Systems Manager reports directly to the COO. The responsibilities of this position include management of the Computer Services Team and ALPHALIMS, our laboratory information management system.

The combined responsibilities of the Information Systems Team, performing under the leadership of the Information Systems Manager, include the:

Development and maintenance of all software and hardware.

Translation and interpretation of routines for special projects.

Interpretation of general data and quality control routines

Optimization of processes through better software and hardware utilization.

Customization, testing and modification of data base applications.

Maintenance and modification of our computer modeling, bar coding, CAD, statistical process control, project management, and data packaging systems.

Development and maintenance of client and internal electronic data deliverables.

Validation and documentation of software used in processing analytical data.

2.9 Environmental Manager

The Environmental Manager oversees our physical facility, laboratory and radiation safety programs, and instrumentation. This position reports to the COO, and manages and supervises the functions and staff assigned to these areas.

Responsibilities of the Environmental Manager include:

Planning, evaluating and making recommendations for facility maintenance, additions and renovations.

Overseeing building renovations and new construction activities.

Implementation of the Chemical Hygiene and Radiation Safety programs.

Installing, maintaining, repairing and modifying analytical instrumentation.

Providing technical expertise and training in instrumentation operation, calibration and maintenance.

Monitoring and ensuring regulatory compliance for waste management operations and off-site disposal.

2.10 Director of Human Resources

The Director of Human Resources reports directly to the CEO. The DHR manages the design, implementation, and ongoing development of our Human Resources. Responsibilities of the DHR include:

Administration, orientation and indoctrination of all new employees

Administration and compliance with Federal, State, and Local employment regulations

Sourcing candidates for all functional positions to maintain and strengthen the technical services provided by GEL

Management of occupational health and safety as it relates to Federal, State, and OSHA regulations

2.11 Employee Training

To ensure that our clients receive the highest quality services possible, we train our employees in the general policies and practices of the company, as well as the specific operating procedures relative to their positions. We conduct and document this training according to GL-HR-E-002 for Employee Training and GL-HR-E-003 for Maintaining Training Documentation.

New employees participate in a company orientation shortly after they are hired. During orientation they receive information on quality systems, ethics, laboratory safety and employment practices. Each new employee is also provided a manual that reiterates our policies on equal opportunity, benefits, leave, conflicts of interest, employee performance and disciplinary action. Employees can access standard operating procedures, the Quality Assurance Plan, Safety, Health and Chemical Hygiene Plan, and the Laboratory Waste Management Plan on GEL's Intranet.

Other training provided on an ongoing basis may include:

Demonstration of initial proficiency in analytical methods and training to SOPs conducted by a trainer who has been documented as qualified and proficient in the process for which training is being provided.

Demonstration of continued analyst proficiency is updated annually, usually during the first quarter of each year. Proficiency is demonstrated by acceptable LCS data, which is readily available for query and review through the ALPHALIMS system.

Company-wide, onsite training.

Courses or workshops on specific equipment and analytical techniques.

University courses.

Professional and trade association conferences, seminars, and courses.

Documentation of employee training is the joint responsibility of the employee and the applicable Group Leader. If an SOP is revised during the course of the year, training to the revised SOP must be documented.

2.12 Ethics and Data Integrity

As our corporate vision statement explains, "We are a company that values: Excellence as a way of life, Quality Service, A Can-Do attitude, and a fundamental commitment to Ethical Standards." Employees attend Ethics education programs that focus on the high standards of data integrity and ethical behavior mandated by our company and expected by our clients. All employees sign an Ethics and Data Integrity Agreement that reflects their commitment to always perform their duties with these high standards. (See Appendix G.)

SECTION 3
QUALITY SYSTEMS

Section 3 - Quality Systems

Our Quality Systems include all quality assurance (QA) policies and quality control procedures (QC) necessary to plan, implement, and assess the work we perform. GEL's QA Program establishes a quality management system (QMS) that governs all of the activities of our organization.

GEL's quality management system is designed to conform to the requirements specified in the standards referenced in Appendix A. Essential elements of our quality management system are described in this section.

3.1 Quality Systems Team

The quality systems team is responsible for managing GEL's QA Program. This team functions independently of the systems it monitors and is comprised of the Quality Systems Director, Lead Auditor, QA Officers and/or Specialists.

Following is a summary of the responsibilities of each position.

3.1.1 Quality Systems Director

Reports to the CEO
Serves as management's representative for quality
Responsible for the implementation and maintenance of the QMS
Supervises the Quality Systems Team and their functions
Initiates and recommends preventive action and solutions to quality problems
Implements appropriate action to control quality problems until solutions are implemented and verified to be effective
Verifies that effective solutions are implemented
Demonstrates knowledge of the Quality System as defined by NELAC and EMCAP

3.1.2 Quality Systems Lead Auditor

Reports to the Quality Systems Director
Demonstrates knowledge of the Quality System defined under NELAC, EMCAP and other quality standards such as ISO 9001:2000.
Plans, schedules and participates in GEL's client audits, internal audits and subcontractor audits
Conducts conformance audits as necessary to verify implementation and closure of audit action items
Serves as liaison to client and third party auditors
Coordinates laboratory responses to audit reports and prepares final response
Monitors progress of corrective actions
Prepares and monitors progress of internal and subcontractor audit reports
Manages Laboratory Certification and Document Control processes

3.1.3 Quality Assurance Officers

Report to the Quality Systems Director
Demonstrate the ability to evaluate data objectively without outside influence
Have documented training and/or experience in QA/QC procedures and knowledge of the Quality system as defined under NELAC
Have knowledge of analytical methods
Assist in the conduct of internal and supplier audits
Administer corrective actions and nonconformances
Monitor and respond to client -identified nonconformances and technical inquiries
Implement and maintain statistical process control (SPC) system
Ensure the monitoring of balances, weights, and temperature regulation of ovens, waterbaths, and refrigerators
Coordinate the monitoring of DI water system and volatile coolers
Write or review Quality documents and standard operating procedures under the direction of the QS Director
Provide training in quality systems and good laboratory practices.
Coordinate the receipt and disposition of external and internal performance evaluation samples.

NOTE: Once PE samples have been prepared in accordance with the instructions provided by the PE vendor, they are managed and analyzed in the same manner as environmental samples from clients. The analytical and reporting processes for PE samples are not specially handled.

3.1.4 Quality Systems Specialists

Report to the Quality Systems Director or Lead Auditor

Assist the team as directed with respect to Records Management, Document Control, Laboratory Certification, temperature and weight calibrations, logbook review, training documentation and nonconformances, etc.

3.2 Quality Documents

Our Quality Systems policies and procedures are documented in the QAP (GL-QS-B-001) and other supporting documents. GEL's management approves all company quality documents. Pre-approval is secured for any departures from such documents that may affect quality.

GEL's Quality documents include a QA Plan, QA project and program plans, and standard operating procedures. The QAP describes the quality standards that we apply to our laboratory operations. These policies are expected to be implemented and understood throughout the company.

We use Quality Assurance Program or Project Plans to specify individual project or program criteria and criteria. These individual plans should be understood and implemented throughout the laboratory fractions to which they apply.

Finally, our Standard Operating Procedures (SOPs) are used to describe in detail those activities that affect quality. SOPs are prepared, authorized, changed and released in accordance with GL-ADM-E-001. SOPs are accessible electronically via GEL's Intranet.

3.3 Document Control

The control of quality documents is critical to the effective implementation of our Quality Program. We define and control this process in accordance with GL-DC-E-001 for Document Control. Responsibilities for document control are divided between the Group Leaders and the Document Control Officer (DCO).

Group Leaders are responsible for:

Supporting the development and maintenance of controlled documents that apply to their respective departments

Reviewing all quality documents annually for continued validity

Ensuring documentation that the affected employees are aware of revisions to documents or manuals.

The DCO is responsible for:

Managing the system for the preparation, authorization, change and release of the Quality Manual, QAP, project plans and standard operating procedures

Ensuring that current controlled documents are accessible via GEL's Intranet.

Managing a system to document current revision numbers and revision dates for all distributed documents and manuals

Managing a system to identify the nature of document revisions.

Maintaining hard or electronic copies of obsolete documents

Maintaining electronic or hard copy originals of all controlled documents

Revisions to controlled quality documents are made by replacing individual sections or the entire document, as determined by the DCO.

3.4 Controlled Document Review

Internally generated controlled documents undergo a multi-level review and approval process before they are issued. These levels include a procedural review, technical and/ or quality review and the final authorization of the appropriate manager or director. To ensure that new or revised standard operating procedures are not implemented prematurely, SOPs are effective upon the date of the final approval signature.

3.5 Quality Records

Quality records provide evidence that specified quality requirements have been met and documented. We generate them in accordance with applicable procedures, programs and contracts. Quality records include but are not limited to:

Observations
Calculations
Calibration data
Certificates of analysis
Certification records
Chains of custody
Audit records
Run logs, instrument data and analytical logbooks
Instrument, equipment and building maintenance logs
Material requisition forms
Monitoring logs
Nonconformance reports and corrective actions

Method development and start-up procedures including method detection limit studies
Technical training records
Waste management records
Standard logs
Software validation documentation
Standard Operating Procedures (SOPs)
Sample collection and field data

Our Quality Records are:

Documented in a legible manner
Indexed and filed in a manner conducive to ready retrieval
Stored in a manner that protects them from loss, damage, and unauthorized alterations
Accessible to the client for whom the record was generated
Retained and disposed in the identified time period

The generation, validation, indexing, storage, retrieval, and disposition of our quality records are detailed in GL-QS-E-008 for Quality Record Management and Disposition. The Quality Records of subcontracted services are also required to meet the conditions established in this SOP.

3.6 Internal and Supplier Quality Audits

We conduct internal audits annually to verify that our operations comply with the requirements of our QA program and those of our clients. We perform supplier audits as necessary to ensure that they too meet the requirements of these programs. Both internal and supplier audits are conducted in accordance with GL-QS-E-001 for the Conduct of Quality Audits.

3.6.1 Audit Frequency

Internal audits are conducted at least annually in accordance with a schedule approved by the Quality Systems Director. Supplier audits are contingent upon the categorization of the supplier, and may or may not be conducted prior to the use of a supplier or subcontractor (see GL-QS-E-001). Type I suppliers and subcontractors, regardless of how they were initially qualified, are re-evaluated at least once every three years.

Additional internal and supplier audits may be scheduled if deemed necessary.

3.6.2 Audit Team Responsibilities

Internal and supplier audits are conducted by qualified staff under the direction of the Lead Auditor or Quality Systems Director. A qualified audit team member shall have the technical expertise to examine the assigned activities.

We do not allow staff to audit activities for which they are responsible or in which they are directly involved. It is the responsibility of the Lead Auditor to ensure that such conflicts of interest are avoided when the audit team is assembled.

The Leadership Team has a significant role in the internal audit process, including:

Provision of audit personnel
Empowerment of the audit team with authority to make the audit effective
Development and implementation of timely corrective action plans

3.6.3 Identification and verification of OFIs

Opportunities for Improvement are identified conditions that adversely affect the quality of products or services. Several examples of objective evidence are used to support an OFI, which might be classified as a finding, concern, observation, and/or recommendation.

The Lead Auditor may initiate a Nonconformance (NCR) or Corrective Action Request and Report (CARR) referencing the OFI. The NCR or CARR is then entered into the NCR system per GL-QS-E-012 for NCR Database Operation.

Implementation of a corrective action is later verified by a re-audit of the deficient area, review of new or revised documents, or, if the OFI does not warrant immediate action, the corrective action may be verified during the next scheduled audit.

3.7 Managerial and Audit Review

Our Leadership Team reviews the audit process at least yearly. This ensures the effectiveness of the corrective action plan and provides the opportunity to introduce changes and improvements.

We document all review findings and corrective actions. Implementation plans and schedules are monitored by the QS Team.

3.8 Nonconformances

Processes, materials, and services that do not meet specifications or requirements are defined as nonconforming. Such non-conformances can include items developed in-house or purchased from vendors, samples received from clients, work in progress, and client reports.

At GEL, we have a nonconformance reporting system (NCR) that helps us prevent the entry of defective goods and services into our processes and the release of non-conforming goods and services to our clients. Our NCR system provides a means for documenting the disposition of nonconforming items and for communicating these to the persons involved in the process affected by the adverse condition(s).

Nonconformances are documented according to GL-QS-E-004 for the Documentation of Nonconformance Reporting and Disposition and Control of Nonconforming Items. We regularly review SOPs, client complaints, and quality records, including completed NCRs, to promptly identify conditions that might result in situations or services that do not conform to specified quality requirements.

Our Quality Assurance Officers process, categorize and trend nonconformances. Trending information is provided to the Leadership Team and Group Leaders of the affected areas.

3.9 Corrective Action

There are two categories of corrective action at GEL. One is corrective action implemented at the analytical and data review level in accordance with the analytical SOP. The other is formal corrective action documented by the Quality Systems Team in accordance with GL-QS-E-002. Formal corrective action is initiated when a nonconformance reoccurs or is so significant that permanent elimination of the problem is required.

We include quality requirements in most analytical SOPs to ensure that data is reported only if the quality control criteria is met or the quality control measures that did not meet the acceptance criteria are documented.

Formal corrective action is implemented according to GL-QS-E-002 for Conducting Corrective Action and documented according to GL-QS-E-012 for NCR Database Operations.

Any employee at GEL can identify and report a nonconformance and request that corrective action be taken. Any GEL employee can participate on a corrective action team as requested by the QS team or Group Leaders. The steps for conducting corrective action are detailed in GL-QS-E-002.

3.10 Performance Audits

In addition to internal and client audits, our laboratory participates in annual performance evaluation studies conducted by independent providers. We routinely participate in the following types of performance audits:

Proficiency testing and other inter-laboratory comparisons.

Performance requirements necessary to retain certifications (Appendix D).

Evaluation of recoveries of certified reference and in-house secondary reference materials using statistical process control data.

Evaluation of relative percent difference between measurements through SPC data.

We also participate in a number of proficiency testing programs for federal and state agencies and as required by contracts. It is our policy that no proficiency evaluation samples be analyzed in any special manner.

Our annual performance evaluation participation generally includes a combination of studies that support the following:

US Environmental Protection Agency Discharge Monitoring Report, Quality Assurance Program (DMR-QA). Annual national program sponsored by EPA for laboratories engaged in the analysis of samples associated with the NPDES monitoring program. Participation is mandatory for all holders of NPDES permits. The permit holder must analyze for all of the parameters listed on the discharge permit. Parameters include general chemistry, metals, BOD/COD, oil and grease, ammonia, nitrates, etc.

Department of Energy Mixed Analyte Performance Evaluation Program (MAPEP). A semiannual program developed by DOE in support of DOE contractors performing waste analyses. Participation is required for all laboratories that perform environmental analytical measurements in support of environmental management activities.

Environmental Measurements Laboratory (EML). Semiannual DOE radionuclide program for analysis of low-level radionuclides in environmental samples. Participation is required for DOE contractor per DOE order 5400.1, Chapter IV, Part 10C. Participation is also required for laboratories performing work in support of DOE/Environmental Management (EM). Matrices evaluated are from actual materials obtained from the environment at DOE facilities.

The PAT program is utilized for metals and organics in air monitoring. It is a quarterly industrial hygiene laboratory proficiency program administered by AIHA for the analysis of metals, organics and asbestos. Successful participation is mandatory in order to obtain and maintain AIHA accreditation.

ERA's InterLab RadCheM Proficiency Testing Program for radiological analyses. This program completes the process of replacing the USEPA EMSL-LV Nuclear Radiation Assessment Division program discontinued in 1998. Laboratories seeking certification for radionuclide analysis in drinking water also use the study. This program is conducted in strict compliance with the USEPA National Standards for Water Proficiency Testing Studies.

Water Pollution (WP). Biannual program for waste methodologies. Parameters include both organic and inorganic analytes.

Water Supply (WS): Biannual program for drinking water methodologies. Both organic and inorganic parameters are included.

At GEL, we also evaluate our analytical performance on a regular basis through statistical process control acceptance criteria. Where feasible, this criteria is applied to both measures of precision and accuracy and is specific to sample matrix.

We establish environmental process control limits at least annually. In Radiochemistry, quality control evaluation is based on static limits rather than those that are statistically derived. Our current process control limits are listed in Appendix E.

We also measure precision through the use of matrix duplicates and/or matrix spike duplicates. The upper and lower control limits (UCL and LCL respectively) for precision are plus or minus three times the standard deviation from the mean of a series of relative percent differences. The static precision criteria for radiochemical analyses is 0 - 20% for activity levels exceeding the contract reporting detection limit (CRDL).

Accuracy is measured through laboratory control samples and/or matrix spikes, as well as surrogates and internal standards. The UCLs and LCLs for accuracy are plus or minus three times the standard derivation from the mean of a series of recoveries. The static limit for radiochemical analyses is 75 - 125%. Specific Instructions for out-of control situations are provided in the applicable analytical SOP.

3.11 Essential Quality Control Measures

Some quality control measures are method-specific. There are, however, general quality control measures that are essential to our quality system. These quality measures are described in Appendix F and include:

Monitoring of negative and positive controls

Defining variability and reproducibility through duplicates

Ensuring the accuracy of test data including calibration and/or continuing calibrations, use of certified reference materials, proficiency test samples, etc.

Evaluating test performance using method detection limits and quantitation limits or range of applicability such as linearity

Selecting the appropriate method of data reduction

SECTION 4
FACILITIES

Section 4 - Facilities

Our laboratory is designed with a full-service approach to handling environmental needs. The layout provides dedicated space for radiochemical analyses, bioassay analysis, organic extractions, semi-volatile organic analyses, volatile organic analyses, metals analyses, general chemistry analyses, and air analyses.

The laboratory and support offices occupy approximately 85,000 square feet engineered to meet the stringent quality control and utility requirements of the modern environmental laboratory. Records are temporarily stored on-site then warehoused in a climate-controlled building off-site. The diagram in Appendix I depicts the layout of the laboratories.

Discussed in this section are:

Facility security
Utility services and deionized water
Prevention of contamination
Assessment of contamination

4. Facility Security

Our facility features secured laboratory and storage areas. Restricted entry assures sample integrity and client confidentiality, which satisfies clients and potential national security interests.

Visitors cannot gain entry without being escorted through the laboratory by authorized personnel. A designated sample custodian and a bar-coded chain-of-custody provide a second level of security.

4.2 Utility Services

Each defined laboratory area is equipped with the following utilities:

Cold Water
Hot Water
Deionized Water
Compressed Air
Natural Gas
Vacuum
110 Volt AC
208 Volt AC (at selected stations)
Specialty gases (as required)

4.2.1 Deionized Water

We have two independent deionized water (DI) systems. One serves radiochemistry while the other serves the remaining laboratories. DI water is made from city water flowing through a deionization system capable of producing 5 gallons per minute of Type II laboratory water. Tables 1 and 2 list the minimum requirements for Type I and Type II DI water.

Table 1: ASTM Type I DI Water

Quality Parameter	Limits
Bacteria, CFU/mL	<10
pH	not specified
Resistivity, min. MΩ-cm at 25C	>16.67
Conductivity, max. μmho/cm at 25C	≤0.06
Trace Metals, Single (Cd,Cr,Cu,Ni,Pb, Zn)	< 0.05 mg/L
Trace Metals, Total	< 0.1 mg/L
Free Chlorine	not specified
Ammonia/Organic Nitrogen	not specified
TOC	not specified
Organic Contaminants	Activated carbon

Table 2: ASTM Type II DI Water

Quality Parameter	Limits
Bacteria, CFU/mL	< 1000
pH	not specified
Resistivity, min. MΩ-cm at 25C	> 1.0
Conductivity, max. μmho/cm at 25C	≤1.0
Trace Metals, Single (Cd,Cr,Cu,Ni,Pb, Zn)	< 0.1 mg/L
Trace Metals, Total	not specified
Free Chlorine	< 0.1 mg/L
Ammonia/Organic Nitrogen	< 0.1 mg/L
TOC	< 1.0 mg/L
Organic Contaminants	not specified

We monitor compliance with the above limits according to GL-LB-E-016 for Collection and Monitoring the DI Water Systems. Our monitoring activities and frequencies can be found in Table 1 of the SOP.

4.3 Prevention of Contamination

Work areas that are free of sample contaminants, constituents and measurement interferences are important to the generation of quality data. With this in mind, we designed our laboratories to prevent contamination and reinforce this design with good laboratory practices.

In addition to keeping our work areas free of dust and dirt accumulations, policies and features that prevent or minimize contamination include:

An air conditioning system that controls the environment of individual laboratories for optimum performance of sensitive instruments and to eliminate potential cross contamination

Segregation of volatile and semi-volatile laboratories to minimize potential contamination associated with the use of commonly required solvents

Negative and positive pressure air locks to isolate selected laboratories to prevent the entry of airborne contaminants

Fume hoods to remove fumes and reduce the risk of aerosol and airborne contaminants and personnel safety hazards are monitored in accordance with GL-FC-E-003 for Fume Hood Face Velocity Performance Checks.

Restricted access to the volatiles laboratory (authorized personnel only)

Designated area for glassware preparation wherein all glassware used in sample prep and analysis is cleaned according to GL-LB-E-003 for Glassware Preparation

Segregated storage areas for volatiles and radioactive samples

Production, use and monitoring of Type I and Type II DI water

4.4 Assessment of Contamination Levels

We evaluate contamination resulting from the following sources on the basis of quality assurance and quality control data derived from the analytical method and method blanks.

Sample containers
Reagent water
Reagents and solvents
Sample storage
Chemical and physical interference
Constituent carryover during analysis

Contamination in each of the volatile storage coolers is monitored by the weekly analysis of water blanks. Four DI water blanks are placed in the cooler at the beginning of each month with one being analyzed each week. If the concentration of any target analyte exceeds the PQL, corrective action is implemented to eliminate the source of contamination, evaluate the effect of samples stored in the cooler, and to notify clients.

SECTION 5
EQUIPMENT and REFERENCE MATERIALS

Section 5 - Equipment and Reference Materials

GEL's ability to efficiently generate data that is reproducible, accurate, and legally defensible is attributable to our use of high-quality instruments, equipment, and reference materials.

Provided in this section are:

GEL's policies governing instruments, equipment, and reference materials
Identification of instrumentation and support equipment
Procurement protocol

5.1 General Policies

It is our policy to purchase instrumentation, equipment and high-quality reference materials that meet or exceed the method and regulatory requirements for the analyses for which we are accredited. If we need to use instruments or equipment not under our permanent control, we ensure that it also meets these standards.

Instrumentation and equipment is placed into service on the basis of its ability to meet method or regulatory specified operating conditions such as range and accuracy. All laboratory instrumentation and testing equipment is maintained in accordance with standard operating procedures (SOPs).

Instrumentation and equipment is used in a manner that assures, where possible, that measurement uncertainty is known and consistent with specified quality requirements. Instruments and equipment are taken out of service and segregated or labeled as such under the following conditions:

Mishandling and/or overloading
Results produced are suspect
Demonstrated defect or malfunction

Tagged or segregated instruments and equipment remain out of service until repaired and shown by test, calibration, or verification to perform satisfactorily. Instruments that are in service and normally calibrated prior to and during use are not tagged.

Each item of equipment, including reference materials is, if appropriate, labeled, marked or otherwise identified to indicate its calibration status. We maintain records for each major item of equipment, instrumentation, and all reference materials significant to quality performance. These records are often in the form of maintenance logs, which are kept in accordance with GL-LB-E-008 for Basic Requirements for the Use and Maintenance of Laboratory Notebooks, Logbooks, Forms, and Other record Keeping Devices.

Documentation included in these records includes but is not limited to:

Equipment name
Manufacturer's name
Type identification
Serial number or other unique identification
Date received and date placed in service (if available)
Current location
Condition when received (if known)
Manufacturer's instruction, where available
Dates and results of calibrations and or verifications
Date of next calibration and/or verification, where written procedures do not specify frequency
Details of maintenance carried out to date and planned for the future
History of any damage, malfunction, modification or repair

5.2 Instrumentation and Support Equipment

Appendix H lists the instruments we use for the analysis of environmental, radiochemical and bioassay samples. Where feasible, our instruments are equipped with autosamplers that improve efficiency and facilitate consistent sample introduction to the sample detector. They are also connected to an area network to facilitate data transfer.

Devices that may not be the actual test instrument but are necessary to support laboratory operations are referred to as support equipment. We also maintain this equipment in proper working order. Support equipment utilized at GEL includes:

balances
ovens
refrigerators
freezers
incubators
water baths
temperature measuring devices
volumetric dispensing devices
muffle furnaces
distillation apparatus
grinders and homogenizers
hot plates and heating mantles
ultraviolet sterilizers.

Guidelines for the required calibration and evaluation of this equipment are discussed in Section 7.

We perform radiochemical and bioassay analytical services in accordance with the instrumentation and reference methods approved by the Department of Energy (DOE), the Environmental Measurements Lab (EML), the Environmental Protection Agency (EPA), ASTM, and Los Alamos Health and Environmental Chemistry (LAHEC). Modifications to these methods may be appropriate as a result of Performance Based Measurement Systems (PBMS).

SOPs are used to describe our procedures for all routine analyses performed by our labs. These procedures include step-by-step instructions for sample collection, storage, preparation, analysis, instrument calibration, quality control, disposal, and data reporting.

5.3 Procurement and Control of Purchased Items

Materials and services that affect the quality of our products are designated as Quality Materials and Services and are only purchased from approved suppliers. We approve and document suppliers according to GL-QS-E-001 for the Conduct of Quality Audits.

At GEL, we maintain documentation of specific quality requirements for Quality Materials and Services. Records that document the quality of a product or service may include:

- certificates of analysis and traceability
- verifications of chemical quality
- inspections of equipment or materials
- verifications or inspections of vendor product specifications

Our procedure for requisitioning supplies, instruments, equipment and other common use material is described in GL-RC-E-002 for Material Requisition. These requests typically include:

- The date and name of person(s) requesting materials
- Account, department, project number to which the material is to be billed
- Recommended supplier or vendor
- Additional information necessary to expedite the purchase request
- Specifications that could affect the quality of products and services
- Vendor's material part number
- Amount of material needed
- Description of material
- Cost per unit
- Person(s) authorizing the purchase
- Time frame in which the material is needed

The equipment, instruments and reference materials we purchase are inspected upon receipt in accordance with GL-RC-E-001 for the Receipt and Inspection of Material and Services. This inspection is to verify that procured items meet the acceptance criteria defined in the procurement documentation. Staff performing initial inspection routinely:

- Open and inspect all items for damage
- Compare the items with the issued purchase order or contract for catalog or part number, description or procurement specification, quality requirement, and acceptance criteria
- Label items with a limited shelf life with the date received
- Determine if the items conform to the specifications agreed to by the vendor.

The individual responsible for the technical acceptance of the item provides procurement and receiving staff with the proper acceptance documentation. Items found not to conform to quality standards are returned to the supplier, identified as nonconforming or disposed according to the established procedures in GL-QS-E-004 for Documentation of Nonconformance Reporting and Dispositioning, and Control of Nonconforming Items.

SECTION 6
HEALTH and SAFETY

Section 6 - Health and Safety

GEL maintains a safe work environment and promotes healthy work practices. Our corporate Safety, Health and Chemical Hygiene Plan was developed by a resident certified industrial hygienist. Procedures outlined in the plan are consistent with Occupational Safety and Health Administration, CERCLA, the Environmental Protection Agency, and SCDHEC.

All employees are trained in the safety practices applicable to their job functions. This training is conducted in accordance with GL-HR-E-002 for Employee Training.

Discussed in the section are:

Fire safety and safety equipment
Safety equipment and procedures related to handling radioactive samples

6.1 Fire Safety

Our facility is equipped with a fire alarm system designed to detect smoke in all areas of the facility. Certain high-risk areas, such as, the cold and ambient storage areas, organic sample preparation lab, hazardous waste lab, and solvent storage are additionally equipped with automatic halon systems. Fire blankets and dry chemical extinguishers are located at strategic points throughout the lab. We routinely inspect these extinguishers in accordance with GL-FC-E-004. Lab personnel are trained in the proper use and selection of fire extinguishers.

In order to decrease the risk of fire, bulk solvents are stored in a halon protected storage room.

6.2 Evacuation

In the unlikely event of a fire (or other emergency), we have defined evacuation routes depicted in Appendix I. This diagram is posted in pertinent areas of the facility and designated staff serve as evacuation leaders for the work groups.

6.3 Safety Equipment

Safety equipment, including safety glassed, lab coats, safety goggles, protective gloves, hard hats, and coveralls, is available to all employees as needed. We also provide respirators when needed to those who have completed training in the use of this specialized equipment.

Eyewashes and overhead showers are located throughout the laboratory. We routinely inspect these as directed in GL-FC-E-002 for Testing of Emergency Eyewash and Shower Equipment.

6.4 Radiation Safety

Since GEL specializes in the handling of radioactive material, we have health physics procedures to ensure its safe handling. While lab personnel do not encounter significant levels of radiation requiring personnel monitoring, a Dosimetry Program is in effect utilizing personal dosimeters for designated personnel. These dosimeters are exchanged quarterly and records of exposure are maintained. Instructions for the proper use of dosimeters are addressed in GL-RAD-S-009 for Dosimetry Procedures.

We take special precautions to ensure that samples are safely processed. Upon receipt, trained personnel use a survey meter to screen all samples for the presence of radioactivity. Protocols for the receipt of radioactive samples and for surveying suspected or known radioactive samples are detailed in GL-RAD-S-007 for Receiving Radioactive Samples and GL-RAD-S-001 for Radiation Survey Procedures. This process is described in Section 9.

Upon leaving a radiologically controlled area, personnel check their hands and feet for potential contamination. This is done utilizing detection instrumentation that employs Geiger-Mueller or scintillation technologies. In addition, stations with portable detection instruments are set up for personnel frisking and in-process contamination surveys.

Key areas throughout the facility are surveyed:

Laboratory analytical areas (Monthly smears)
Radioactive Sample Storage Areas (Monthly smears and exposure rate)
Sample Receipt and Waste Handling Areas (Monthly smears and exposure rate)
Unrestricted and Radioactive Material Prohibited Areas (Quarterly smears)

SECTION 7
MEASUREMENT, TRACEABILITY, AND CALIBRATION

Section 7 - Traceability and Calibration

Traceability of measurements and the calibration of testing equipment are imperative to our ability to produce accurate and legally defensible data. As such, we have implemented procedures to ensure that equipment calibration and measurement verification are traceable to nationally recognized standards.

Where possible, calibration certificates provide traceability to national standards of measurement. Calibration certificates provide measurement results and any associated uncertainty of measurement, and/or a statement of compliance with the identified specification. Calibration certifications are maintained as quality records.

When traceability to a national standard is not applicable, verification of measurement is achieved through in inter-laboratory comparisons, proficiency tests, or independent analyses.

The following measurement and traceability practices are described in this section:

Calibration criteria for support equipment
General requirements
Balances
Temperature sensitive devices and temperature monitoring
Air displacement pipets
Calibration criteria for instruments
Calibration verification
Initial calibration verification
Continuing calibration verification

7.1 Calibration Criteria for Support Equipment

This section addresses calibration protocols for support equipment, including balances, temperature - sensitive equipment, and air displacement pipets. The general criteria applicable to the calibration of support equipment is as follows:

Equipment is maintained in proper working order. Records of all maintenance activities including service calls are kept.

Calibrations or verifications over the entire range of use, using NIST traceable references when available, are conducted annually.

If results of calibration and verification are not within the specifications for the equipment's application, then:

1. The equipment is removed from service until repaired
2. Under certain conditions, a deviation curve may be prepared. All measurements are corrected for the deviation, recorded and maintained.

Prior to use each day, balances, ovens, freezers, refrigerators, incubators and water baths are checked with NIST traceable references (where possible) in the expected use range.

If prescribed by the test method, additional monitoring is performed for a device used in a critical test (such as an incubator or water bath).

Support equipment is used only if the reference standard specifications (provided by the supplier or described in the analytical method) are met.

Reference standards of measurement such as Class S or equivalent weights or traceable thermometers may be used for calibration when demonstrated that their performance as reference standards will not be invalidated.

Reference standards of measurement are calibrated by a body that can provide, where possible, traceability to a national standard.

Reference standards and measuring and testing equipment are, where relevant, subject to in-service checks between calibrations and verifications.

Reference materials, where possible, are traceable to national or international standards of measurement, or to national or international standard reference materials.

Mechanical volumetric dispensing devices, except Class A glassware, are checked monthly for accuracy.

7.1.1 Balances

Our balances are under a service contract for annual calibration, maintenance and cleaning. Each balance is labeled with a serial number, service date, date of next service, and signature of the service technician.

Balances are setup, calibrated, and operated in the range required by the analytical method in accordance with GL-LB-E-002 for Balances. Prior to using a balance, the analyst is responsible for checking its calibration.

Calibration and calibration verification are performed using weights that are or have been calibrated against

Class S or equivalent weights. These weights are traceable to NIST and calibrated annually by the South Carolina Department of Agriculture (or other independent agency).

Calibration and calibration verification is recorded in the balance calibration logbook If the calibration or calibration verification does not meet the specified acceptance criteria, the balance is recalibrated. If the calibration criteria is still not met, the balance is removed from service and tagged as such.

7.1.2 Refrigerators, Freezers, Incubators, Ovens, Water Baths and Similar Devices

Careful control of temperature is often central to the production of acceptable data. Temperature excursions beyond the established limits may invalidate a procedure and the associated data. Constant monitoring in accordance with GL-LB-004 for Temperature Monitoring assures us that regulatory and/or method temperature requirements are being met.

We measure temperatures with thermometers that are calibrated annually against a NIST traceable thermometer. The NIST traceable thermometers are independently calibrated at least once per year. The protocol for thermometer calibration is described in GL-QS-E-007. We monitor the temperature of the following equipment according to GL-LB-004:

Refrigerators and freezers used to store samples, standards, and other temperature sensitive materials
Incubators
Ovens
Water Baths
Autoclaves

We monitor the temperatures of refrigerators and freezers prior to use on each working day. The temperatures of ovens, water baths, and other devices used as part of an analytical process must be monitored prior to, during, and immediately after use. Incubators and other devices used for microbiological or other specialized analytical methods may require more frequent monitoring as specified in the corresponding SOP.

Temperature measurements are documented on logs specific to each piece of equipment. The logs are posted on or near each refrigerator, freezer, waterbath, oven or other temperature control device. Each log includes the following information:

Date and time of each measurement
Initials of person taking measurement
Acceptance limits for device being monitored
Whether device conforms with specifications at time of measurement
Name, location and number of device being monitored
Name and telephone number of person to contact in event of device failure
Notation of any out of control condition

The sterilization pressure of each autoclave run must be documented in addition to the sterilization temperature. When the process to maintain and document temperatures within acceptance limits does not conform to specifications, a nonconformance report (NCR) is issued. Appropriate action is then taken to disposition the nonconformance according to GL-QS-E-004 for Nonconformance Identification, Control, Documentation, Reporting, and Dispositioning.

Examples of nonconformances are:

Failure to maintain process temperature within acceptance limits
Failure of device to achieve calibration
Total failure of temperature control device
Failure to monitor the temperature as required

7.1.3 Air Displacement Pipets

Air displacement pipets offer a level of precision and accuracy exceeded only by Class A transfer pipets. Due to disposable tips, these pipets eliminate the possibility of cross-contamination.

We calibrate air displacement pipets monthly using five replicate measurements of a frequently used volume setting in accordance with GL-LB-E-010 for Maintenance and Use of Air Displacement Pipets. As specified in the SOP, the calibration of an air displacement pipet is verified daily prior to use, based on a single point measurement.

The acceptance criteria for each measurement is based on the standard deviation of the five calibration measurements. Tolerance limits for commonly used verification volumes and accuracy and precision checks are included in the pipet calibration logbook. Calibrations and daily calibration verifications are traceable to each pipet using the unique identification found on its label.

If a pipet does not meet the calibration tolerance limits, its is removed from service until it again demonstrates compliance after being cleaned and/or repaired. Analysts whose jobs may require the use of air displacement pipets are trained in their proper use and calibration.

7.2 Instrument Calibrations

To ensure that the data generated by an instrument is accurate, we calibrate the instrument using standards containing known concentrations of target analytes. We verify the accuracy of calibration standards by analyzing an additional standard containing the target analytes. This initial calibration verification standard (ICV) originates from a second source. The stability of the instrument over the calibration range is verified by the analysis of a continuing calibration verification standard (CCV).

Traceability of calibration, calibration verification, and other quality control standards to the recognized standard is documented per GL-LB-E-007 for Laboratory Standards Documentation. Individual identification numbers are assigned to each source standard and each subsequent intermediate and working standard prepared.

The identification number makes it possible to trace a standard to a parent standard and ultimately to the source standard. The date each standard is prepared, the recipe used in the preparation, the person preparing the standard, and the standard's expiration date are documented in the appropriate standards log. The information is accessible via the standard ID number.

We record the ID numbers on instrument run logs, analytical logbooks, sample preparation logs, and instrument raw data. Calibration standards that are used in the analysis of a particular sample or group of samples can be traced to NIST, US EPA, or other nationally recognized standard.

Calibration procedures for specific instruments, and the frequencies of performance for defined methods, are described in the applicable operating or analytical SOP. General guidelines include:

Verification of initial calibrations with a standard obtained from a second source (unless one is not available).

Analysis of verification standards (ICV and CCV) with each initial calibration within 15% of the true value unless historical data has demonstrated that wider limits are applicable.

Preparation of calibration curves as specified in the reference method.

If a test method does not address the preparation of a calibration curve, the appropriate number of standards to use in the initial calibration is based on the percent relative standard deviation (%RSD.)

The %RSD is determined from either seven replicate measurements of a standard whose concentration is close to the lowest anticipated calibration standard or a calibration linearity test. The linearity test, such as response or calibration facts, is based on at least three standards having concentrations that cover the expected calibration range.

The minimum number of standards we use in initial calibration depends on the resulting %RSD. Table 1 shows the number of calibration standards used in conjunction with a blank. If the resulting curve is nonlinear, we use additional standards. If the %RSD is less than 2, we use at least three calibration standards.

Table 1: % RSD and Calibration Standards

%RSD	Number of Calibration Standards
2 - < 10	3
10 - < 25	5
> 25	7

Calibration curves are subject to a calibration linearity test, such as a linear regression or %RSD of response factors (internal standard calibration) or calibration factors (external standard calibration). Additional requirements depend upon the analytical method.

If a linear regression is used, the correlation coefficient is no less than 0.99.

If, over the calibration range, the RSD or response factor is less than 15%, or the RSD of calibration factor is less than 30%, linearity through the origin can be assumed. In these cases, an average relative response factor may be used. If these conditions are not met, the complete calibration curve should be used.

For results to be reported as quantitative, they must be bracketed by calibration or calibration verification standards. Results that do not meet this condition are reported as having a lower confidence level.

7.3 Calibration Verification

Unless otherwise specified by the method or demonstrated through historical data, the recovery of target analyte(s) in calibration verification standards shall be between 85 - 115%. We discuss additional requirements below.

7.3.1 Initial Calibration Verification (ICV)

If an initial calibration curve is not established on the day of analysis, the integrity of the curve should be verified each day of use or every 24-hour period. Verification requires the initial analysis of a blank and standard from a second source. The standard concentration should be at the method-defined level. If not specified, a standard at a mid-level concentration may be used.

If the initial calibration verification does not meet acceptance criteria, the analytical procedure is stopped and evaluated, and appropriate corrective measures are taken. Initial calibration verification must be acceptable before any samples are analyzed.

7.3.2 Continuing Calibration Verification

Additional standards called CCVs are analyzed after the initial calibration curve or the integrity of the initial calibration curve is accepted. CCVs are analyzed at a frequency of 5% or every 12 hours, whichever is more frequent. If instrument consistently drifts outside acceptance criteria before the next calibration, the frequency is increased.

CCVs may be from the same source as the calibration standards or a second source. The concentration is determined by the anticipated or known concentration of the samples and/or method-specified levels. At least one CCV shall be at a low-level concentration.

To the extent possible, we bracket the samples in each interval (every 20 samples or every 12 hours) with CCV concentrations closely representing the lower and upper range of reported sample concentrations. If this is not possible, the standard calibration checks should vary in concentration throughout the range of the data being acquired.

If the recovery of a CCV does not meet the acceptance criteria and routine corrective actions fail to produce a second consecutive check within acceptance criteria, a new initial calibration curve should be constructed. Analytes of interest found in corresponding environmental samples may be reported, however, if all of these criteria are met:

1. CCV recovery for target analyte exceeds the acceptance criteria (biased high)
2. Target analyte in the environmental sample is not detected at a concentration exceeding the level required by client contract (i.e., MDL, PQL).

Non-detects that meet this criteria are also referred to as "passable non-detects."

If samples are found to contain target analytes that exceed the associated quantitation limits and the CCV recovery does not meet the acceptance criteria, the affected samples are analyzed. This occurs only after a new calibration curve has been established, evaluated and accepted.

7.4 Bioassay Instrument Calibration and Frequency

Our Bioassay instruments are calibrated at the frequency of the instrument's use, stability, and method requirements. The calibration procedure for each instrument is described in the corresponding analytical SOP. A summary, however, is presented below. Client specified calibration frequencies are used when more stringent than our own requirements.

Gamma Spectrometer: daily source check; weekly background check; and annual calibration.

Alpha Spectrometer: daily pulser check; monthly background check; and monthly calibration.

Ra-226 Lucas Cells: daily source and background checks before use; annual calibration.

LSC: daily source and background checks before use; and calibration every 6 months.

Kinetic Phosphorimeter: daily source and background checks, high and low range, before use; and daily calibration, before use.

GFPC: daily source and weekly background checks, and annual calibration.

SECTION 8
ANALYTICAL METHODS AND STANDARD OPERATING PROCEDURES

Section 8 - Analytical Methods and Standard Operating Procedures (SOPs)

We provide a wide array of parameters including volatile organics, extractable organics, metals, general inorganic/wet chemistry, radiochemistry, radiobioassay and limited microbiology. The procedures we use to determine these parameters are consistently executed due to our extensive system of SOPs and our training requirements for analytical staff.

A list of our SOPs and the analytical methods they represent (if applicable) is provided in Appendix J. Discussed here are:

Selection of analytical methods
Standard operating procedures
Method validation and initial demonstration of capability
Sample aliquots
Data verifications
Standard and reagent documentation and labeling (Refer to Section 10.1)
Computers and data requirements

8.1 Selection of Analytical Method

Project Managers are ultimately responsible for selecting the test codes and methods assigned to a client based on client requirements and sample collection techniques. In selecting methods, our goal is to meet the specific needs and requirements of the client while providing data that is scientifically valid.

When the use of a specific test method is mandated, only that method is used. If the analysis cannot be performed by the client-requested method, we notify the client. We do not perform method substitutions without the client's consent. We recommend that clients who submit data to regulatory agencies also obtain the agency's approval of method modifications.

A Project Management ALPHA LIMS User Manual (GL-CS-M-001) is available to assist PMs and PMAs in selecting test codes and methods and communicating the client's analytical and data reporting specifications.

8.2 Standard Operating Procedures (SOPs)

We determine each parameter by the protocol detailed in the corresponding SOP. The defined protocol originates from the analytical method or methods referenced in the SOP and may incorporate regulatory and client requirements. Descriptions of the methods we employ can be found in:

EPA SW846 3rd Edition, Revision III
EPA/600/479/020
Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC)
American Society for Testing and Materials (ASTM)
Standard Methods for the Examination of Water and Wastewater (SM)
South Carolina Department of Health and Environmental Control (SCDHEC)
Code of Federal Regulations (CFR) Titles 40 and 49
Department of Energy Environmental Measurements Laboratory (EML)
Los Alamos Health and Environmental Chemistry (LAHEC)
DOE
HASL
EPA CLP

In addition to these references, a number of our radiochemistry procedures were developed in conjunction with Florida Sate University (FSU) under the guidance of Dr. Bill Burnett.

Laboratory sections have access to GEL's SOPs to ensure that each operational system and analytical procedure is performed in a uniform manner. SOPs are controlled according to GL-DC-E-001 for Document Control and are posted on the Intranet by the Document Control Officer.

We write and issue SOPs in accordance with GL-ADM-E-001 for the Preparation, Authorization, Change and Release of Standard Operating Procedures. A technical and/or quality review is made of each new or revised SOP prior to its implementation.

Technical reviews ensure that procedures are technically sound and method-compliant, and are conducted by a senior analyst, group leader, or data reviewer. The quality review is an independent review by a member of the Quality Systems team and ensures that the quality requirements of the method, regulatory agencies, and GEL are adequately and accurately identified.

SOPs are modified when:

Instruments or equipment change

An error is identified
Improvements in technology and/or reagents need to be incorporated
Reference methods are revised or discontinued

Proposed revisions are submitted for review on Documentation Initiation and Revision Request (DIRR) forms. Changes are not implemented without a technical and quality review.

We review our SOPs annually and revise them as necessary. Analytical SOPs either contain or reference other SOPs that contain:

reference method
applicable matrix or matrices
method detection limit
scope and application including parameters to be analyzed
method summary
definitions
interferences and limitations
specific safety requirements
required equipment and supplies
reagents and standards
sample collection, preservation, shipment, and storage
quality control
calibration and standardization
procedure
calculations
method performance
pollution prevention
data assessment and acceptance criteria for quality control measures
corrective actions for out of control or unacceptable data
waste management
references
tables, diagrams, flowcharts, validation data
identification of any modifications we have made to the published procedure

8.3 Method Validation and Initial Demonstration of Capability

An initial demonstration of method performance is required before a new analytical method is implemented and any time that there is a significant change in instrumentation or methodology. Exempted from this requirement are microbiological analyses and any tests for which spiking solutions are not available. Analyses that are exempt include those for determining:

total dissolved, total suspended, total volatile, and total solids
pH
odor
color
free liquids
temperature
dissolved oxygen
turbidity

We conduct the initial demonstration as described in 8.3.1. Records of initial demonstration are maintained in accordance with GL-QS-E-008 for Quality Records Management and Disposition. These records are available upon request.

After we demonstrate our ability to perform a specific analysis, we continue to demonstrate method performance through the analysis of laboratory control samples and performance evaluation samples.

If spiking solutions or quality control samples are not available, an analyst is trained by a qualified trainer to conduct the analysis. Analyst capability and proficiency is evaluated by the appropriate Group Leader before the analyst is qualified to perform the analysis on client samples. The evaluation is documented and maintained according to GL-HR-E-003 for Maintaining Technical Training Records.

8.3.1 Procedure for Initial Demonstration of Capability

We conduct initial demonstrations of capability for mandated analytical or EPA reference test methods following the procedure outlined below. This procedure is adapted from the EPA test method published in 40CFR part 136, Appendix A.

Step 1: A quality control sample is obtained from an outside source (if possible). If one is not available, the sample may be prepared internally using stock standards that are prepared independently from those used in instrument calibration.

Step 2: The QC sample is diluted in a volume of clean matrix to a concentration approximately 10 times the method-stated or method detection limit determined in accordance with GL-LB-E-001 for the Determination of Method Detection Limits. Sufficient volume of the diluted QC sample is prepared so that at least four aliquots of the required method are analyzed

Step 3: Four aliquots of the diluted quality control sample are prepared and analyzed according to the analytical test method. This may occur concurrently or over a period of days.

Step 4: With the results obtained from the analysis of the diluted QC sample, the average recovery (x) in the appropriate reporting units (such as ug/L) and the standard deviation of the population sample (n-1) (in the same units) is calculated for each parameter of interest.

Step 5: For each parameter, the standard deviation (s) and the average recovery (x) are compared to the corresponding acceptance criteria for precision and accuracy in the test method (if applicable) or in laboratory-generated acceptance criteria (if a non-standard method). If "s" and "x" for all parameters meet the acceptance criteria, analysis of samples may begin. If any one parameter exceeds the acceptance range, the performance is unacceptable for that parameter.

Step 6: When one or more tested parameters fail one or more of the acceptance criteria we:

1. Locate and correct the source of the problem and repeat the test for every parameter of interest.
2. Repeat the test for all parameters that failed to meet criteria. Repeated failure will confirm a general problem with the measurement system. If this occurs, locate and correct the source of the problem. Repeat the test for all compounds of interest.

8.4 Sample Aliquots

When obtaining aliquots from a sample, it is imperative that the subsamples be representative of the parent sample. This ensures that the results obtained from the analysis of the aliquots are representative of the entire parent sample, not just the subsample. We employ different techniques to obtain subsamples.

We can obtain representative aliquots of soil samples for the determination of metals through quartering. This involves the repeated quartering of the sample until the resulting quarter is equivalent to the amount of sample needed for analysis. Quartering may not be appropriate for obtaining subsamples for volatiles or other analyses where potential contamination or loss of target analytes is a concern.

Water samples are inverted several times prior to the collection of a subsample. This ensures a thorough mix and is absolutely required for the accurate determination of analytes like total and total suspended solids.

The appropriate techniques for obtaining sample aliquots for designated analyses are discussed in the applicable SOPs.

8.5 Data Verification

All of the data we include in final reports to our clients undergoes extensive data verification. At GEL, we have a multi-level review process that takes place in all areas of the laboratory beginning with sample login. This process and the responsibilities of each level of review are delineated in a number of procedures, including GL-OA-E-044 for Organics Data Validation, GL-GC-E-092 for General Chemistry Data Validation and Packaging, GL-MA-E-017 for Metals Data Validation, and GL-RAD-D-003 for Data Review, Validation, and Package Assembly.

8.5.1 Sample Login:

Samples are analyzed by the methods and for the target analytes identified when samples are logged into our database. If there is an error in this entry that is not promptly identified, the incorrect analytical method may be used or certain analytes may not be determined.

To prevent this, the person who enters the information into the database is generally the client's assigned Project Manager or PM Assistant. This entered information is reviewed against the client confirmation letter and/or chain of custody. If errors are identified, they are immediately corrected.

8.5.2 Data Validation in the Laboratory

The multi-level review process in our laboratory includes initial review by the analyst, a second review by a peer, and a final review by a group leader or data reviewer. Where appropriate based on personnel and client needs, the industrial division institutes two levels of review.

Our analytical data reviews ensure that:

The analytical procedures comply with current SOPs.

Quality control samples are analyzed at the frequency specified in the SOP or client specifications.

The acceptance criteria for quality control samples is met, including recoveries of matrix spikes and laboratory control samples, the relative percent difference for matrix duplicates, matrix spike duplicates, laboratory control sample duplicates, and concentrations of target analytes in the method blank.

Instrument data, run logs, and logbooks are reviewed to ensure that all method quality control criteria were met (e.g., calibration, initial calibration verifications, and continuing calibration verifications).

Documentation is sufficient to reconstruct the analytical procedure.

Data is maintained according to GL-LB-E-008, "Basic Requirements for the Use and

Maintenance of Laboratory Notebooks, Logbooks, and Other Record Keeping Devices."

Raw data is in agreement with the computer generated batch sheets and data reports.

The calculations, dilution factors, concentration reported, and nominal concentrations are verified.

Comments, qualifiers, or nonconformances for noncompliant or questionable data are documented.

Data generated when the analytical process appears to be out of statistical control is not reported.

8.5.3 Validation of Data Reports and Packages

Before we report data to the client, we review the requested data report for package accuracy, completeness, and client-specifications. Responsibilities for review are dependent upon the type of report or package being generated. (Refer to Section 11 for Data Report Formats.)

When a client is receiving a certificate of analysis or certificate of analysis and Quality Control Summary Report, the Project Manager (PM) or Project Manager Assistant (PMA) reviews the information for accuracy, completeness and the addition of pertinent comments made by the laboratory about the analysis or sample. The PM or PMA also reviews data for consistency as described in the Project Management ALPHALIMS Manual, GL-CS-M-001.

If a client requests a case narrative, our data validators review the analyst-prepared case narrative for accuracy and to assure its consistency with the information included on the certificate of analysis and Quality Control Summary Report. If a client requests a more detailed level of data package up to and including a CLP-like package, every laboratory fraction of data is reviewed by that fraction's data validator. The data is then compiled into a final data package again reviewed by the PM or PMA.

8.6 Standard and Reagent Documentation and Labeling

The documentation and labeling of standards and reagents is addressed in GL-LB-E-007 for Laboratory Standards Documentation, and in Section 10.1 of the QAP, Record Keeping System and Design.

8.7 Computer and Electronic Data Related Requirements

Our Information Management System SOPs (IMS) describe the way in which we manage our software programs and hardware systems. Control of software development and modification activities is described in GL-IMS-E-001. All development and revision activities are validated, verified, and controlled with revision software or other procedures prior to production use.

Analytical software that is purchased from a vendor is validated and verified in accordance with GL-IMS-E-004 for the "Verification and Validation of Software." Documentation requirements are also described in this SOP.

SECTION 9

SAMPLE HANDLING, ACCEPTANCE, RECEIPT & INTERNAL CHAIN OF CUSTODY

Section 9 - Sample Handling, Acceptance, Receipt, and Internal Chain of Custody

The way we receive and handle samples is critical to providing our clients with data that is of the highest quality and legally defensible. We have strict policies that govern the acceptance and receipt of a sample, sample handling and integrity, maintenance of the internal chain of custody, and storage of the sample upon completion of the required analytical processes. This section describes the policies and practices that we employ, including the following:

- Agreements to perform analysis
- Proper labeling of submitted samples
- Chains of custody
- Sample receipt procedures
- Sample receipt procedures for radioactive samples
- Sample tracking
- Sample storage
- Sample disposal

9.1 Agreement to Perform Analysis

Before we accept samples, we should have an agreement with the client that specifies the analytical methods, the number of samples to be analyzed, the price for the analysis, the date by which the client must receive results, and the reporting format. Any special requirements the client may have, such as non-routine methods and reporting limits, should be part of that agreement.

An agreement to perform analysis should be in one of three forms, further detailed in our Analytical Services Reference Manual and the SOPs for Delegated Authorization to Commit the Company and Request for Proposal (RFP)/Contract Review (GL-CO-E-002 and GL-CO-E-003):

- Client confirmation letter (CCL) between the client and project manager for a specific group of samples. This letter includes the cost, turn-around time, requested analysis, sample matrix, number of samples, and type of client report.
- Sample acceptance by the Project Manager from an established client based on previously agreed to conditions and confirmed by the client's submission of the sample(s).
- Contractual agreement for analytical services over a designated time period or project that delineates the specifications agreed upon.

9.2 Sample Labels and Chain of Custody Forms

Once an agreement is established, we assume joint responsibility with the client to ensure that the samples submitted are properly labeled and accompanied by full and complete documentation that includes chain of custody and, where possible, material safety data sheets. Samples that are submitted without proper documentation may be refused.

Sample labels should include the:

- client's sample identification
- location, date, and time of collection
- collector's name
- chemical preservatives used
- constituents of interest (if space permits)

When requested, we ship labeled sample containers with appropriate preservatives and a chain of custody to the client for use during sample collection. We prepare and ship these containers according to GL-RC-E-003 for Sample Bottle Preparation and Shipment. There are several advantages to using these containers, including:

- Dedication of appropriate type sample container for the intended analyte or analytical method.
- Proper sample preservation for analytical test
- Traceability of bottle lot number to the manufacturer's certification that the containers are clean and show no signs of contamination.

Chain of custody forms include the following information and are initiated at the time of sample collection:

- name and address of client
- client sample identification
- date and time of sample collection
- sample matrix
- description of sampling site location
- number of containers
- methods, chemical and physical constituents for which the analyses are to be conducted
- preservatives
- date and signature of person who collected the sample

date of transfer and signature of person relinquishing sample to the laboratory.

When our Field Services personnel collect samples, our standard chain of custody form and certified containers are automatically used. Our standard chain of custody forms are also available to our clients and are included with each shipment of pre-labeled and preserved containers. GEL chain of custody forms should always be used unless otherwise agreed to by contract.

9.3 Sample Conditions

In addition to properly documenting sample container labels and the chain of custody form, we need to make sure that samples meet the established requirements for analytical testing. This is particularly critical for samples that are being analyzed to meet regulatory requirements.

Samples should be collected in the appropriate type of container, preserved as directed, and stored in the conditions specified in the analytical method or established regulatory guidelines. In addition, samples should be submitted with sufficient time to conduct the specified analysis within the regulatory or method holding time. Aliquots should be of sufficient volume to perform the requested analyses. A summary of these conditions and holding times for routine analyses can be found in Appendix K.

9.4 Sample Receipt

Samples submitted to us are received in a central sample receiving area by our sample custodian or login clerk. Every sample is subject to the protocols established in GL-SR-E-001 for Sample Receipt, Login, and Storage.

Our sample custodian acknowledges receipt of a sample by signing the chain of custody and recording the date and time custody was transferred from the client to the laboratory. The date, time, and person receiving the sample are also recorded on a standard or client-specific Sample Receipt and Review form.

The sample custodian is also responsible for noting the condition of a sample upon its arrival. This information is recorded on both the sample chain of custody and the Sample Review and Receipt form. As detailed in GL-SR-E-001, the sample custodian should:

Inspect all sample containers for integrity.

Document any unusual physical damage or signs of tampering with custody seals.

Place any samples that appear to be leaking or have unusual odor under the fume hood while notifying the responsible project manager.

Review the chain of custody submitted by the client for completeness.

Compare descriptions and other information on the sample container labels to that listed on the chain of custody.

Verify the sample is within the regulatory holding time for the analyses.

Measure and record the temperature of sample aliquots that are to be used for analyses requiring thermal preservation.

Measure and record the pH of all sample aliquots submitted for analyses that require chemical preservation to a specific pH.

Verify that there are adequate sample aliquots for the requested analyses.

Verify that appropriate sample containers were used for requested analyses.

If the sample custodian discovers any abnormalities or departures from standard conditions, the PM is informed immediately. The PM will then notify the client as quickly as possible so that a decision can be made to proceed with the analysis or submit another sample or additional sample aliquots.

Common abnormalities or departures from standard conditions include:

Sample containers with signs of damage, leaking, or tampering.

Incomplete/missing chain of custody.

NOTE: If a nonradioactive sample has no chain of custody, the sample custodian should initiate one. "INITIATED ON RECEIPT" should be documented on the chain of custody.

Discrepancies between the information on the chain of custody and the sample container labels.

Method or regulatory holding time is exceeded.

Sample is not preserved to the method or regulatory-required pH.

The sample container does not meet method or regulatory criteria.

The sample temperature exceeds or falls below the thermal preservation regulation or method requirement by more than 2 C.

NOTE: If a sample is hand delivered to the laboratory immediately after collection with evidence that the chilling process has begun (arrival on ice), the sample shall be deemed acceptable.

Radioactivity that exceeds that allowed by our radioactive license. (The handling of radioactive samples is discussed in 9.5.)

Samples that are not appropriate for the requested analyses or have no full test specifications require:

Retention of all correspondence and records of conversations concerning the final disposition of the sample.

Full documentation on the chain of custody and Sample Receipt and Review form of the nonconforming condition and a decision to proceed with analysis.

Documentation that the analysis is qualified appropriately on the final report.

9.5 Receipt of Radioactive Samples

The radioactive samples we receive are subject to the same monitoring identified in 9.4 when radioactivity levels do not exceed the level permitted by our license. Special procedures governing the receipt of radioactive samples are described in the GL-RAD-S-007 for the Receiving of Radioactive Samples. These procedures prevent the inadvertent spread of radioactive contamination.

Because we cannot exceed the limits of our radioactive license, it is imperative that our clients notify us of impending shipments of radioactive samples. We reserve the right to refuse and return any radioactive sample where the radioactivity:

Exceeds our permitted level by itself or in combination with other samples already on site; or

Exceeds our administrative level of 25mR/hr.

The following special requirements for receiving radioactive samples are applicable:

Only designated staff trained in the proper handling of radioactive materials handle radioactive samples.

If a sample is labeled as "Radioactive II", the custodian will not open the sample but will immediately inform the Radiation Safety Officer (RSO).

The radioactivity of the sample will be measured by scanning the exterior surface of the cooler using a survey meter calibrated in mR/hr. See GL-RAD-S-001 for our Radiation Survey Procedures.

If the radioactive level of the exterior of the cooler exceeds 0.5 mr/hr, the RSO will be notified before the cooler is opened.

If the radioactivity level of a sample or group of samples is found to exceed 25mR/hr, the RSO will be notified immediately. The client will be contacted and arrangements will be made to return the sample(s) or reduce the per sample exposure.

If a chain of custody is not submitted with a sample, it will be placed on hold until a chain of custody is submitted.

The inside of the cooler will be surveyed to ensure that no leakage or contamination has occurred.

Each sample container will be surveyed and the highest reading will be documented on the Radioactive Shipment Inventory.

9.6 Sample Tracking

We track the samples we receive by a unique laboratory identification number that is automatically assigned when information pertaining to the sample is first entered into our database. Pursuant to GL-SR-E-001, the following information is entered for each sample received:

client and/or project code
client sample ID
sample matrix
equivalent laboratory sample matrix
type of report format specified by client
date and time of collection
date received
initials of person making entries
number of containers submitted for the sample
requested analyses
pertinent observations or comments affecting the sample analysis or rejection

As soon as this information is entered, ALPHA LIMS automatically assigns a unique number to the sample and its containers. We use the number to track the location of a sample container and to link to any subsamples and subsequent digestates and extracts.

The unique laboratory identification number is printed on a durable barcode label that contains the client identification, sample date and time. Once labeled, the sample container's identification number is uploaded into the database by scanning the barcode. Information included in the database at the time of sample scanning is the container's storage location, bottle type and volume, physical characteristics of the bottle, preservative, and the initials of the person entering this information. Entering of this information into the database is an important part of initiating our electronic internal chain of custody.

9.7 Internal Chain of Custody

Chain of custody procedures ensure traceability and sample integrity. Our legal and evidentiary chain of custody protocol establishes a continuous record of the physical possession, storage, and disposal of sample containers, collected samples and aliquots, and sample digestates or extracts.

The internal chain of custody starts with the scanning of a container's barcode label into an electronic database while identifying the location of the sample and the person having custody, or placing the sample in a secured storage area. If we supply the containers, the chain of custody may begin when the containers are provided to the client.

With regard to the internal chain of custody, a sample is defined as being in someone's custody if:

- It is in one's actual physical possession
- It is in one's view after being in one's physical possession
- It is in one's possession and then is locked up so that no tampering may occur
- It is kept in a secured area restricted to authorized personnel only

The protocol for ensuring sample integrity using the internal chain of custody is detailed in GL-LB-E-012 for Verifying the Maintenance of Sample Integrity. The electronic internal chain of custody works in conjunction with the chain of custody submitted by the client with a sample to:

- Account for all time associated with a sample, its subsamples, and extracts or digestates from the time the sample is received at GEL to its disposal.
- Identify all individuals who physically handled the sample
- Provide evidence that the sample was stored in accordance with method and regulatory protocols

The electronic internal chain of custody is stored in ALPHA LIMS so that information demonstrating the proper maintenance of custody can be provided to the client on the data reports or electronic data deliverables.

9.8 Sample Storage

In order to ensure the maintenance of sample integrity, all aliquots are stored in secured areas designated for sample storage. The storage location of each sample aliquot can be tracked using the internal chain of custody. Areas designated for sample storage include:

- Main cooler where most samples requiring maintenance at a temperature range of 2 - 6 C are stored.
- Volatile coolers for samples to be analyzed for volatile contaminants.
- Radioactive cooler for segregation of radioactive sample aliquots requiring refrigeration.
- Ambient storage for non-radioactive samples not requiring refrigeration.
- Ambient storage for radioactive samples.
- Refrigerators for the storage of samples requiring bacteriological analysis and temporary storage for those requiring the determination of biochemical oxygen demand.

The temperature of each refrigerated storage unit is monitored at least twice a workday and documented per "Temperature Monitoring and Documentation Requirements for Refrigerators Freezers, Ovens Incubators, and Other Similar Devices," (GL-LB-E-004). In addition, the main and radioactive coolers are monitored twenty-four hours a day by temperature sensors that are connected to our main security system. If the temperatures exceed the required range, an alarm is sounded and the security system notified the facilities manager or his designee immediately. This allows corrective actions to be initiated promptly.

Prior to and immediately after analysis, samples and their digestates and extracts are stored in compliance with the requirements of the requested analytical methods and GL-SR-E-001 for Sample Receipt, Login, and Storage. If a single aliquot is supplied for analyses by several methods, the most stringent analytical storage requirements are applied to the sample.

If samples are to be analyzed for volatile organic compounds, they are stored in designated volatile coolers that are maintained at a temperature range of 2 - 6 C. No sample aliquots are stored in these refrigerators unless they are to be analyzed for volatiles. These storage units are monitored on a weekly basis for contamination by the analysis of volatile cooler storage blanks.

At the beginning of each month, eight 40-mL vials are filled with treated deionized water, which is used for volatile method blanks and placed in each volatiles cooler. Each week, one or two vials are analyzed by EPA 8260B and the data is reported to the Quality Department. If the analysis reveals evidence of potential contamination, appropriate corrective actions are immediately implemented.

Sample aliquots for non-volatile analysis, which also should be maintained between 2 - 6 C, are stored in the main cooler unless they are radioactive. In order to reduce the chance of contamination, radioactive samples are stored in a designated cooler.

Sample aliquots designated for the determination of total coliform bacteria, fecal coliform bacteria, or total plate count are delivered to the bacteriology laboratory and stored in the designated refrigerator at a temperature range of 2-6 C. This allows easy access for the analyst ensuring that the short regulatory holding times are met. After analysis is complete, the remaining sample aliquot is disposed of in accordance with the Laboratory Waste Management Plan.

Sample aliquots to be analyzed for biochemical oxygen demand (BOD) are also delivered to the bacteriology laboratory and stored in the designated BOD cooler. This cooler is also maintained at 2 - 6 C. After initiation of this analysis, the sample aliquots are returned to the main cooler.

After all analyses are complete and results are submitted to the client, sample aliquots are transferred to the sample archive area. They are stored in this area until they are disposed.

Radioactive and non-radioactive samples remain segregated in archive to reduce the risk of contamination.

9.9 Sample Disposal

Our policies concerning sample disposal are described in the Laboratory Waste Management Plan (GL-LB-G-001) and can be divided into two categories: those governing the disposal of sample laboratory waste, and those directing the disposal of remaining sample aliquots after the completion of all analyses.

9.9.1 Sample laboratory waste

Unless otherwise requested by contract, laboratory sample waste is collected throughout the laboratory in designated satellite containers found in sample collection and accumulation areas. Sample wastes are segregated based on the type of analysis by which they were generated, by matrix, and radioactivity. This contains certain process contaminants thus decreasing the amount of waste material that may be labeled hazardous. It also ensures that solid and aqueous wastes are not mixed.

The satellite collection containers are regularly emptied by the Laboratory Waste Manager (or designee) into labeled 55-gallon drums in the waste staging areas. The following information is recorded in a log located in the staging area: container identification, satellite station source, date transferred to 55-gallon drum, volume transferred, and initials of the person transferring the material.

We have separate radioactive and non-radioactive staging areas. The composited sample wastes then undergo hazardous waste characterization. The analyses requested differ depending upon sample matrix. Aqueous sample waste composites are typically analyzed for metals, base neutrals and acids, pesticides, PCBs, pH, cyanide, and volatile compounds. Solid sample waste composites are analyzed for the TCLP parameters, BTEX, TPH, total lead, and water content.

Sample waste is disposed in accordance with the Laboratory Waste Management Plan (GL-LB-G-001).

9.9.2 Remaining Sample Aliquots

Sample not consumed during the sample preparation or analytical procedures is either returned to the client in accordance with GL-SR-E-002 for Return of Samples or disposed pursuant to the Laboratory Waste Management Plan. All radioactive samples are returned to the client unless otherwise specified by contract. Non-radioactive samples are returned to a client under the conditions and terms agreed to by contract. A chain of custody listing the laboratory waste technician as the relinquishing party is enclosed with each set of samples being returned to a client. Unless otherwise specified by the client, all non-radioactive samples are shipped by UPS. If the samples are radioactive, the procedure for shipment is delineated in GL-RAD-S-008 for the Shipment of Radioactive Samples.

It is our policy to hold samples for a minimum of thirty days after invoicing and before disposal, unless otherwise specified by contract or if the sample is part of litigation. If the sample is part of litigation, disposal of the physical sample shall occur only with concurrence of the affected legal authority, sample data user, and/or client.

When sample analyses are complete and regulatory and/or contractual holding times have expired, samples are moved from their storage locations to the radioactive or non-radioactive archives. Samples that are to be returned to the client or held for an extended time period are segregated from the other samples. Radioactive and non-radioactive samples remain segregated.

When internal or client-specified storage time expires, samples with like matrices are composited into 55-gallon drums. The composites are then subject to the same treatment and disposal protocol as described in 9.9.1. In addition to the log documenting which samples are composted in which drum, the barcode labels for each disposed sample are scanned into our data base and assigned the status of disposed.

SECTION 10
RECORDS

Section 10 - Records

Our quality records provide the documentation we need to support analytical results and conclusions. Documented evidence that quality assurance and quality control requirements have been met is critical to providing data that fulfills the specifications of applicable procedures, programs and contracts.

As described in Section 3 of this Quality Assurance Plan (QAP), quality records include but are not limited to:

- Observations
- Calculations
- Calibration data
- Certificates of analysis
- Certification records
- Chains of custody
- External, supplier, and internal audits
- Run logs
- Instrument data and analytical logbooks
- Instrument, equipment and building maintenance logs
- Material requisition forms
- Monitoring logs
- Nonconformance reports
- Corrective actions
- Method development and start-up procedures including MDL studies
- Training records
- Waste management records
- Standard logs
- Software validation
- Standard operating procedures (SOPs)
- Sample collection and field data

Our procedures provide a legal and evidentiary chain of custody are described in Section 9 of this QAP. Described in this section are:

- Record keeping system and design
- Records management and storage
- Sample handling records
- Records of support activities
- Analytical records
- Administrative records

10.1 Record Keeping System and Design

We manage, maintain and store our quality records according to GL-QS-E-008 for Quality Records Management and Disposal. The protocols established in this document work in conjunction with those for specific types of records addressed in other SOPs to govern our record keeping system. Our record keeping system allows the historical reconstruction of all laboratory activities that produced analytical data.

We facilitate historical reconstruction by maintaining the following records and information, from the time a sample is received until it is disposed.

A master list of all employee signatures and initials is maintained in Human Resources. This allows the identification of any GEL personnel who accept, handle, analyze, prepare, review, store, or dispose of a sample, its subsamples, associated data and reports, and other related documentation.

If we provide bottles and containers to a client or sampling personnel, these records are kept in accordance with GL-RC-E-003 for Sample Bottle Preparation and Shipment. These electronic and paper records include:

- Supplier and lot numbers of containers and/or bottles provided
- Certifications that the containers are free of contaminates that may bias the analyses
- Addition of preservatives and identity of person responsible for this preservation.
- Barcode of containers supplied to a particular client or for a specific field-sampling event.

The person or agency responsible for collecting a sample is documented on the chain of custody and entered into ALPHA LIMS. Other records supporting the acceptance of a sample include:

- Date and time of sample receipt
- Person accepting sample
- Condition of sample upon receipt
- Client-confirmation letter and/or sample quote
- Client chain of custody
- Electronically generated sample ID numbers specific to each sample aliquot and linked to the client's sample description, sample collection and receipt information, and analyses to be performed.
- Identification of each person who has custody of a sample, its subsamples, extracts, or digestates. (This is provided through the internal chain of custody procedures described in Section 9.)

Documentation that materials purchased for use in the analysis or preparation of samples meet specifications is maintained in accordance with GL-RC-E-001 for Receipt and Inspection of Material and Services.

Records of equipment calibrations are maintained and traceable by date and ID number to a specific analysis. These records include certifications of calibration and service that have been initialed or signed.

Our thermometers are calibrated against the NIST traceable thermometer and records of this calibration are maintained as described in GL-QS-E-007 for Thermometer Calibration. Records of the daily and monthly calibration verifications of our analytical balances are kept in accordance with GL-LB-E-002 for Balances. The calibration records for our air-displacement pipets are maintained in pipet calibration logs specific to each pipet according to GL-LB-E-010 for Maintenance and Use of Air Displacement Pipets.

When methods and/or regulations specify that samples, subsamples, extracts, and/or digestates be stored at designated temperatures, or when the method, itself, has temperature sensitive steps, we document those temperatures on monitoring logs at the frequency defined in the corresponding SOPs. We can trace the specific storage location of a sample through the internal chain of custody.

We require that the initials of all personnel responsible for monitoring temperatures be recorded in the temperature monitoring logs pursuant to GL-LB-E-004, "Temperature Monitoring and Documentation Requirements for Refrigerators, Freezers, Ovens, Incubators, and Other Similar Devices." The logs are reviewed for completeness in accordance with GL-QS-E-005 for the Review of Monitoring Devices.

Documentation on the instruments and equipment used for the analysis of samples is recorded in run logs, laboratory logbooks, instrument data and/or sample preparation logs. Routine or corrective maintenance that is performed on equipment or instruments is recorded in the maintenance log specific to the instrument. We document these records in accordance with GL-LB-E-008 for Basic Requirements for the Use and Maintenance of Laboratory Notebooks, Forms and Other Record Keeping Devices.

The standards containing known quantities of target analytes that we use in instrument calibration, calibration verification, and as quality control samples, such as matrix spikes and laboratory control samples, are documented according to GL-LB-E-007 for Standards Documentation. These records contain the following information.

Recipe by which each standard was prepared
Traceability of each child standard to its parent
Date each standard was prepared
Initials of person preparing the standard
Expiration dates
Concentration of each standard

This information allows us to document that the standards used were prepared in accordance with the established protocol, produced using source standards that meet the method and regulatory criteria, and used prior to their expiration date.

If required, reagents used in the preparation, dilution, and analysis of samples are verified to be free of interferences or target analytes. We record these verifications in the reagent logs in accordance with GL-LB-E-008.

Analytical and sample preparation methods applied to each sample aliquot are documented via the internal chain of custody, method information, and information recorded in lab notebooks, sample preparation logs, run logs, and instrument data. The laboratory protocol we employ during analysis is dictated by the SOP in effect at the time the sample was analyzed or prepared by a specific method.

Run logs, laboratory notebooks, instrument data and sample preparation logs are used to document the preparation and analysis of samples and the associated instrument calibrations. These logs and notebooks are governed by GL-LB-E-009 for Run Logs and GL-LB-E-008 for Basic Requirements for the Use and Maintenance of Laboratory Notebooks, Logbooks, Forms, and Other Record Keeping Devices. As stated in these SOPs, sample preparation and analytical records that are not electronically generated should be:

Legible
Recorded in permanent ink
Corrected using one line marked through the error, initialed and dated
Initialed by the responsible party

We maintain electronic records for each analytical batch. These records include the ID numbers of each client and quality control sample prepared and/or analyzed together, the method of preparation and analysis, and the matrix of the samples included in the batch.

Through our electronic statistical process control system (SPC), the acceptance criteria applied for all quality control (QC) samples is stored and maintained. The acceptance limits for target analytes are method, matrix, and time-period specific, which allows us to regenerate the criteria applied to QC samples associated with identified client samples.

Our Quality Systems Team maintains the records of nonconformances and corrective actions associated with specific samples, batches, and processes. We maintain these records according to GL-QS-E-004 for the Documentation of Non- conformance Reporting and Dispositioning, and Control of Nonconforming Items; and GL-QS-E-002 for Conducting a Corrective Action.

Electronic data records are maintained in a secured database designed to protect the integrity of the data. Data that is uploaded directly from instruments and that manually entered is backed up by a second system.

Permanent records of electronic data deliverables are maintained along with the corresponding sample preparation and analytical data review records. This documentation includes the initials of the reviewer and date of the review.

Records of the data we report to our clients are maintained in a manner that protects client confidentiality, as well as any potential national security concerns. These records include copies of certificates of analysis, quality control summary reports, case narratives, CLP forms, and other information we provided to the client. The copies may be paper or electronic. The majority of the data packages submitted to Federal clients are stored electronically prior to being submitted to the client.

Records of samples being disposed or returned to the client are documented in accordance with GL-SR-E-002 for Return of Samples and the Laboratory Waste Management Plan. Such records include the date samples are returned or disposed, the destination of the samples, and name of the person transferring the samples.

10.2 Record Storage

We store quality records in compliance with GL-QS-E-008 for Quality Records Management and Disposition. The records are:

Stored in a secured area to maintain data integrity and protect client confidentiality, including any national security concerns.

Kept in areas where they are protected from fire loss, environmental deterioration, and, in the case of electronic records, electronic or magnetic sources.

Indexed and filed in a manner allowing for ready retrieval.

Accessible to the client for whom the record was generated.

Retained for an identified period of time that equals or exceeds five years as determined by applicable law and client contract requirements.

Electronic data records are stored on compact disks.

All of the hardware and software we need to reconstruct data is maintained according to GL-IMS-E-002 for Computer Software Development and Maintenance. Records that are stored or generated by network or personal computers have either hard copy or write-protected backup.

10.3 Sample Handling Policy

Records of all procedures applicable to samples are maintained in our possession. These records include documents that pertain to:

Preservation, including sample container and holding time

Sample identification, receipt, acceptance or rejection, and login

Sample storage and tracking including shipping receipts, transmittal forms, routing and assignment records

Sample preparation (ID codes, cleanup and separation protocols, volumes, weights, instrument printouts, meter readings, calculations, reagents)

Sample analysis

Standard and reagent origin, receipt, preparation, and use

Equipment receipt, use, specification, operating conditions and preventative maintenance

Instrument calibration frequency and acceptance criteria

Data and statistical calculations, review, confirmation, interpretation, assessment and reporting conventions

Method performance criteria including expected quality control requirements

Quality control protocols

Electronic data security, software documentation and verification, software and hardware audits, backups and records of any changes to automated data entries

Automated sample handling systems

Disposal of hazardous samples

10.4 Records of Laboratory Support Activities

In addition to sample handling records, we maintain the following:

Original raw data for calibrations, samples and quality control measures, including worksheets and data output records (chromatograms, strip charts, and other instrument readout records)

A written description of or reference to the specific method used, including the computational steps used to translate parameter observations into a reportable analytical value

Copies of final reports

Archived standard operating procedures

Correspondence relating to project-specific laboratory activities

Corrective action reports, audits and audit responses

Proficiency test results

10.5 Analytical Records

We document and maintain analytical records, such as strip charts, tabular printouts, computer data files, analytical notebooks, and run logs according to GL-LB-E-008 for Basic Requirements for the Use and Maintenance of Laboratory Notebooks, Logbooks, Forms, and Other Record Keeping Devices, and GL-LB-E-009 for Run Logs. The information that is documented in analytical records includes:

Laboratory sample ID code

Date and time of analysis

Instrument ID and operating conditions/parameter (or reference to such data)

Method of analysis

All calculations

Dilutions

Initials of analyst or operator

Units of measurement

Our policy is to produce and maintain analytical records that are:

Accurate

Reviewed and verified

Legible and understandable

Traceable and authentic to their source

Grouped in a contemporary manner with data entered and information recorded as it is obtained

10.6 Administrative Records

A number of pertinent records are maintained by Human Resources or Quality Systems, including:

Staff qualifications and experience.

Training records, including initial demonstrations of proficiency. (See procedure GL-HR-E-002 for Employee Training.)

A log of names, initials and signatures for individuals having responsibility for initialing laboratory records.

We monitor continuing demonstrations of proficiency through ALPHALIMS per GL-HR-E-002 for Employee Training.

SECTION 11

LABORATORY REPORT FORMAT and CONTENTS

Section 11 - Laboratory Report Format and Contents

Accurate data is of little benefit to a client unless it is reported in a format that is easy to interpret and provides all pertinent information relating to the analysis of a sample. At GEL, we have developed certificate of analysis report formats that meet the different needs of our clients yet provide all of the information necessary to satisfy regulatory requirements while allowing for the interpretation of the data. Each format provides accurate, clear, unambiguous and objective data.

In addition to a certificate of analysis, a client can request and receive an extended data package. This package may include any of the following: certificates of analysis; summaries of quality control; case narratives; instrument data; sample preparation data; measurement traceability and calibration information; and electronic data deliverables. If clients require the reporting of data following the established contract laboratory protocol (CLP), we can provide a CLP-like data package that will meet their needs.

It is important that the certificate of analysis format and data package requirements be discussed with the client prior to our acceptance of the samples. Project Managers and contract staff are responsible for establishing an agreement with the client concerning data reporting and the potential cost to the client for data packages and/or specialized reporting. Our analytical data is reported to three significant figures, unless otherwise required by client contract.

Laboratory reports and data packages are store and transmitted in a manner that protects client confidentiality and potential matters of national security. No reports or data packages are released to persons or organizations outside GEL without the expressed consent of the client. If directed by a regulatory agency or subpoenaed to submit documents to a court of law, we will notify the client of the demand and the records being released.

The following elements of report formats and data packages are described in this section:

Certificates of analysis (C of A)
Quality control summary reports (QCSR)
Analytical case narratives
Electronic data deliverables (EDDs)
Types of data packages and reporting formats
Review of data packages and reports

11.1 Certificates of Analysis

We have two primary C of A report formats, Level 1 and Level 2. Both contain the following information when applicable:

Title
GEL address and phone number
Name of PM or person serving as the primary client contact
Barcode identification of the C of A
Number of page and total number of pages
Name and address of client, where appropriate
Project name or code if applicable
Client-provided sample description
Unique laboratory ID number for the sample
Sample matrix
Characterization and condition of the sample where relevant
Date of receipt of sample
Date and time of sample collection, if provided
Date and time of sample analysis, reanalysis, and/or sample preparation
Initials of analyst and person responsible for sample prep
Analytical batch number
Sample analysis and preparation methods (or unambiguous description of any non-standard method used)
Reference to sampling procedure
Additions to or deviations or exclusions from the test method, and other information relevant to a specific test, such as environmental conditions and the use and meaning of data qualifiers
Nonconformances that affect the data
Whether data is calculated on a dry weight or wet weight basis
Identification of the reporting units, such as ug/1 or mg/kg
Statement of the estimated uncertainty of the test result, if applicable
Signature and title of the person(s) accepting responsibility for the content of the C of A
Date C of A was issued
Clear identification of data provided by outside sources, such as air temperature or ambient water temperature

Identification of the reporting detection limit (RDL) or practical quantitation limit (PQL) for each analyte, if applicable.

If a portion of the sample analysis is subcontracted, the C of A will identify the subcontractor or applicable accreditation number, and the data that was determined by the subcontracting laboratory

.Level 2 Certificates of analysis contain the following additional information:

Dilution factors

Method detection limits

Surrogate recoveries and the acceptance criteria for all organic analyses

Estimated concentrations determined for nondetects and appropriate "U" and "J" qualifiers for nondetects and concentrations that fall between the MDL and PQL respectively.

Once issued, a C of A is not altered unless a subsequent C of A is identified as a revised report.

11.2 Quality Control Summary Report (QCSR)

We prepare and analyze samples in groups of twenty or less. The quality control data that demonstrates the sample preparation and/or analytical efficiency of the batch is summarized on a QCSR. The data reported on the QCSR may be limited to a sample delivery group contained in the batch or may include all quality control for the batch. Information reported on QCSR includes:

Quality control sample ID number

Type of quality control sample

Concentrations determined, where applicable, for method blanks, matrix spikes, matrix spike duplicates, matrix duplicates, laboratory control samples, serial dilutions, and laboratory control sample duplicates

Acceptance criteria for matrix spikes, matrix spike duplicates, matrix duplicates, laboratory control samples, and laboratory control sample duplicates

Nominal concentrations of matrix spikes, matrix spike duplicates, LCSs, and LCS duplicates

Concentration of parent sample for the matrix spikes, matrix spike duplicates, or sample duplicates

Percent recoveries for LCS and matrix spikes

Relative percent differences for the matrix spike duplicates, matrix duplicates, and LCS duplicates

Analytical batch number with which the quality control data is associated

Parent sample numbers for matrix spikes, matrix duplicates, and matrix spike duplicates

Sample or sample delivery group ID

Project code

Date issued, page numbers/total number of pages

Identification of recoveries or relative percent differences that do not meet the acceptance criteria

11.3 Analytical Case Narratives

Analytical case narratives are written by an analyst or data validator to describe the overall conditions affecting the analysis of a batch or a specific sample in the batch. Case narratives usually include:

Sample delivery group ID number

Analytical batch number

Methods of preparation and analysis

Sample matrix

Initial of person preparing and/or reviewing the narrative

Specific sample ID numbers

Identification and description of batch quality control samples including parent sample identification

Affirmation that all sample preparation conditions specified by the method or regulatory agencies were met or identification of specific deviations

Affirmation that all analysis criteria specified by the method or regulatory agencies were met or identification of specific deviations

Instrumentation employed if applicable and verification of its calibration

Summary of batch quality control as compared to acceptance criteria

Identification of nonconformances

Pertinent comments and observations of factors that affect sample data quality

11.4 Electronic Data Deliverables (EDDs)

Electronic data deliverables are generated according to client specifications. EDDs use programs supplied by the client or created internally by our EDD team. Internally generated EDDs are usually written in Pearl or Microsoft Excel.

11.5 Types of Data Packages and Reports

We offer three levels of data reports and the ability to design packages to meet the needs of our clients. The levels of data reports are summarized in Table 1.

Table 1: Data Report Formats

Level	Contents
1	Level 1 C of A

2	Level 2 C of A
3	Level 2 C of A plus QCSR

If a client so requests, the above reports can be accompanied by EDDs, case narratives, copies of associated nonconformance reports, and other support documentation. The client's specific requirements are communicated to the laboratory and data reviewers through ALPHA LIMS.

If a client requests a CLP-like data package, and we agree to provide one, it is compiled in accordance with GL-LB-E-013 for the Generation and Assembly of CLP Data Packages. If a client does not request a full CLP-like data package but asks for data to be provided on CLP forms generated from software, we follow the applicable procedures in GL-LB-E-013.

11.6 Review of Data Reports, EDDs, and Data Packages

Level 1, Level 2, and Level 3 data reports are reviewed for accuracy and completeness by the PM or PMA according to GL-ADM-E-002 for Process, Review, and Distribution of Certificates of Analysis and COA packages. CLP-like data packages are reviewed in the laboratory by a data reviewer, who is responsible for reviewing specific fractions of the data package for accuracy, consistency, and completeness in accordance with the SOP for that lab area.

No data package fraction is to be provided to the data packaging team without the approval of the appropriate data reviewer. Data reviewers oversee the review of associated EDDs and ensure that the EDD is in agreement with the package.

Project managers are responsible for reviewing the complete data package to ensure that all of the client's needs are met and to be able to notify the client of any nonconformances or failures to provide requested information prior to the submission of the package.

CLP-like data packages are reviewed in compliance with the basic protocol. Specific requirements are described in GL-LB-013 for the Generation and Review of CLP Data Packages.

SECTION 12
SUBCONTRACTING ANALYTICAL SAMPLES & OUTSIDE SUPPORT SERVICES

Section 12 - Subcontracting Analytical Samples and Outside Support Services

We provide a full array of organic, inorganic, and radiochemical analyses. The subcontracting of samples to other facilities, while infrequent, may occur when:

- The client has requested analytical services for which we are not certified or do not offer as a routine product.
- The regulatory or method holding times and/or client due dates are in danger of not being met as the result of instrument malfunction or the unexpected influx of a large group of samples.

No samples are subcontracted without the client's consent. The laboratories selected to receive subcontracted samples are expected to meet the following criteria:

- Demonstrated technical capability to provide data that meets and conforms to our quality standards.
- Established certification, if available, for the requested analyses.
- Successful proficiency evaluation results, if available.
- Commitment to meet time requirements for delivery of results to the client.
- Agreement to provide all documentation requested in conjunction with the analysis.
- NELAP accreditation for the analysis if it is covered or mandated under the NELAP Program.

We audit potential subcontractors for technical and administrative compliance as directed in GL-QS-E-001 for Conduct of Quality Audits. An audit may be in the form of a book audit instead of an on-site review.

If there is evidence of a technical, administrative, or quality deterioration, the laboratory is removed from our list of approved subcontractor laboratories pending further evaluation, which may include on on-site audit. Once the laboratory again demonstrates compliance with GEL's standards, it can be reclassified as an approved subcontractor laboratory.

At GEL, we have a multi-faceted and trained staff. There are occasions, however, when it may be necessary to obtain the services of professionals outside of GEL. This may be due to such things as sample workload, introduction of a new instrument or method requiring special knowledge, or employee leaves of absence.

Any outside support services or service personnel are subject to the same scrutiny as a subcontract laboratory. If a service fails to meet our standards for excellence, the appropriate parties are promptly notified. If immediate corrections are not implemented and services are not of adequate quality to maintain confidence, the contract is canceled.

SECTION 13
CLIENT SATISFACTION

Section 13 - Client Satisfaction

Meeting the needs and expectations of our clients is essential to meeting our commitment to be the environmental laboratory of first choice. An important part of meeting this commitment involves receiving and resolving client concerns and complaints.

Client complaints that question the quality of laboratory data or data deliverables are directed to Quality Systems. These concerns are responded to with input from the laboratory, EDD team or data packaging group as may be needed.

The types of complaints, area(s) affected, and any impacts on quality are trended on a quarterly basis. This information is available to members of the Leadership Team and other managers and group leaders.

We use ALPHA LIMS to monitor client complaints, nonconformances and corrective actions. Every complaint is entered into the system upon receipt and assigned an internal and external due date. The external due date is often established by client contract. The internal due date allows time for the Quality Systems Team to review the response and transmit it to the client on or before the due date.

If we notice a trend that significantly affects the quality of our data, a corrective action is initiated following GL-QS-E-002 for Conducting Corrective Action. The implementation and verification of the corrective action affirms an effective and permanent solution.

The Quality Systems Team promptly audits those areas of activity or responsibility for which a complaint or concern has been stated.

APPENDIX A: REFERENCES

National Environmental Laboratory Accreditation Program, NELAP, 2001.

10 CFR 50, Appendix B, US Code of Federal Regulations.

40 CFR Part 136, October 1984, Part VII, EPA 600 Series Methodologies for the Analysis of Organic Contaminants.

DOE Order 414.1, Quality Assurance, U.S. Department of Energy.

EPA Requirements for Quality Assurance Project Plans (QAPPs), US EPA QA/R5.

Model Statement of Work for Analytical Laboratories, Prepared for Department of Energy Albuquerque Operations Office by AGRA Earth and Environmental, Rev 4, February 2002.

Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs, American National Standard ANSI/ASQC E4-1994.

Measurement Associated Instrument Quality Assurance for Radiobioassay Laboratories ANSI N42.23-1995.

US Department of Defense Quality Systems Manual for Environmental Laboratories, June 2002.

US Department of Energy Quality Systems Manual for Analytical Services, Draft Revision B, July 2002.

APPENDIX B: DEFINITIONS

The following definitions are used throughout the text of our Quality Systems Plan. These definitions were reprinted from "Definitions for Quality Systems," NELAC, July 2, 1998. The original source of each definition is provided.

ALPHA LIMS: GEL's laboratory information management system.

Acceptance Criteria: specified limits placed on characteristics of an item, process, or service defined in the requirement documents. (ASQC)

Accreditation: the process by which an agency or organization evaluates and recognizes a program of study or an institution as meeting certain predetermined qualifications or standards, thereby accrediting the laboratory. In the context of the National Environmental Laboratory Accreditation Program (NELAP), this process is a voluntary one.

Accuracy: the degree of agreement between an observed value and an accepted reference value. Accuracy includes a combination of random error (precision) and systematic error (bias) components which are due to sampling and analytical operations; a data quality indicator. (Glossary of Quality Assurance Terms, QMAS, 8/31/92)

Analytical Detection Limit: the smallest amount of an analyte that can be distinguished in a sample by a given measurement procedure throughout a given (e.g., 0.95) confidence interval. (Applicable only to radiochemistry)

Analytical Reagent (AR) Grade: designation for the high purity of certain chemical reagents and solvents given by the American Chemical Society. (Quality Systems)

Batch: environmental samples, which are prepared and/or analyzed together with the same process and personnel, using the same lot(s) of reagents. A **preparation batch** is composed of one to 20 environmental samples of the same NELAC-defined matrix, meeting the above mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 24 hours. An **analytical batch** is composed of prepared environmental samples (extracts, digestates or concentrates) which are analyzed together as a group using the same calibration curve or factor. An analytical batch can include prepared samples originating from various environmental matrices and can exceed 20 samples. (Quality Systems)

Blank: a sample that has not been exposed to the analyzed sample stream in order to monitor contamination during sampling, transport, storage or analysis. The blank is subject to the usual analytical and measurement process to establish a zero baseline or background value and is sometimes used to adjust or correct routine analytical results. (ASQC, Definitions of environmental Quality Assurance Terms, 1996)

Blind Sample: a subsample for analysis with a composition known to the submitter. The analyst/laboratory may know the identity of the sample but not its composition. It is used to test the analyst's or laboratory's proficiency in the execution of the measurement process.

Calibrate: to determine, by measurement or comparison with a standard, the correct value of each scale reading on a meter or other device, or the correct value for each setting of a control knob. The levels of the applied calibration standard should bracket the range of planned or expected sample measurements.

Calibration: the set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, or values represented by a material measure, and the corresponding known values of a measurement. (VIM - 6.13)

Calibration Curve: the graphical relationship between the known values, such as concentrations, of a series of calibration standards and their analytical response.

Calibration Standard: a solution prepared from the primary dilution standard solution or stock standard solutions and the internal standards and surrogate analytes. The calibration solutions are used to calibrate the instrument response with respect to analyte concentration. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Certified Reference Material (CRM): a reference material one or more of whose property values are certified by a technically valid procedure, accompanied by or traceable to a certificate or other documentation which is issued by a certifying body. (ISO Guide 30 - 2.2)

Chain of Custody: an unbroken trail of accountability that documents the physical security of samples, data and records.

Confirmation: verification of the presence of a component through the use of an analytical technique that differs from the original test method. These may include:

Second column confirmation
Alternate wavelength
Derivatization
Mass spectral interpretation
Alternative detectors or
Additional cleanup procedures

Corrective Action: action taken to eliminate the causes of an existing nonconformity, defect or other undesirable situation in order to prevent recurrence. (ISO 8402)

Data Audit: a qualitative and quantitative evaluation of the documentation and procedures associated with environmental measurements to verify that the resulting data are of acceptable quality (i.e., that they meet specified acceptance criteria).

Data Reduction: the process of transforming raw data by arithmetic or statistical calculations, standard curves, concentration factors, etc., and collation into a more useful form.

Detection Limit: the lowest concentration or amount of the target analyte that can be determined to be different from zero by a single measurement at a stated degree of confidence. See Method Detection Limit.

Document Control: the act of ensuring that documents (and revisions thereto) are proposed, reviewed for accuracy, approved for release by authorized personnel, distributed properly and controlled to ensure use of the correct version at the location where the prescribed activity is performed. (ASQC, Definitions of Environmental Quality Assurance Terms, 1996)

Duplicate Analyses: the analyses or measurements of the variable of interest performed identically on two subsamples of the same sample. The results from duplicate analyses are used to evaluate analytical or measurement precision but not the precision of sampling, preservation or storage internal to the laboratory.

Environmental Detection Limit (EDL): the smallest level at which a radionuclide in an environmental medium can be unambiguously distinguished for a given confidence interval using a particular combination of sampling and measurement procedures, sample size, analytical detection limit, and processing procedure. The EDL shall be specified for the 0.95 or greater confidence interval. The EDL shall be established initially and verified annually for each test method and sample matrix. (NELAC, Radioanalysis Subcommittee)

Holding Times (Maximum Allowable Holding Times): the maximum times that samples may be held prior to analysis and still be considered valid. (40 CFR Part 136)

Initial Demonstration of Capability: procedure to establish the ability of the laboratory to generate acceptable accuracy and precision which is included in many of the EPA's analytical test methods. In general, the procedure includes the addition of a specified concentration of each analyte (using a QC check sample) in each of four separate aliquots of laboratory pure water. These are carried through the entire analytical procedure and the percentage recovery and the standard deviation are determined and compared to specified limits. (40 CFR Part 136)

Internal Standard: a known amount of standard added to a test portion of a sample and carried through the entire measurement process as a reference for evaluating and controlling the precision and bias of the applied analytical test method.

Laboratory: body that calibrates and/or tests.

NOTES:

1. In cases where a laboratory forms part of an organization that carries out other activities besides calibration and testing, the term "laboratory" refers only to those parts of that organization that are involved in the calibration and testing process.
2. As used herein, the term "laboratory" refers to a body that carries out calibration or testing
    - ◊ at or from a permanent location
    - ◊ at or from a temporary facility, or
    - ◊ in or from a mobile laboratory. (ISO 25)

Laboratory Control Sample: a sample matrix, free from the analytes of interest, spiked with verified known amounts of analytes from a source independent of the calibration standards or a material containing known and verified amounts of analytes. It is generally used to establish intra-laboratory or analyst specific precision and bias to assess the performance of all or a portion of the measurement system. (NELAC)

Laboratory Duplicate: aliquots of a sample taken from the same container under laboratory conditions and processed and analyzed independently.

Legal Chain of Custody (COC): an unbroken trail of accountability that ensures the physical security of samples, data and records. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Limit of Detection (LOD): the lowest concentration level that can be determined by a single analysis and with a defined level of confidence to be statistically different from a blank. (Analytical Chemistry, 55, p.2217, Dec. 1983, modified)(See also Method Detection Limit.)

Matrix: the component or substrate that contains the analyte of interest. For purposes of batch determination, the following matrix types shall be used:

- ◊ Aqueous: any aqueous sample excluded from the definition of a drinking water matrix or saline/estuarine source. Includes surface water, groundwater and effluents.
- ◊ Drinking Water: any aqueous sample that has been designated a potable or potential potable water source.
- ◊ Saline/Estuarine: any aqueous sample from an ocean or estuary, or other salt-water source.
- ◊ Non-aqueous liquid: any organic liquid with <15% settleable solids.
- ◊ Biological Tissue: any sample of a biological origin such as fish tissue, shellfish, or plant material. Such samples shall be grouped according to origin.
- ◊ Solids: includes soils, sediments, sludges and other matrices with >15% settleable solids.
- ◊ Chemical Waste: a product or by-product of an industrial process.
- ◊ Air Samples: media used to retain the analyte of interest from an air sample such as sorbent tubes or summa canisters. Each medium shall be considered as a distinct matrix. (Quality Systems)

Matrix Spike: prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Matrix spikes are used, for example, to determine the effect of the matrix on a method's recovery efficiency. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Matrix Spike Duplicate (spiked sample/fortified sample duplicate): a second replicate matrix spike is prepared in the laboratory and analyzed to obtain a measure of the precision of the recovery for each analyte. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

May: permitted, but not required. (TRADE)

Method Blank: a sample of a matrix similar to the batch of associated samples (when available) that is free from the analytes of interest and is processed simultaneously with and under the same conditions as samples containing an analyte of interest through all steps of the analytical procedures. (NELAC)

Method Detection Limit: the minimum concentration of a substance (an analyte) that can be measured and reported with 99% confidence that the analyte concentration is greater that zero and is determined from analysis of a sample in a given matrix containing the analyte. (40 CFR Part 136 Appendix B)

Must: denotes a requirement that must be met. (Random House College Dictionary)

Negative Control: measures taken to ensure that a test, its components, or the environment do not cause undesired effects, or produce incorrect test results.

NELAC: National Environmental Laboratory Accreditation Conference. A voluntary organization of state and federal environmental officials and interest groups purposed primarily to establish mutually acceptable standards for accrediting environmental laboratories. A subset of National Environmental Laboratory Accreditation Program.

Performance Audit: the routine comparison of independently obtained quantitative measurement system data with routinely obtained data in order to evaluate the proficiency of an analyst or laboratory.

Performance Based Measurement System (PBMS): a set of processes wherein the data quality needs, mandates or limitations of a program or project are specified and serve as criteria for selecting appropriate test methods to meet those needs in a cost-effective manner.

Positive Control: measures taken to ensure that a test and/or its components are working properly and producing correct or expected results from positive test subjects.

Precision: the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves; a data quality indicator. Precision is usually expressed as standard deviation, variance or range, in either absolute or relative terms. (NELAC)

Preservation: refrigeration and or reagents added at the time of sample collection to maintain the chemical and or biological integrity of the sample.

Proficiency Test Sample (PT): a sample, the composition of which is unknown to the analyst and is provided to test whether the analyst/laboratory can produce analytical results within specified acceptance criteria. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Proficiency Testing: determination of the laboratory calibration or testing performance by means of inter-laboratory comparisons. (ISO/IEC Guide 2 - 12.6, amended)

Proficiency Testing Program: the aggregate of providing rigorously controlled and standardized environmental samples to a laboratory for analysis, reporting of results, statistical evaluation of the results in comparison to peer laboratories and the collective demographics and results summary of all participating laboratories.

Protocol: a detailed written procedure for field and/or laboratory operation (e.g., sampling, analysis) that must be strictly followed.

Pure Reagent Water: shall be water in which no target analytes or interferences are present at a concentration which would impact the results when using a particular analytical test method.

Quality Assurance: an integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality within a stated level of confidence. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Quality Control: the overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the need of users. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Quality Manual: a document stating the quality policy, quality system and quality practices of an organization. This may also be called a Quality Assurance Plan or a Quality Plan. NOTE: the quality manual may call up other documentation relating to the laboratory's quality arrangements.

Quality System: a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, and assessing work performed by the organization and for carrying out required QA and QC. (ANSI/ASQC E-41994)

Quantitation Limits: the maximum or minimum levels, concentrations, or quantities of a target variable (e.g., target analyte) that can be quantified with the confidence level required by the data user. For organic and general chemistry

Range: the difference between the minimum and the maximum set of values.

Raw Data: any original factual information from a measurement activity or study recorded in a laboratory notebook, worksheets, records, memoranda, notes, or exact copies thereof that are necessary for the reconstruction and evaluation of the report of the activity or study. Raw data may include photography, microfilm or microfiche copies, computer printouts, magnetic media, including dictated observations, and recorded data from automated instruments. If exact copies of raw data have been prepared (e.g., tapes, which have been transcribed verbatim, dated and verified accurate by signature), the exact copy or exact transcript may be submitted.

Reagent Blank (method reagent blank): a sample consisting of reagent(s), without the target analyte or sample matrix, introduced into the analytical procedure at the appropriate point and carried through all subsequent steps to determine the contribution of the reagents and of the involved analytical steps. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Reference Material: a material or substance one or more properties of which are sufficiently well established to be used for the calibration of an apparatus, the assessment of a measurement method, or for assigning values to materials. (ISO Guide 30 -2.1)

Reference Standard: a standard, generally of the highest metrological quality available at a given location, from which measurements made at that location are derived. (VIM - 6.08)

Requirement: a translation of the needs into a set of individual quantified or descriptive specifications for the characteristics of an entity in order to enable its realization and examination.

Selectivity: (Analytical chemistry) the capability of a test method or instrument to respond to a target substance or constituent in the presence of non-target substances.

Sensitivity: the capability of a test method or instrument to discriminate between measurement responses representing different levels (e.g., concentrations) of a variable of interest.

Shall: denotes a requirement that is mandatory whenever the criterion for conformance with the specification requires that there will be no deviation. This does not prohibit the use of alternative approaches or methods for implementing the specification so long as the requirement is fulfilled. (*Style Manual for Preparation of Proposed American National Standards*, American National Standards Institute, eighth edition, March 1991P)

Should: denotes a guideline or recommendation whenever noncompliance with the specification is permissible. (*Style Manual for Preparation of Proposed American National Standards*, American National Standards Institute, eighth edition, March 1991P)

Standard Operating Procedures (SOPs): a written document which details the method of an operation, analysis or action whose techniques and procedures are thoroughly prescribed and which is accepted as the method for performing certain routine or repetitive tasks. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Spike: a known mass of target analyte added to a blank sample or subsample; used to determine recovery efficiency or for other quality control purposes.

Standard Reference Material (SRM): a certified reference material produced by the U.S. National Institute of Standards and Technology and characterized for absolute content, independent of analytical test method.

Surrogate: a substance with properties that mimic the analyte of interest. It is unlikely to be found in environment samples and is added to them for quality control purposes. (Glossary of Quality Assurance Terms, QAMS, 8/31/92)

Test: a technical operation that consists of the determination of one or more characteristics or performance of a given product, material equipment, organism, physical phenomenon, process or service according to a specified procedure.

NOTE: the result of a test is normally recorded in a document sometimes called a test report or a test certificate. (ISO/IEC Guide 2 - 12.4)

Test Method: defined technical procedure for performing a test.

Tolerance Chart: a chart in which the plotted quality control data is assessed via a tolerance level (e.g. +/- 10% of a mean) based on the precision level judged acceptable to meet overall quality/data use requirements instead of a statistical acceptance criteria (e.g. +/-3 sigma). (ANSI N42.23-1995, Measurement and Associated Instrument Quality Assurance for Radiochemistry Laboratories)

Traceability: the property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparisons.

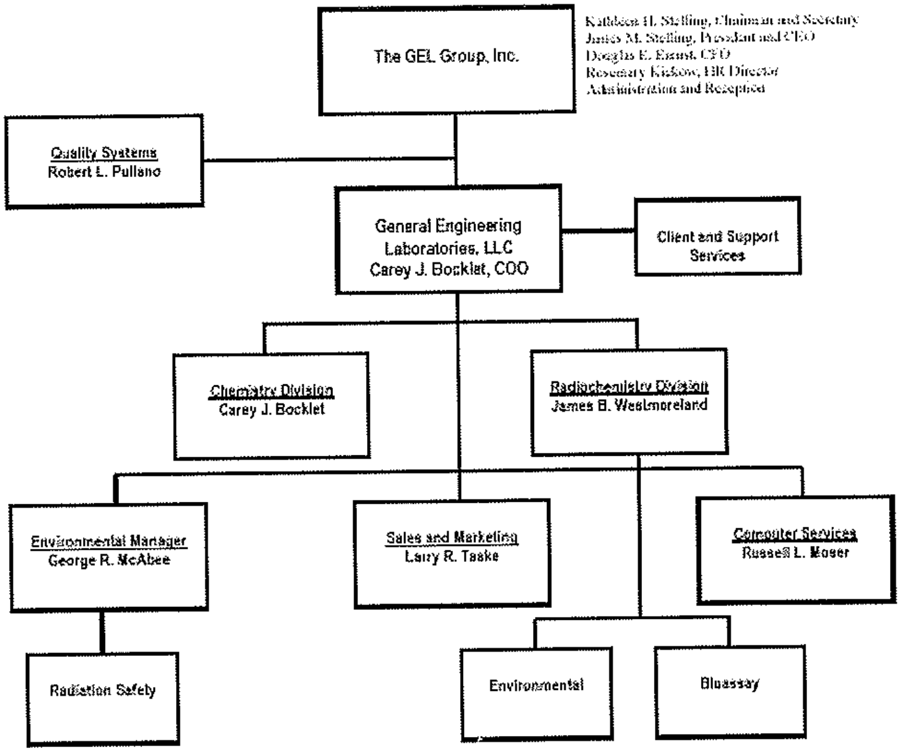
Verification: confirmation by examination and provision of evidence that specified requirements have been met.

NOTE: In connection with the management of measuring equipment, verification provides a means for checking that the deviations between values indicated by a measuring instrument and corresponding known values of a measured quantity are consistently smaller than the maximum allowable error defined in a standard, regulation or specification peculiar to the management of the measuring equipment.

The result of verification leads to a decision either to restore in service, to perform adjustments, or to repair, or to downgrade, or to declare obsolete. In all cases it is required that a written trace of the verification performed shall be kept on the measuring instrument's individual record.

Validation: the process of substantiating specified performance criteria.

APPENDIX C: CORPORATE ORGANIZATION CHART



APPENDIX D: CERTIFICATIONS

General Engineering Laboratories, LLC (GEL) maintains environmental laboratory certification in many states, including primary NELAP in Florida and secondary NELAP in Utah, New York, California and New Jersey. *Because the status of a certification may change, please call to confirm the status of any certification of interest to you*

- **U.S. Army Corps of Engineers** (USACE) - Validation by the Hazardous, Toxic and Radioactive Waste (HTRW) Center of Expertise
- **U.S. Navy** approval for Naval Facilities Command Southern Division Remedial Action Contract
- **U.S. Department of Agriculture** Foreign soil importation permit # S-52597
- **National Environmental Laboratory Accreditation Program (NELAP)** Primary issued through the State of Florida - Department of Health – Bureau of Laboratories; Secondary issued through the States of California, Illinois, Kansas, New York, New Jersey , Pennsylvania and Utah
- **Clinical Laboratory Improvement Amendments (CLIA)** U.S. Department of Health and Human Services Certificate of Compliance for Acceptance of Human Specimens (GEL ID: 42D0904046) (Radiobioassay)

- **Alaska Contaminated Sites Program** Department of Environmental Conversation, including UST/LUST.
- **Arkansas** Department of Environmental Quality Laboratory Certification Program for Wastewater, Groundwater, Solid Waste (Lab ID 88-0651)
- **California** Secondary NELAP Certification for Drinking Water, Wastewater, Hazardous Waste and Radiochemistry (Laboratory ID No. 01151CA)
- **Colorado** Department of Public Health and Environment, Reciprocal Certification to SC DHEC Environmental Laboratory Certification Program for Safe Drinking Water Chemistry and Radiochemistry
- **Connecticut** Department of Public Health, Bureau of Regulatory Services - Potable Water, Waste Water, Solid Waste, Soil, and Radiochemistry (GEL ID: PH-0169)
- **Delaware** Health and Social Services, Office of Drinking Water, Drinking Water Compliance
- **Florida** Department of Health, Bureau of Laboratories, Primary NELAP Certification, Safe Drinking Water, Clean Water Act, RCRA and Radiochemistry (Laboratory ID No. 87156)
- **Georgia** Department of Natural Resources, Reciprocal NELAP Certification, Drinking Water, Non-potable Water, and Solid/Hazardous Waste
- **Idaho** Department of Health and Welfare, Division of Health, Bureau of Laboratories, Safe Drinking Water forInorganics, Volatile Organics and Radiologicals
- **Illinois** Environmental Protection Agency, Secondary NELAP Certification for Drinking Water, Wastewater, Hazardous Waste and Radiochemistry (Certificate No. 000732)
- **Kansas** Department of Health and Environment, Secondary NELAP Certification for Wastewater and Solid/Hazardous Waste (Certificate No. E-10332)
- **Kentucky** Department of Environmental Protection, Division of Environmental Services, Chemical Analysis of Drinking Water (Laboratory ID No. 90129)
- **Maryland** Department of Health and Mental Hygiene, Laboratories Administration, Water QualityRadiologicals (Certification No. 270)
- **Michigan** Department of Environmental Quality, Drinking Water & Radiological Protection Division, Safe Drinking Water for Inorganic Chemistry (Laboratory ID No. 9903)
- **Nevada** Department of Human Resources, Health Division, Bureau of Licensure and Certification, Clean Water Chemistry and Drinking Water Radiochemistry

- **New Jersey** Department of Environmental Protection, Secondary NELAP Certification for Safe Drinking Water, Solid and Hazardous Waste, Water Pollution and Radiochemistry (Laboratory ID No. SC002)
- **New York** Department of Health, Secondary NELAP Certification for Potable Water, Non-potable Water, Solids/Hazardous Waste and Radiochemistry (Laboratory ID No. 11501)
- **North Carolina** Department of the Environment and Natural Resources, Division of Water Quality, Wastewater/Ground Water (Certificate No. 233)
- **North Dakota** Department of Health, Chemistry Division, Safe Drinking Water, Clean Water, RCRA/CERCLA and Radiochemistry (Certificate No. R-158)
- **Oklahoma** Department of Environmental Quality, General Water Quality/Sludge Testing (Laboratory ID No. 9904)
- **Pennsylvania** Department of Environmental Protection, Bureau of Laboratories, Secondary NELAP Certification for Radiochemistry Safe Drinking Water (Laboratory ID No. 68-485)
- **South Carolina** Department of Health and Environmental Control, Environmental Laboratory Certification Program, Clean Water, Safe Drinking Water, Solid/Hazardous Wastes, and Radiochemistry (Certificate No. 10120001)
- **South Carolina** Department of Health and Environmental Control (DHEC) Radioactive Material License (License No. 362)
- **Tennessee** Department of Health, Division of Laboratory Services, Drinking Water, Organics, Inorganics and Radionuclides (Laboratory ID No. 02934)
- **Texas** Commission on Environmental Quality, Public Drinking Water Laboratory Certification Program, Drinking Water, including Radiochemistry (Certificate No. TX 213-2002A)
- **Utah** Department of Health, Division of Epidemiology and Laboratory Services, Secondary NELAP Certification for Safe Drinking Water, Clean Water and RCRA including Radiochemistry (Laboratory ID: GEL)
- **Vermont** Department of Environmental Conservation, Water Supply Division, Drinking Water Certification, Organics, Inorganics and Radionuclides
- **Virginia** Department of General Services, Division of Consolidated Laboratory Services, Safe Drinking Water including Radiologicals (Laboratory ID No. 00151)
- **Washington** Department of Ecology, Non-Potable Water Analyses including Radiochemistry (Laboratory Accreditation No. C223)
- **Wisconsin** Department of Natural Resources, Drinking Water and Clean Water (Laboratory ID No. 999887790)

APPENDIX E: PRECISION AND ACCURACY CONTROL LIMITS

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
BNA CLP Solids, OLM 4.2 CLP BNA - OLM 3.1 CLP BNA -									
1,2,4-Trichlorobenzene	NA	38 - 107	0 - 23	38.2 - 109.8	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	35.1 - 109.5	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene-d4	NA	NA	NA	NA	NA	NA	NA	20 - 130	NA
1,2-Diphenylhydrazine	NA	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	28 - 104	0 - 27	41.8 - 103	0 - 30	NA	NA	NA	NA
1,4-Dioxane	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2,4,5-Trichlorophenol	NA	NA	NA	58.4 - 99.3	0 - 30	NA	NA	NA	NA
2,4,6-Tribromophenol	NA	NA	NA	NA	NA	NA	NA	19 - 122	NA
2,4,6-Trichlorophenol	NA	NA	NA	52.7 - 97.7	0 - 30	NA	NA	NA	NA
2,4-Dichlorophenol	NA	NA	NA	50.8 - 98.2	0 - 30	NA	NA	NA	NA
2,4-Dimethylphenol	NA	NA	NA	53.3 - 92.2	0 - 30	NA	NA	NA	NA
2,4-Dinitrophenol	NA	NA	NA	21.1 - 113.4	0 - 30	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	28 - 89	0 - 47	56.5 - 119.2	0 - 30	NA	NA	NA	NA
2,6-Dinitrotoluene	NA	NA	NA	59.6 - 98.9	0 - 30	NA	NA	NA	NA
2-Chloronaphthalene	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Chlorophenol	NA	25 - 102	0 - 50	45.5 - 95.2	0 - 30	NA	NA	NA	NA
2-Chlorophenol-d4	NA	NA	NA	NA	NA	NA	NA	20 - 130	NA
2-Fluorobiphenyl	NA	NA	NA	NA	NA	NA	NA	30 - 115	NA
2-Fluorophenol	NA	NA	NA	NA	NA	NA	NA	25 - 121	NA
2-Methyl-4,6-dinitrophenol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	34.3 - 109.4	0 - 30	NA	NA	NA	NA
2-Nitrophenol	NA	NA	NA	44.9 - 99.8	0 - 30	NA	NA	NA	NA
3,3'-Dichlorobenzidine	NA	NA	NA	34.5 - 129.6	0 - 30	NA	NA	NA	NA
4-Bromophenylphenylether	NA	NA	NA	58.7 - 113.3	0 - 30	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	26 - 103	0 - 33	57.5 - 100.9	0 - 30	NA	NA	NA	NA
4-Chloroaniline	NA	NA	NA	8.8 - 76.2	0 - 30	NA	NA	NA	NA
4-Chlorophenylphenylether	NA	NA	NA	52.0 - 112.9	0 - 30	NA	NA	NA	NA
4-Nitrophenol	NA	11 - 114	0 - 50	30.4 - 135.9	0 - 30	NA	NA	NA	NA
Acenaphthene	NA	31 - 137	0 - 19	48.2 - 107.6	0 - 30	NA	NA	NA	NA
Acenaphthylene	NA	NA	NA	42.7 - 112.2	0 - 30	NA	NA	NA	NA
Anthracene	NA	NA	NA	61.1 - 106.8	0 - 30	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	45.3 - 111.9	0 - 30	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	65.4 - 105	0 - 30	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	53.3 - 116.8	0 - 30	NA	NA	NA	NA
Benzo(ghi)perylene	NA	NA	NA	46.1 - 125.4	0 - 30	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	50.2 - 121.9	0 - 30	NA	NA	NA	NA
Benzoic acid	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Benzyl alcohol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Butylbenzylphthalate	NA	NA	NA	49.7 - 110.7	0 - 30	NA	NA	NA	NA
Chrysene	NA	NA	NA	22.2 - 144.9	0 - 30	NA	NA	NA	NA
Di-n-butylphthalate	NA	NA	NA	66.9 - 111.8	0 - 30	NA	NA	NA	NA
Di-n-octylphthalate	NA	NA	NA	61.4 - 119.3	0 - 30	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	52.3 - 120.1	0 - 30	NA	NA	NA	NA
Dibenzofuran	NA	NA	NA	47.6 - 113.2	0 - 30	NA	NA	NA	NA
Diethylphthalate	NA	NA	NA	62.2 - 106.7	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Dimethylphthalate	NA	NA	NA	58.1 - 100.6	0 - 30	NA	NA	NA	NA
Diphenylamine	NA	NA	NA	71.4 - 109.5	0 - 30	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	63.4 - 104.9	0 - 30	NA	NA	NA	NA
Fluorene	NA	NA	NA	49.7 - 113.5	0 - 30	NA	NA	NA	NA
Hexachlorobenzene	NA	NA	NA	57.8 - 112.5	0 - 30	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	40.9 - 111	0 - 30	NA	NA	NA	NA
Hexachlorocyclopentadiene	NA	NA	NA	21.2 - 104.2	0 - 30	NA	NA	NA	NA
Hexachloroethane	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA	34.1 - 135.5	0 - 30	NA	NA	NA	NA
Isophorone	NA	NA	NA	28.4 - 115.4	0 - 30	NA	NA	NA	NA
N-Nitrosodipropylamine	NA	41 - 126	0 - 38	14.9 - 116.2	0 - 30	NA	NA	NA	NA
Naphthalene	NA	NA	NA	38.2 - 113	0 - 30	NA	NA	NA	NA
Nitrobenzene	NA	NA	NA	37.4 - 109.8	0 - 30	NA	NA	NA	NA
Nitrobenzene-d5	NA	NA	NA	NA	NA	NA	NA	23 - 120	NA
Pentachlorophenol	NA	17 - 109	0 - 47	45.4 - 102.6	0 - 30	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	58.2 - 110.6	0 - 30	NA	NA	NA	NA
Phenol	NA	26 - 90	0 - 35	36.2 - 99.7	0 - 30	NA	NA	NA	NA
Phenol-d5	NA	NA	NA	NA	NA	NA	NA	24 - 113	NA
Pyrene	NA	35 - 142	0 - 36	50.7 - 110.4	0 - 30	NA	NA	NA	NA
bis(2-Chloroethoxy)methane	NA	NA	NA	36.2 - 108	0 - 30	NA	NA	NA	NA
bis(2-Chloroethyl) ether	NA	NA	NA	28.0 - 102.9	0 - 30	NA	NA	NA	NA
bis(2-Chloroisopropyl)ether	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	45.2 - 136.7	0 - 30	NA	NA	NA	NA
m,p-Cresols	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
m-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
o-Cresol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
o-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
p-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
p-Terphenyl-d14	NA	NA	NA	NA	NA	NA	NA	18 - 137	NA
BNA CLP Waters, OLM 4.2 CLP BNA - OLM 3.1 CLP BNA -									
1,2,4-Trichlorobenzene	NA	39 - 98	0 - 28	39 - 97	0 - 28	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	39.3 - 97.2	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene-d4	NA	NA	NA	NA	NA	NA	NA	16 - 110	NA
1,2-Diphenylhydrazine	NA	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	34.7 - 91.8	0 - 30	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	36 - 97	0 - 28	27 - 123	0 - 28	NA	NA	NA	NA
1,4-Dioxane	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2,4,5-Trichlorophenol	NA	NA	NA	63.4 - 95.9	0 - 30	NA	NA	NA	NA
2,4,6-Tribromophenol	NA	NA	NA	NA	NA	NA	NA	10 - 123	NA
2,4,6-Trichlorophenol	NA	NA	NA	62.1 - 94.2	0 - 30	NA	NA	NA	NA
2,4-Dichlorophenol	NA	NA	NA	55.8 - 95.9	0 - 30	NA	NA	NA	NA
2,4-Dimethylphenol	NA	NA	NA	14.7 - 123.1	0 - 30	NA	NA	NA	NA
2,4-Dinitrophenol	NA	NA	NA	25.1 - 150.2	0 - 30	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	24 - 96	0 - 38	24 - 96	0 - 30	NA	NA	NA	NA
2,6-Dinitrotoluene	NA	NA	NA	64.5 - 106.7	0 - 38	NA	NA	NA	NA
2-Chloronaphthalene	NA	NA	NA	53.8 - 96.9	0 - 30	NA	NA	NA	NA
2-Chlorophenol	NA	27 - 123	0 - 40	36.9 - 94.1	0 - 40	NA	NA	NA	NA
2-Chlorophenol-d4	NA	NA	NA	NA	NA	NA	NA	33 - 110	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
2-Fluorobiphenyl	NA	NA	NA	NA	NA	NA	NA	43 - 116	NA
2-Fluorophenol	NA	NA	NA	NA	NA	NA	NA	21 - 110	NA
2-Methyl-4,6-dinitrophenol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Methylnaphthalene	NA	NA	NA	48.2 - 97.8	0 - 30	NA	NA	NA	NA
2-Nitrophenol	NA	NA	NA	49.4 - 101.2	0 - 30	NA	NA	NA	NA
3,3'-Dichlorobenzidine	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
4-Bromophenylphenylether	NA	NA	NA	65.6 - 103.6	0 - 30	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	23 - 97	0 - 42	23 - 97	0 - 42	NA	NA	NA	NA
4-Chloroaniline	NA	NA	NA	8.5 - 122.5	0 - 30	NA	NA	NA	NA
4-Chlorophenylphenylether	NA	NA	NA	64.9 - 103.8	0 - 30	NA	NA	NA	NA
4-Nitrophenol	NA	Oct-80	0 - 50	Oct-80	0 - 50	NA	NA	NA	NA
Acenaphthene	NA	46 - 118	0 - 31	46 - 118	0 - 31	NA	NA	NA	NA
Acenaphthylene	NA	NA	NA	57.4 - 100.1	0 - 30	NA	NA	NA	NA
Anthracene	NA	NA	NA	67.6 - 104.5	0 - 30	NA	NA	NA	NA
Benzo(a)anthracene	NA	NA	NA	61.7 - 105.1	0 - 30	NA	NA	NA	NA
Benzo(a)pyrene	NA	NA	NA	67.1 - 105.4	0 - 30	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	NA	NA	62.0 - 105.4	0 - 30	NA	NA	NA	NA
Benzo(ghi)perylene	NA	NA	NA	42.3 - 129.6	0 - 30	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	NA	NA	65.8 - 109.5	0 - 30	NA	NA	NA	NA
Benzoic acid	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Benzyl alcohol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Butylbenzylphthalate	NA	NA	NA	39.8 - 117.3	0 - 30	NA	NA	NA	NA
Chrysene	NA	NA	NA	56.5 - 110.5	0 - 30	NA	NA	NA	NA
Di-n-butylphthalate	NA	NA	NA	57.8 - 115.4	0 - 30	NA	NA	NA	NA
Di-n-octylphthalate	NA	NA	NA	49.0 - 126.1	0 - 30	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	NA	NA	58.6 - 117.7	0 - 30	NA	NA	NA	NA
Dibenzofuran	NA	NA	NA	60.0 - 109.2	0 - 30	NA	NA	NA	NA
Diethylphthalate	NA	NA	NA	17.8 - 144.4	0 - 30	NA	NA	NA	NA
Dimethylphthalate	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Diphenylamine	NA	NA	0 - 38	59.2 - 114.4	0 - 30	NA	NA	NA	NA
Fluoranthene	NA	NA	NA	67.6 - 104.4	0 - 30	NA	NA	NA	NA
Fluorene	NA	NA	NA	62.4 - 107.7	0 - 30	NA	NA	NA	NA
Hexachlorobenzene	NA	NA	NA	66.9 - 107.1	0 - 30	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	40.1 - 101.9	0 - 30	NA	NA	NA	NA
Hexachlorocyclopentadiene	NA	NA	NA	12.4 - 95.3	0 - 30	NA	NA	NA	NA
Hexachloroethane	NA	NA	NA	25.4 - 100.5	0 - 30	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	NA	NA	59.6 - 130.2	0 - 30	NA	NA	NA	NA
Isophorone	NA	NA	NA	48.0 - 109.5	0 - 30	NA	NA	NA	NA
N-Nitrosodipropylamine	NA	41 - 116	NA	41 - 116	0 - 38	NA	NA	NA	NA
Naphthalene	NA	NA	NA	55.9 - 94.9	0 - 30	NA	NA	NA	NA
Nitrobenzene	NA	NA	NA	56.3 - 100.3	0 - 30	NA	NA	NA	NA
Nitrobenzene-d5	NA	NA	NA	NA	NA	NA	NA	35 - 114	NA
Pentachlorophenol	NA	9 - 103	0 - 50	9 - 103	0 - 50	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	67.7 - 104	0 - 30	NA	NA	NA	NA
Phenol	NA	12 - 110	0 - 42	12 - 110	0 - 42	NA	NA	NA	NA
Phenol-d5	NA	NA	NA	NA	NA	NA	NA	10 - 110	NA
Pyrene	NA	26 - 127	0 - 31	26 - 127	0 - 31	NA	NA	NA	NA
bis(2-Chloroethoxy)methane	NA	NA	NA	47.5 - 101.2	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
bis(2-Chloroethyl) ether	NA	NA	NA	39.7 - 93.5	0 - 30	NA	NA	NA	NA
bis(2-Chloroisopropyl)ether	NA	NA	NA	13.7 - 119.3	0 - 30	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	35.2 - 137.7	0 - 30	NA	NA	NA	NA
m,p-Cresols	NA	NA	NA	11.2 - 108.2	0 - 30	NA	NA	NA	NA
m-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
o-Cresol	NA	NA	NA	17.7 - 100.9	0 - 30	NA	NA	NA	NA
o-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
p-Nitroaniline	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
p-Terphenyl-d14	NA	NA	NA	NA	NA	NA	NA	33 - 141	NA
VOA CLP Solids, OLM 4.2 CLP Volatile - OLM 3.1 CLP Volatile - OLM 3.1 CLP Prep -									
1,1,1,2-Tetrachloroethane	NA	NA	NA	79 - 121	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	73 - 127	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	65 - 134	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	NA	NA	NA	71 - 124	NA	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	70 - 131	NA	NA	NA	NA	NA
1,1-Dichloroethylene	NA	59 - 172	0 - 22	70 - 144	NA	82 - 136	0 - 30	NA	NA
1,1-Dichloropropene	NA	NA	NA	72 - 136	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	NA	NA	NA	67 - 130	NA	NA	NA	NA	NA
1,2,3-Trichloropropane	NA	NA	NA	67 - 130	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	NA	NA	NA	62 - 134	NA	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	59 - 127	NA	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	NA	NA	NA	60 - 135	NA	NA	NA	NA	NA
1,2-Dibromoethane	NA	NA	NA	74 - 128	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	73 - 111	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	74 - 123	NA	NA	NA	NA	NA
1,2-Dichloroethane-d4	NA	NA	NA	NA	NA	NA	NA	70 - 121	NA
1,2-Dichloropropane	NA	NA	NA	73 - 133	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	53 - 123	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	67 - 127	NA	NA	NA	NA	NA
1,3-Dichloropropane	NA	NA	NA	62 - 134	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	66 - 127	NA	NA	NA	NA	NA
2,2-Dichloropropane	NA	NA	NA	71 - 135	NA	NA	NA	NA	NA
2-Butanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Chlorotoluene	NA	NA	NA	69 - 119	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	92 - 154	NA	NA	NA	NA	NA
4-Chlorotoluene	NA	NA	NA	65 - 117	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	83 - 138	NA	NA	NA	NA	NA
Acetone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Benzene	NA	66 - 142	0 - 21	74 - 133	NA	85 - 126	0 - 30	NA	NA
Benzyl chloride	NA	NA	NA	55 - 159	NA	NA	NA	NA	NA
Bromobenzene	NA	NA	NA	71 - 119	NA	NA	NA	NA	NA
Bromochloromethane	NA	NA	NA	67 - 142	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	73 - 116	NA	NA	NA	NA	NA
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	59 - 113	NA
Bromoform	NA	NA	NA	66 - 135	NA	NA	NA	NA	NA
Bromomethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Carbon tetrachloride	NA	NA	NA	69 - 133	NA	NA	NA	NA	NA
Chlorobenzene	NA	60 - 133	0 - 21	78 - 118	NA	70 - 115	0 - 30	NA	NA
Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank

Chloroethane	NA	NA	NA	62 - 125	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	71 - 118	NA	NA	NA	NA	NA
Chloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dibromochloromethane	NA	NA	NA	73 - 120	NA	NA	NA	NA	NA
Dichlorodifluoromethane	NA	NA	NA	49 - 88	NA	NA	NA	NA	NA
Ethylbenzene	NA	NA	NA	73 - 118	NA	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	58 - 114	NA	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	67 - 125	NA	NA	NA	NA	NA
Isopropyltoluene	NA	NA	NA	62 - 127	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	52 - 152	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	53 - 137	NA	NA	NA	NA	NA
Styrene	NA	NA	NA	74 - 123	NA	NA	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Toluene	NA	59 - 139	0 - 21	79 - 129	NA	73 - 117	0 - 30	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	84 - 138	NA
Trichloroethylene	NA	62 - 137	0 - 24	69 - 127	NA	70 - 130	0 - 30	NA	NA
Trichlorofluoromethane	NA	NA	NA	54 - 111	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	64 - 111	NA	NA	NA	NA	NA
cis-1,2-Dichloroethylene	NA	NA	NA	71 - 134	NA	NA	NA	NA	NA
cis-1,3-Dichloropropylene	NA	NA	NA	59 - 138	NA	NA	NA	NA	NA
m,p-Xylenes	NA	NA	NA	74 - 122	NA	NA	NA	NA	NA
n-Butylbenzene	NA	NA	NA	56 - 139	NA	NA	NA	NA	NA
n-Propylbenzene	NA	NA	NA	63 - 120	NA	NA	NA	NA	NA
o-Xylene	NA	NA	NA	70 - 122	NA	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	64 - 126	NA	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	67 - 116	NA	NA	NA	NA	NA
trans-1,2-Dichloroethylene	NA	NA	NA	66 - 128	NA	NA	NA	NA	NA
trans-1,3-Dichloropropylene	NA	NA	NA	60 - 129	NA	NA	NA	NA	NA
VOA CLP Waters, OLM 4.2 CLP Volatile - OLM 3.1 CLP Volatile -									
1,1,1,2-Tetrachloroethane	NA	NA	NA	79 - 121	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	73 - 127	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	65 - 134	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	NA	NA	NA	71 - 124	NA	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	70 - 131	NA	NA	NA	NA	NA
1,1-Dichloroethylene	NA	NA	NA	70 - 144	NA	61 - 145	0 - 14	NA	NA
1,1-Dichloropropene	NA	NA	NA	72 - 136	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	NA	NA	NA	67 - 130	NA	NA	NA	NA	NA
1,2,3-Trichloropropane	NA	NA	NA	67 - 130	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	NA	NA	NA	62 - 134	NA	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	59 - 127	NA	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	NA	NA	NA	60 - 135	NA	NA	NA	NA	NA
1,2-Dibromoethane	NA	NA	NA	74 - 128	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	73 - 111	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	74 - 123	NA	NA	NA	NA	NA
1,2-Dichloroethane-d4	NA	NA	NA	NA	NA	NA	NA	76 - 114	NA
1,2-Dichloropropane	NA	NA	NA	73 - 133	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	53 - 123	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	67 - 127	NA	NA	NA	NA	NA
Parameter	**Duplicate**	**MS**	**MSD**	**LCS**	**LCSD**	**PS**	**PSD**	**Yield**	**Blank**
1,3-Dichloropropane	NA	NA	NA	62 - 134	NA	NA	NA	NA	NA

1,4-Dichlorobenzene	NA	NA	NA	66 - 127	NA	NA	NA	NA	NA
2,2-Dichloropropane	NA	NA	NA	71 - 135	NA	NA	NA	NA	NA
2-Butanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Chlorotoluene	NA	NA	NA	69 - 119	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	92 - 154	NA	NA	NA	NA	NA
4-Chlorotoluene	NA	NA	NA	65 - 117	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	83 - 138	NA	NA	NA	NA	NA
Acetone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	74 - 133	NA	76 - 127	0 - 11	NA	NA
Benzyl chloride	NA	NA	NA	55 - 159	NA	NA	NA	NA	NA
Bromobenzene	NA	NA	NA	71 - 119	NA	NA	NA	NA	NA
Bromochloromethane	NA	NA	NA	67 - 142	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	73 - 116	NA	NA	NA	NA	NA
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	86 - 115	NA
Bromoform	NA	NA	NA	66 - 135	NA	NA	NA	NA	NA
Bromomethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Carbon tetrachloride	NA	NA	NA	69 - 133	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	78 - 118	NA	75 - 130	0 - 13	NA	NA
Chloroethane	NA	NA	NA	62 - 125	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	71 - 118	NA	NA	NA	NA	NA
Chloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dibromochloromethane	NA	NA	NA	73 - 120	NA	NA	NA	NA	NA
Dichlorodifluoromethane	NA	NA	NA	49 - 88	NA	NA	NA	NA	NA
Ethylbenzene	NA	NA	NA	73 - 118	NA	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	58 - 114	NA	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	67 - 125	NA	NA	NA	NA	NA
Isopropyltoluene	NA	NA	NA	62 - 127	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	52 - 152	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	53 - 137	NA	NA	NA	NA	NA
Styrene	NA	NA	NA	74 - 123	NA	NA	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	79 - 129	NA	76 - 125	0 - 13	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	88 - 110	NA
Trichloroethylene	NA	NA	NA	69 - 127	NA	71 - 120	0 - 14	NA	NA
Trichlorofluoromethane	NA	NA	NA	54 - 111	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	64 - 111	NA	NA	NA	NA	NA
cis-1,2-Dichloroethylene	NA	NA	NA	71 - 134	NA	NA	NA	NA	NA
cis-1,3-Dichloropropylene	NA	NA	NA	59 - 138	NA	NA	NA	NA	NA
m,p-Xylenes	NA	NA	NA	74 - 122	NA	NA	NA	NA	NA
n-Butylbenzene	NA	NA	NA	56 - 139	NA	NA	NA	NA	NA
n-Propylbenzene	NA	NA	NA	63 - 120	NA	NA	NA	NA	NA
o-Xylene	NA	NA	NA	70 - 122	NA	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	64 - 126	NA	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	67 - 116	NA	NA	NA	NA	NA
trans-1,2-Dichloroethylene	NA	NA	NA	66 - 128	NA	NA	NA	NA	NA
trans-1,3-Dichloropropylene	NA	NA	NA	60 - 129	NA	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
ECD CLP Water, OLM 4.2 CLP ECD - OLM 3.1 CLP ECD -									
4,4'-DDD	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4,4'-DDE	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4,4'-DDT	NA	38 - 127	0 - 27	49.2 - 134	NA	NA	NA	NA	NA
4cmx	NA	NA	NA	NA	NA	NA	NA	30 - 150	NA
Aldrin	NA	40 - 120	0 - 22	52.0 - 134.5	NA	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA	0 - 20	NA	NA	NA	NA
Chlordane (tech.)	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Decachlorobiphenyl	NA	NA	NA	NA	NA	NA	NA	30 - 150	NA
Dieldrin	NA	52 - 126	0 - 18	62.6 - 123.8	NA	NA	NA	NA	NA
Endosulfan I	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endosulfan II	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endosulfan sulfate	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endrin	NA	56 - 121	0 - 21	52.6 - 141.6	NA	NA	NA	NA	NA
Endrin aldehyde	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endrin ketone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Heptachlor	NA	40 - 131	0 - 20	58.6 - 137.3	NA	NA	NA	NA	NA
Heptachlor epoxide	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methoxychlor	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Toxaphene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
alpha-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
alpha-Chlordane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
beta-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
delta-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	56 - 123	0 - 15	55.4 - 131.5	NA	NA	NA	NA	NA
gamma-Chlordane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
ECD CLP Solids, OLM 4.2 CLP ECD - OLM 3.1 CLP ECD -									
4,4'-DDD	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4,4'-DDE	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4,4'-DDT	NA	23 - 134	0 - 50	59.3 - 121.1	NA	NA	NA	NA	NA
4cmx	NA	NA	NA	NA	NA	NA	NA	30 - 150	NA
Aldrin	NA	34 - 132	0 - 43	53.5 - 127.5	NA	NA	NA	NA	NA
Aroclor-1260	NA	NA	NA	NA	0 - 20	NA	NA	NA	NA
Chlordane (tech.)	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Decachlorobiphenyl	NA	NA	NA	NA	NA	NA	NA	30 - 150	NA
Dieldrin	NA	31 - 134	0 - 38	51.6 - 125.4	NA	NA	NA	NA	NA
Endosulfan I	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endosulfan II	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endosulfan sulfate	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endrin	NA	42 - 139	0 - 45	48.2 - 132.5	NA	NA	NA	NA	NA
Endrin aldehyde	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Endrin ketone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Heptachlor	NA	35 - 130	0 - 31	56.5 - 128.4	NA	NA	NA	NA	NA
Heptachlor epoxide	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methoxychlor	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Toxaphene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
alpha-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
alpha-Chlordane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
beta-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
delta-BHC	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	46 - 127	0 - 50	56.9 - 119	NA	NA	NA	NA	NA
gamma-Chlordane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Inorganic Carbon Water, EPA 415.1 -									
Total Inorganic Carbon	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Organic N Solids, EPA 351.2/350.1 Modified -									
Total Organic Nitrogen	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Organic N Waters, EPA 351.2/350.1 -									
Total Organic Nitrogen	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Total N Solids, EPA 351.2/353.1 Modified -									
Total Nitrogen	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Total N Waters, EPA 351.2/353.1 -									
Total Nitrogen	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
FCMPN Solid, SM 9221 E1 Modified -									
Fecal Coliform-MPN	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
Toxicity of Lab Water, DHEC Method -									
Toxicity	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
Total Plate Count Water, SM 9215 B -									
Total Plate Count	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
TCMF Water, SW846 9132 - SM 9222B Modified -									
Total Coliform-MF	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
TCMPN Water, SW846 9131									
Total Coliform-MPN	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
Inhibitory Residue Solid, SM 9020 Part 3.2A -									
Inhibitory Residue	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
FCMF Water, SM 9222D -									
Fecal Coliform-MF	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
FCMPN Water, SM 9221E1 -									
Fecal Coliform-MPN	0 - 200	NA	NA	NA	NA	NA	NA	NA	NA
Percent Ash @ 750C in Water, ASTM D 3174 MODIFIED -									
Percent Ash 750C	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Percent Ash @ 750C	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Suspended Solids Solid, SM 2540E -									
Volatile Suspended Solids	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Settleable Solids Water, EPA 160.5 -									
Settleable Solids	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Specific Conductance, EPA 120.1 Modified -									
Conductivity	0 - 20	NA	NA	80 - 120	NA	NA	NA	NA	NA
Specific Conductance	0 - 20	NA	NA	80 - 120	NA	NA	NA	NA	NA
Fluoride Waste Water, EPA 340.2 -									
Fluoride	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
Alpha Spec-Americium/Curium in Filters, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-242	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-245/246	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Alpha Spec-Americium/Curium in Liquids, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Americium-242/243	-20	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Curium-242	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-245/246	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha Spec-Americium/Curium in Solids, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-242	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Curium-245/246	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecAmericium in Filters, DOE EML HASL 300 -									
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	-
Americium-243	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecAmericium in Liquids, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Americium-242/243	NA	NA	NA	NA	NA	NA	NA	NA	-
Americium-243	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Alpha SpecAmericium in Solids, DOE EML HASL 300 -									
Americium-241	NA	NA	NA	NA	NA	NA	NA	NA	-
Americium-243	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecNeptunium in Filters, DOE EML HASL 300 -									
Neptunium-237	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecNeptunium In Liquid, DOE EML HASL 300 -									
Neptunium-237	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecNeptunium in Solids, DOE EML HASL 300 -									
Neptunium-237	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecPlutonium in Filters, DOE EML HASL 300 -									
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-239/240	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-242	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecPlutonium in Liquids, DOE EML HASL 300 -									
Plutonium-238	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-239/240	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-242	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-244	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecPlutonium in Solids, DOE EML HASL 300 -									
Plutonium-238	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-239/240	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Plutonium-242	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Plutonium-244	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecPolonium in Filters, DOE EML HASL 300 -									
Polonium-208	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Polonium-209	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Alpha SpecPolonium in Liquids, DOE EML HASL 300 -									
Polonium-208	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Polonium-209	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecPolonium in Solids, DOE EML HASL 300 -									
Polonium-208	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Polonium-209	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecThorium in Filters, DOE EML HASL 300 -									
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-229	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecThorium in Liquids, DOE EML HASL 300 -									
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-229	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecThorium in Solids, DOE EML HASL 300 -									
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-229	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Thorium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecTotal Uranium in Liquids, DOE EML HASL 300 -									
Total Uranium	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Alpha SpecTotal Uranium in Solids, DOE EML HASL 300 -									
Total Uranium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecUranium in Filters, DOE EML HASL 300 -									
Uranium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecUranium in Liquids, DOE EML HASL 300 -									
Pct Uranium-235	NA	NA	NA	NA	NA	NA	NA	NA	-
Uranium-232	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-233/234	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-235/236	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-238	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha SpecUranium in Solids, DOE EML HASL 300 -									
Total Uranium	-20	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Uranium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Bioassay Americium in Fecal, DOE EML HASL 300 -									
Americium-241	NA	NA	NA	75 - 125	NA	NA	NA	30 - 125	-
Bioassay Alpha Spec Americium Curium Plutonium in Fecal, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-242	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-245/246	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Bioassay Alpha Spec AmericiumCurium Plutonium In Urine, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Plutonium in Fecal, DOE EML HASL 300 -									
Americium-241	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Plutonium in Urine, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Thorium in Fecal, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Thorium in Urine, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Uranium in Fecal, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayAlpha Spec Uranium in Urine, DOE EML HASL 300 -									
Americium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Curium-243/244	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Plutonium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Polonium-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Thorium-230	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Bioassay GasFlow Lead 210 in Urine, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Bioassay GasFlow Radium 228 in Urine, EPA 904.0 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayGross Alpha and Beta in Urine, GL-RAD-B-008 -									
ALPHA	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BETA	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Bioassay LSCDistillation Tritium in Urine, EPA 906.0 -									
Tritium	NA	NA	NA	75 - 125	NA	NA	NA	25 - 125	-
Bioassay Lucas Cell Radium 226 in Urine, EPA 903.1 Modified -									
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
BioassayTotal Uranium KPA in Urine, ASTM D 5174 -									
Total Uranium	NA	NA	NA	75 - 125	NA	NA	NA	NA	NA
Gamma Iodine131 in Filters, DOE EML HASL 300 -									
Iodine-131	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Iodine131 in Liquids, DOE EML HASL 300 -									
Iodine-131	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gamma Iodine131 in Solids, DOE EML HASL 300 -									
Iodine-131	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Iron 55 in Filters, DOE RESL Fe-1 -									
Iron-55	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Iron 55 in Liquids, DOE RESL Fe-1 -									
Iron-55	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Iron 55 in Solids, DOE RESL Fe-1 -									
Iron-55	0 - 20	75 - 125	NA	75 - 125	0 - 20	NA	NA	25 - 125	NA
Gamma Lead 210 in Filters, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Lead 210 in Liquids, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Gamma Lead 210 in Solids, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Nickel 59 in Filters, DOE RESL Ni-1 -									
Nickel-59	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Nickel 59 in Liquids, DOE RESL Ni-1 -									
Nickel-59	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gamma Nickel 59 in Solids, DOE RESL Ni-1 -									
Nickel-59	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gamma Radium228 in Filters, DOE EML HASL 300 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Radium 228 in Liquids, DOE EML HASL 300 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Radium 228 in Solids, DOE EML HASL 300 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Spec in Filters, EPA 901.1 -									
Cesium-137	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gamma Spec in Liquid, EPA 901.1 - DOE EML HASL 300 -									
Cesium-137	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Radium-228	NA	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Thorium-228	NA	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Thorium-232	NA	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Total Uranium	NA	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Gamma Spec Radium 226 in Solids, DOE EML HASL 300 -									
Cesium-137	-20	-	NA	75 - 125	NA	NA	NA	NA	-
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gamma Tellerium 125m in Filters, NERC ORD -									
Tellurium-125m	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
GammaTellerium 125m in Liquid, NERC ORD -									
Tellurium-125m	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gamma Tellerium 125m in Solids, NERC ORD -									
Tellurium-125m	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Lead 210 in Filters, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Lead-210 in Liquids, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas Flow Lead 210 in Solids, DOE EML HASL 300 -									
Lead-210	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Radium 228 in Filters, EPA 904.0 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Radium 228 in Liquids, EPA 904.0 -									
Radium-228	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas Flow Strontium in Filters, EPA 905.0 Modified -									
Strontium-89	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Strontium-90	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas Flow Strontium in Milk, EPA 905.0 Modified -									
Strontium-89	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Strontium-90	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Gas Flow Strontium in Solids, EPA 905.0 Modified -									
Strontium-89	0 - 20	75 - 125	75 - 125	75 - 125	NA	NA	NA	25 - 125	-
Strontium-90	0 - 20	75 - 125	75 - 125	75 - 125	NA	NA	NA	25 - 125	-
Gas Flow Strontium in Tissue, EPA 905.0 Modified -									
Strontium-89	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Strontium-90	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Strontium in Vegetation, EPA 905.0 Modified -									
Strontium-89	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Strontium-90	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas FlowTotal Radium in Filters, EPA 900.1 -									
Total Radium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Total Radium in Liquids, EPA 903.0 - EPA 900.1 -									
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Total Radium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas FlowTotal Radium in Solids, EPA 900.1 -									
Total Radium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas FlowTotal Strontium in Filters, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas FlowTotal Strontium in Liquids, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas FlowTotal Strontium in Milk, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas Flow Total Strontium in Solids, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Gas FlowTotal Strontium in Tissue, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gas FlowTotal Strontium in Vegetation, EPA 905.0 Modified -									
Total Strontium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Gross AlphaNon Vol Beta in Filters, EPA 900.0 -									
ALPHA	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
BETA	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Carbon 14 in Filters, EPA EERF C-01 -									
Carbon-14	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Carbon 14 in Liquids, EPA EERF C-01 -									
Carbon-14	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Carbon 14 in Solids, EPA EERF C-01 -									
Carbon-14	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Nickel 63 in Filters, DOE RESL Ni-1 -									
Nickel-63	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Nickel 63 in Liquids, DOE RESL Ni-1 -									
Nickel-63	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Nickel 63 in Solids, DOE RESL Ni-1 -									
Nickel-63	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Plutonium in Filters, DOE EML HASL 300 -									
Plutonium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Plutonium in Liquids, DOE EML HASL 300 -									
Plutonium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
LSC Plutoniumin Solids, DOE EML HASL 300 -									
Plutonium-241	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Promethium 147 in Filters, EPA EERF PM-01-1 -									
Promethium-147	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Promethium 147 in Liquids, EPA EERF PM-01-1 -									
Promethium-147	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Promethium 147 in Solids, EPA EERF PM-01-1 -									
Promethium-147	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Radon 222 in Filters, SM 7500 Rn B(Modified) -									
Radon-222	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Radon-222 in Liquids, SM 7500 Rn B(Modified) -									
Radon-222	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Selenium79 in Filters, NERC ORD -									
Selenium-79	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Selenium79 in Liquids, NERC ORD -									
Selenium-79	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Selenium79 in Solids, NERC ORD -									
Selenium-79	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Technetium-99 in Solids, DOE EML HASL 300 -									
Technetium-99	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Technetium-99 in Filters, DOE EML HASL 300 -									
Technetium-99	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Tritium Distillation in Filters, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Tritium Distillation in Liquids, EPA 906.0 -									
Tritium	0 - 20	75 - 125	75 - 125	75 - 125	NA	NA	NA	25 - 125	-
LSC Tritium Distillation in Solids, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Tritium Vacuum in Filters, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Tritium Vacuum in Liquids, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
LSC Tritium Vacuum in Solids, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Lucas Cell Radium 226 in Filters, EPA 903.1 Modified -									
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Lucas Cell Radium 226 in Liquids, EPA 903.1 Modified -									
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Lucas Cell Radium 226 in Solids, EPA 903.1 Modified -									
Radium-226	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Total Uranium KPA in Filters, ASTM D 5174 -									
Total Uranium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Total Uranium KPA in Liquids, ASTM D 5174 -									
Total Uranium	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Total Uranium KPA in Solids, ASTM D 5174 -									
Total Uranium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Iron-55 in water, DOE RESL Ni-1 -									
Iron-55	0 - 30	-	NA	-	NA	NA	NA	NA	-

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
CN-WAD Soils, ASTM D 2036 Modified -									
Cyanide, Weak Acid Dissociable	0 - 30	75 - 125	NA	70 - 130	NA	NA	NA	NA	NA
Corrosivity to Steel	0 - 5	NA	NA	95 - 105	0 - 20	NA	NA	NA	NA
Fluoride Solid, EPA 340.2 -									
Fluoride	0 - 30	70 - 130	NA	70 - 130	0 - 30	70 - 130	NA	NA	NA
Fluorine	0 - 30	70 - 130	NA	70 - 130	0 - 30	70 - 130	NA	NA	NA
Hydrazine	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Odor Water, Ortho-PO4 Solid									
Ortho-phosphate	0 - 30	70 - 130	NA	70 - 130	0 - 30	70 - 130	NA	NA	NA
Gross Alpha Non Vol Beta in Liquids, EPA 900.0 -									
ALPHA	0 - 20	75 - 125	75 - 125	75 - 125	0 - 20	NA	NA	NA	-
BETA	0 - 20	75 - 125	75 - 125	75 - 125	0 - 20	NA	NA	NA	-
LSC Technetium-99 in Liquids, DOE EML HASL 300 -									
Technetium-99	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
LSC Tritium Direct in Liquids, EPA 906.0 -									
Tritium	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	NA
Organotins Liquids, Uhler & Durell Analysis -									
Dibutyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Monobutyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Tetrabutyl tin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Tributyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Organotins Solids, Uhler & Durell Analysis -									
Dibutyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Monobutyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Tetrabutyl tin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Tributyltin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
Gas Flow Strontium in Liquids, EPA 905.0 Modified -									
Strontium-89	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Strontium-90	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Mercury CLP Liquids, ILM 4.0 CLP Metals -									
Mercury	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
LSC Total Activity, GL-RAD-A-041 -									
Total Activity	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	NA	NA	NA	-
Dioxin, SW846 8280 -									
1,2,3,4,6,7,8-HpCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDF	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,2,3,4,7,8-HxCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,2,3,4,7,8-HxCDF	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,2,3,7,8-PCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
1,2,3,7,8-PCDF	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
2,3,7,8-TCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
2,3,7,8-TCDF	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
C13-1,2,3,4-TCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
C13-2,3,7,8-TCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
C13-OCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HpCDD, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HpCDD, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HpCDF, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
HpCDF, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HxCDD, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HxCDD, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HxCDF, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
HxCDF, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
OCDD	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
OCDF	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
PCDD, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
PCDD, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
PCDF, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
PCDF, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
TCDD, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
TCDD, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
TCDF, Isomers	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
TCDF, Totals	0 - 30	70 - 130	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
Corrosivity to Steel, SW846 1110 Modified -									
Corrosivity to Steel	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
608 Pesticide/PCB wastewater, SW846 8081A SC_NPDES - EPA 608 SC_NPDES - EPA 608 -									
4,4'-DDD	NA	31 - 141	0 - 40	31 - 141	0 - 40	NA	NA	NA	NA
4,4'-DDE	NA	30 - 145	0 - 40	30 - 145	0 - 40	NA	NA	NA	NA
4,4'-DDT	NA	25 - 160	0 - 40	25 - 160	0 - 40	NA	NA	NA	NA
4cmx	NA	NA	NA	NA	NA	NA	NA	39.1 - 111.8	NA
Aldrin	NA	42 - 122	0 - 40	42 - 122	0 - 40	NA	NA	NA	NA
Aroclor-1016	NA	50 - 114	0 - 40	50 - 114	0 - 40	NA	NA	NA	NA
Aroclor-1260	NA	8 - 127	0 - 40	8 - 127	0 - 40	NA	NA	NA	NA
Chlordane (tech.)	NA	45 - 119	0 - 40	45 - 119	0 - 40	NA	NA	NA	NA
Decachlorobiphenyl	NA	NA	NA	NA	NA	NA	NA	25.2 - 125.0	NA
Dieldrin	NA	36 - 146	0 - 40	36 - 146	0 - 40	NA	NA	NA	NA
Endosulfan I	NA	45 - 153	0 - 40	45 - 153	0 - 40	NA	NA	NA	NA
Endosulfan II	NA	0 - 202	0 - 40	0 - 202	0 - 40	NA	NA	NA	NA
Endosulfan sulfate	NA	26 - 144	0 - 40	26 - 144	0 - 40	NA	NA	NA	NA
Endrin	NA	30 - 147	0 - 40	30 - 147	0 - 40	NA	NA	NA	NA
Heptachlor	NA	34 - 111	0 - 40	34 - 111	0 - 40	NA	NA	NA	NA
Heptachlor epoxide	NA	37 - 142	0 - 40	37 - 142	0 - 40	NA	NA	NA	NA
alpha-BHC	NA	37 - 134	0 - 40	37 - 134	0 - 40	NA	NA	NA	NA
beta-BHC	NA	17 - 147	0 - 40	17 - 147	0 - 40	NA	NA	NA	NA
delta-BHC	NA	19 - 140	0 - 40	19 - 140	0 - 40	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	32 - 127	0 - 40	32 - 127	0 - 40	NA	NA	NA	NA
Mercury CLP Solids, ILM 4.0 CLP Metals -									
Mercury	0 - 30	60 - 135	0 - 30	62 - 145	0 - 20	NA	NA	NA	NA
LSC Iron-55 in solids, DOE RESL Ni-1 -									
Iron-55	0 - 30	75 - 125	NA	75 - 125	NA	NA	NA	NA	-
Radium 226 by Gamma Spec, DOE EML HASL 300 -									
Radium-226	-20	NA	NA	NA	NA	NA	NA	NA	-
Bioassay Thorium in Urine pCi/s, DOE EML HASL 300 -									
Thorium-232	NA	NA	NA	75 - 125	NA	NA	NA	75 - 125	-
Bioassay Uranium in Urine pCi/s, DOE EML HASL 300 -									
Uranium-238	NA	NA	NA	75 - 125	NA	NA	NA	75 - 125	-

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Metals Liquid SW846/CLP-static limitsSW846 7471A-SW846 7470A-SW846 3010/6020 - SW846 3010/6010B - SW846 3005/6020 - SW846 3005/6010B									
Aluminum	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Antimony	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Arsenic	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Barium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Beryllium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Boron	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Cadmium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Calcium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Cesium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Chromium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Cobalt	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Copper	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Gold	0 - 20	NA	0 - 20	NA	0 - 20	NA	NA	NA	NA
Iron	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Lead	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Lithium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Magnesium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Manganese	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Mercury	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Molybdenum	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Nickel	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Palladium	0 - 20	NA	0 - 20	NA	0 - 20	NA	NA	NA	NA
Phosphorous	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Platinum	0 - 20	NA	0 - 20	NA	0 - 20	NA	NA	NA	NA
Potassium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Selenium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Silica	NA	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Silicon	NA	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Silver	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Sodium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Strontium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Sulfur	NA	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Thallium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Thorium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Tin	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Titanium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Uranium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Uranium-235	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Uranium-238	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Vanadium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Zinc	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Zirconium	0 - 20	75 - 125	0 - 20	80 - 120	0 - 20	NA	NA	NA	NA
Metals Liquid EPA 200 Series-static limits, EPA 245.2 - EPA 200.8 SC_NPDES - EPA 200.8 - EPA 200.7 -									
Aluminum	0 - 20	75 - 125	0 - 20	85 - 115	0 - 20	NA	NA	NA	NA
Antimony	0 - 20	75 - 125	0 - 20	85 - 115	0 - 20	NA	NA	NA	NA
Arsenic	0 - 20	75 - 125	0 - 20	85 - 115	0 - 20	NA	NA	NA	NA
Barium	0 - 20	75 - 125	0 - 20	85 - 115	0 - 20	NA	NA	NA	NA
Beryllium	0 - 20	75 - 125	0 - 20	85 - 115	0 - 20	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Flashpoint CC 140 Solids, SW846 1010 -									
Flashpoint-140	0 - 20	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Bioassay Americium in fecal, DOE EML HASL 300 -									
Americium-241	NA	NA	NA	75 - 125	NA	NA	NA	25 - 110	.01 - 5
Alpha Spec Uranium Yields in Solids, DOE EML HASL 300 -									
Uranium-232	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-233/234	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-235/236	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-238	-20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Alpha Spec Uranium Yields in Liquids, DOE EML HASL 300 -									
Uranium-232	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-233/234	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-235/236	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Uranium-238	0 - 20	75 - 125	NA	75 - 125	NA	NA	NA	25 - 125	-
Bioassay Americium in Urine pCL DOE EML HASL 300 -									
Americium-241	NA	NA	NA	75 - 125	NA	NA	NA	-	-
Bioassay Plutonium in Urine pCL, DOE EML HASL 300 -									
Plutonium-238	NA	NA	NA	75 - 125	NA	NA	NA	-	-
Plutonium-239/240	NA	NA	NA	75 - 125	NA	NA	NA	-	-
Bioassay Neptunium in Urine pCL, DOE EML HASL 300 -									
Neptunium-237	NA	NA	NA	75 - 125	NA	NA	NA	-	-
Alaska Liquid, AK103 - AK102/103 - AK102 - AK101 -									
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
Diesel Range Organics	NA	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	NA	NA
Gasoline Range Organics	NA	60 - 120	0 - 20	60 - 120	0 - 20	60 - 120	0 - 20	NA	NA
Residual Range Organics	NA	60 - 120	0 - 20	60 - 120	0 - 20	60 - 120	0 - 20	NA	NA
n-Triacontane-d62	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
Alaska Solid, SW846 5035 - AK103 - AK102/103 - AK102 - AK101 -									
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
Diesel Range Organics	NA	60 - 140	0 - 20	75 - 125	0 - 20	60 - 140	0 - 20	NA	NA
Gasoline Range Organics	NA	60 - 120	0 - 20	60 - 120	0 - 20	60 - 120	0 - 20	NA	NA
Residual Range Organics	NA	60 - 120	0 - 20	60 - 120	0 - 20	60 - 120	0 - 20	NA	NA
n-Triacontane-d62	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	60 - 120	NA
ICPMS Solids, SW846 3051/6020 - SW846 3050B/6020 - ILM 4.0 CLP Metals -									
Aluminum	0 - 20	75 - 125	0 - 20	43.6 - 156.4	0 - 20	75 - 125	NA	NA	NA
Antimony	0 - 20	75 - 125	0 - 20	.2 - 210.7	0 - 20	75 - 125	NA	NA	NA
Arsenic	0 - 20	75 - 125	0 - 20	79.2 - 120.8	0 - 20	75 - 125	NA	NA	NA
Barium	0 - 20	75 - 125	0 - 20	79.6 - 120.4	0 - 20	75 - 125	NA	NA	NA
Beryllium	0 - 20	75 - 125	0 - 20	75.8 - 124	0 - 20	75 - 125	NA	NA	NA
Boron	0 - 20	75 - 125	0 - 20	76.8 - 123	0 - 20	75 - 125	NA	NA	NA
Cadmium	0 - 20	75 - 125	0 - 20	80.5 - 119.5	0 - 20	75 - 125	NA	NA	NA
Calcium	0 - 20	75 - 125	0 - 20	75.9 - 124.1	0 - 20	75 - 125	NA	NA	NA
Cesium	-20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Chromium	0 - 20	75 - 125	0 - 20	77 - 123	0 - 20	75 - 125	NA	NA	NA
Cobalt	0 - 20	75 - 125	0 - 20	82.7 - 117.3	0 - 20	75 - 125	NA	NA	NA
Copper	0 - 20	75 - 125	0 - 20	80.0 - 120.3	0 - 20	75 - 125	NA	NA	NA
Gold	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Iron	0 - 20	75 - 125	0 - 20	47.4 - 152.3	0 - 20	75 - 125	NA	NA	NA
Lead	0 - 20	75 - 125	0 - 20	77.1 - 122.9	0 - 20	75 - 125	NA	NA	NA
Lithium	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Magnesium	0 - 20	75 - 125	0 - 20	70.5 - 129.5	0 - 20	75 - 125	NA	NA	NA
Manganese	0 - 20	75 - 125	0 - 20	75.6 - 124.4	0 - 20	75 - 125	NA	NA	NA
Molybdenum	0 - 20	75 - 125	0 - 20	79.4 - 120.6	0 - 20	75 - 125	NA	NA	NA
Nickel	0 - 20	75 - 125	0 - 20	78.3 - 121.7	0 - 20	75 - 125	NA	NA	NA
Osmium	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Palladium	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Phosphorous	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Platinum	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Potassium	0 - 20	75 - 125	0 - 20	63.5 - 136.5	0 - 20	75 - 125	NA	NA	NA
Rhenium	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Rhodium	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Ruthenium	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Selenium	0 - 20	75 - 125	0 - 20	74.0 - 125.6	0 - 20	75 - 125	NA	NA	NA
Silica	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Silicon	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Silver	0 - 20	75 - 125	0 - 20	55.0 - 145.1	0 - 20	75 - 125	NA	NA	NA
Sodium	0 - 20	75 - 125	0 - 20	50.9 - 149.1	0 - 20	75 - 125	NA	NA	NA
Strontium	0 - 20	75 - 125	0 - 20	73.8 - 126.2	0 - 20	75 - 125	NA	NA	NA
Sulfur	NA	NA	NA	NA	0 - 20	75 - 125	NA	NA	NA
Thallium	0 - 20	75 - 125	0 - 20	73.8 - 126.2	0 - 20	75 - 125	NA	NA	NA
Thorium	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Tin	0 - 20	75 - 125	0 - 20	54.7 - 144.9	0 - 20	75 - 125	NA	NA	NA
Titanium	0 - 20	75 - 125	0 - 20	8.6 - 191.4	0 - 20	75 - 125	NA	NA	NA
Uranium	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Uranium-235	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Uranium-238	NA	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Vanadium	0 - 20	75 - 125	0 - 20	70 - 130	0 - 20	75 - 125	NA	NA	NA
Zinc	0 - 20	75 - 125	0 - 20	77 - 123	0 - 20	75 - 125	NA	NA	NA
Zirconium	0 - 20	75 - 125	0 - 20	75 - 125	0 - 20	75 - 125	NA	NA	NA
Mercury Solids, SW846 7471A Prep - SW846 7471A - SW846 7470A Prep - SW846 7470A - ILM 4.0 CLP Metals -									
Mercury	0 - 20	75 - 125	0 - 20	65.8 - 134.2	0 - 20	NA	NA	NA	NA
Trace Solids, SW846 3051/6010B - SW846 3050B/6010B - ILM 4.0 CLP Metals - EPA 625 Selective Ion Monitoring -									
Aluminate	NA	NA	NA	NA	NA	75 - 125	0 - 20	NA	NA
Aluminum	0 - 20	75 - 125	0 - 20	43.5 - 156.5	0 - 20	75 - 125	0 - 20	NA	NA
Antimony	0 - 20	75 - 125	0 - 20	.2 - 227.9	0 - 20	75 - 125	0 - 20	NA	NA
Arsenic	0 - 20	75 - 125	0 - 20	79.2 - 120.8	0 - 20	75 - 125	0 - 20	NA	NA
Barium	0 - 20	75 - 125	0 - 20	79.6 - 120.4	0 - 20	75 - 125	0 - 20	NA	NA
Beryllium	0 - 20	75 - 125	0 - 20	79.3 - 121.1	0 - 20	75 - 125	0 - 20	NA	NA
Boron	0 - 20	75 - 125	0 - 20	75.3 - 125.2	0 - 20	75 - 125	0 - 20	NA	NA
Cadmium	0 - 20	75 - 125	0 - 20	80.8 - 119.2	0 - 20	75 - 125	0 - 20	NA	NA
Calcium	0 - 20	75 - 125	0 - 20	75.7 - 124.3	0 - 20	75 - 125	0 - 20	NA	NA
Chromium	0 - 20	75 - 125	0 - 20	77.4 - 122.6	0 - 20	75 - 125	0 - 20	NA	NA
Cobalt	0 - 20	75 - 125	0 - 20	79.2 - 121	0 - 20	75 - 125	0 - 20	NA	NA
Copper	0 - 20	75 - 125	0 - 20	79.2 - 120.3	0 - 20	75 - 125	0 - 20	NA	NA
Iron	0 - 20	75 - 125	0 - 20	47.4 - 152.6	0 - 20	75 - 125	0 - 20	NA	NA
Lead	0 - 20	75 - 125	0 - 20	77.5 - 122.5	0 - 20	75 - 125	0 - 20	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Magnesium	0 - 20	75 - 125	0 - 20	70.5 - 129.5	0 - 20	75 - 125	0 - 20	NA	NA
Manganese	0 - 20	75 - 125	0 - 20	75.6 - 124.4	0 - 20	75 - 125	0 - 20	NA	NA
Molybdenum	0 - 20	75 - 125	0 - 20	75.7 - 124.2	0 - 20	75 - 125	0 - 20	NA	NA
Nickel	0 - 20	75 - 125	0 - 20	78.2 - 121.3	0 - 20	75 - 125	0 - 20	NA	NA
Phosphorous	0 - 20	75 - 125	0 - 20	54 - 131	0 - 20	75 - 125	0 - 20	NA	NA
Potassium	0 - 20	75 - 125	0 - 20	63.5 - 136.5	0 - 20	75 - 125	0 - 20	NA	NA
Selenium	0 - 20	75 - 125	0 - 20	71.8 - 127.8	0 - 20	75 - 125	0 - 20	NA	NA
Silica	0 - 20	75 - 125	0 - 20	55 - 145	0 - 20	75 - 125	0 - 20	NA	NA
Silicon	0 - 20	75 - 125	0 - 20	60.1 - 140.5	0 - 20	75 - 125	0 - 20	NA	NA
Silver	0 - 20	75 - 125	0 - 20	55.0 - 145.2	0 - 20	75 - 125	0 - 20	NA	NA
Sodium	0 - 20	75 - 125	0 - 20	50.6 - 149.4	0 - 20	75 - 125	0 - 20	NA	NA
Strontium	0 - 20	75 - 125	0 - 20	74.2 - 125.8	0 - 20	75 - 125	0 - 20	NA	NA
Sulfur	0 - 20	75 - 125	0 - 20	82.5 - 118	0 - 20	75 - 125	0 - 20	NA	NA
Thallium	0 - 20	75 - 125	0 - 20	73.8 - 126.4	0 - 20	75 - 125	0 - 20	NA	NA
Tin	0 - 20	75 - 125	0 - 20	72.6 - 127.4	0 - 20	75 - 125	0 - 20	NA	NA
Titanium	0 - 20	75 - 125	0 - 20	8.6 - 191.4	0 - 20	75 - 125	0 - 20	NA	NA
Uranium	0 - 20	75 - 125	0 - 20	73.3 - 122.8	0 - 20	75 - 125	0 - 20	NA	NA
Vanadium	0 - 20	75 - 125	0 - 20	70.0 - 130.5	0 - 20	75 - 125	0 - 20	NA	NA
Zinc	0 - 20	75 - 125	0 - 20	76.8 - 123.2	0 - 20	75 - 125	0 - 20	NA	NA
LCMS Explosives and PCL Liquids, SW846 8321A Modified -									
1,2-dinitrobenzene	NA	NA	NA	NA	NA	NA	NA	65.2 - 114.6	NA
1,3,5-Trinitrobenzene	NA	75.8 - 123.5	0 - 30	56.9 - 122.7	0 - 30	70 - 130	-	NA	NA
2,4,6-Trinitrotoluene	NA	77.2 - 122.8	0 - 30	65.5 - 127.0	0 - 30	70 - 130	-	NA	NA
2,4-Dinitrotoluene	NA	50 - 150	0 - 30	62.4 - 115.8	0 - 30	70 - 130	-	NA	NA
2,6-Dinitrotoluene	NA	73.0 - 129.4	0 - 30	71.0 - 117.9	0 - 30	70 - 130	-	NA	NA
2-Amino-4,6-dinitrotoluene	NA	83.1 - 131.8	0 - 30	69.1 - 122.6	0 - 30	70 - 130	-	NA	NA
4-Amino-2,6-dinitrotoluene	NA	39.8 - 115.3	0 - 30	42.6 - 109.4	0 - 30	70 - 130	-	NA	NA
Ammonium Picrate	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	NA	NA	NA
HMX	NA	52.5 - 182.0	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
Nitrobenzene	NA	32.8 - 100.8	0 - 30	39.4 - 107.7	0 - 30	70 - 130	-	NA	NA
Nitroglycerin	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
PETN	NA	63.2 - 170.3	0 - 30	50.9 - 166.0	0 - 30	70 - 130	-	NA	NA
Perchlorate	NA	85 - 115	0 - 20	85 - 115	0 - 30	70 - 130	-	NA	NA
Perchlorate-101	NA	85 - 115	0 - 20	85 - 115	0 - 30	70 - 130	NA	NA	NA
Picric acid	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
RDX	NA	57.4 - 134.1	0 - 30	64.1 - 121.8	0 - 30	70 - 130	-	NA	NA
Tetryl	NA	31.3 - 147.2	0 - 30	50.6 - 118.8	0 - 30	70 - 130	-	NA	NA
m-Dinitrobenzene	NA	61.4 - 119.6	0 - 30	68.4 - 109.0	0 - 30	70 - 130	-	NA	NA
m-Nitrotoluene	NA	26.2 - 115.5	0 - 30	44.3 - 112.4	0 - 30	70 - 130	-	NA	NA
o-Nitrotoluene	NA	27.7 - 117.6	0 - 30	41.4 - 108.9	0 - 30	70 - 130	-	NA	NA
p-Nitrotoluene	NA	29.3 - 118.6	0 - 30	37.6 - 119.3	0 - 30	70 - 130	-	NA	NA
LCMS Explosives and PCL Solids, SW846 8321A Modified -									
1,2-dinitrobenzene	NA	NA	NA	NA	NA	NA	NA	63.2 - 119.2	NA
1,3,5-Trinitrobenzene	NA	54.1 - 131.2	0 - 25.0	64.8 - 127.5	0 - 27.4	70 - 130	-	NA	NA
2,4,6-Trinitrotoluene	NA	50 - 150	0 - 32.7	66.5 - 127.3	0 - 30	70 - 130	-	NA	NA
2,4-Dinitrotoluene	NA	58.9 - 133.7	0 - 31.9	61.5 - 125.5	0 - 30	70 - 130	-	NA	NA
2,6-Dinitrotoluene	NA	74.6 - 120.5	0 - 22.3	54.8 - 139.1	0 - 30	70 - 130	-	NA	NA
2-Amino-4,6-dinitrotoluene	NA	38.5 - 141.7	0 - 33.6	58.9 - 138.8	0 - 30	70 - 130	-	NA	NA
4-Amino-2,6-dinitrotoluene	NA	42.8 - 127.6	0 - 32.8	36.3 - 148.7	0 - 30	70 - 130	-	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Ammonium Picrate	NA	25.1 - 120.5	0 - 31.5	35.7 - 133.6	0 - 30	70 - 130	NA	NA	NA
HMX	NA	67.3 - 142.1	0 - 32.6	64.0 - 144.3	0 - 30	70 - 130	-	NA	NA
Nitrobenzene	NA	36.9 - 133.8	0 - 32.4	42.0 - 118.7	0 - 30	70 - 130	-	NA	NA
Nitroglycerin	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
PETN	NA	45.5 - 158.6	0 - 30.5	55.2 - 153.8	0 - 30	70 - 130	-	NA	NA
Perchlorate	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
Perchlorate-101	NA	50 - 150	0 - 30	70 - 130	0 - 30	70 - 130	-	NA	NA
Picric acid	NA	25.1 - 120.5	0 - 31.5	35.7 - 133.6	0 - 30	70 - 130	-	NA	NA
RDX	NA	57.6 - 141.6	0 - 16.0	57.2 - 144.6	0 - 30	70 - 130	-	NA	NA
Tetryl	NA	39.4 - 104.1	0 - 34.0	33.7 - 162.9	0 - 25.3	70 - 130	-	NA	NA
m-Dinitrobenzene	NA	66.8 - 123.7	0 - 27.0	64.9 - 124.1	0 - 21.7	70 - 130	-	NA	NA
m-Nitrotoluene	NA	36.3 - 132.6	0 - 34.1	46.8 - 118.5	0 - 30	70 - 130	-	NA	NA
o-Nitrotoluene	NA	33.8 - 128.7	0 - 34.0	46.1 - 114.9	0 - 30.8	70 - 130	-	NA	NA
p-Nitrotoluene	NA	33.0 - 140.5	0 - 36.9	50.0 - 117.3	0 - 30	70 - 130	-	NA	NA
HPLC Explosives Water, SW846 8330 -									
1,2-dinitrobenzene	NA	NA	NA	NA	NA	NA	NA	62.0 - 123.8	NA
1,3,5-Trinitrobenzene	NA	43.3 - 135.3	0 - 30	52.0 - 127.6	0 - 30	NA	NA	NA	NA
2,4,6-Trinitrotoluene	NA	65.6 - 126.2	0 - 30	84.0 - 108.2	0 - 30	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	67.8 - 118.8	0 - 30	69.4 - 112.3	0 - 30	NA	NA	NA	NA
2,6-Dinitrotoluene	NA	52.7 - 136.8	0 - 30	68.2 - 117.5	0 - 30	NA	NA	NA	NA
2-Amino-4,6-dinitrotoluene	NA	59.1 - 125.2	0 - 30	63.9 - 125.0	0 - 30	NA	NA	NA	NA
4-Amino-2,6-dinitrotoluene	NA	30.3 - 131.5	0 - 30	40.7 - 122.3	0 - 30	NA	NA	NA	NA
HMX	NA	62.2 - 128.3	0 - 30	80.8 - 111.6	0 - 30	NA	NA	NA	NA
Nitrobenzene	NA	54.6 - 118.4	0 - 30	49.2 - 112.9	0 - 30	NA	NA	NA	NA
Nitroglycerin	NA	50 - 150	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
PETN	NA	69.4 - 149.0	0 - 30	72.8 - 132.6	0 - 0	NA	NA	NA	NA
RDX	NA	50.5 - 134.4	0 - 30	75.5 - 110.9	0 - 30	NA	NA	NA	NA
Tetryl	NA	30.0 - 126.6	0 - 30	38.0 - 124.9	0 - 30	NA	NA	NA	NA
m-Dinitrobenzene	NA	64.9 - 116.2	0 - 30	66.3 - 109.1	0 - 30	NA	NA	NA	NA
m-Nitrotoluene	NA	62.0 - 116.6	0 - 30	54.0 - 116.5	0 - 30	NA	NA	NA	NA
o-Nitrotoluene	NA	59.3 - 123.3	0 - 30	53.6 - 116.6	0 - 30	NA	NA	NA	NA
p-Nitrotoluene	NA	58.9 - 125.3	0 - 30	55.6 - 117.9	0 - 30	NA	NA	NA	NA
HPLC Explosives Solids, SW846 8330 -									
1,2-dinitrobenzene	NA	NA	NA	NA	NA	NA	NA	76.3 - 114.0	NA
1,3,5-Trinitrobenzene	NA	79.7 - 117.7	0 - 30	56.9 - 129.6	0 - 30	NA	NA	NA	NA
2,4,6-Trinitrotoluene	NA	73.0 - 132.7	0 - 30	60.5 - 130.4	0 - 30	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	75.1 - 118.0	0 - 30	56.0 - 126.9	0 - 30	NA	NA	NA	NA
2,6-Dinitrotoluene	NA	75.1 - 129.9	0 - 30	56.6 - 130.6	0 - 30	NA	NA	NA	NA
2-Amino-4,6-dinitrotoluene	NA	66.7 - 124.2	0 - 30	57.1 - 133.2	0 - 30	NA	NA	NA	NA
4-Amino-2,6-dinitrotoluene	NA	43.4 - 126.4	0 - 30	57.4 - 119.3	0 - 30	NA	NA	NA	NA
HMX	NA	74.0 - 131.0	0 - 30	61.3 - 137.7	0 - 30	NA	NA	NA	NA
Nitrobenzene	NA	72.4 - 115.0	0 - 30	54.9 - 123.5	0 - 30	NA	NA	NA	NA
Nitroglycerin	NA	84.6 - 123.2	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
PETN	NA	77.2 - 131.7	0 - 30	79.0 - 119.0	0 - 30	NA	NA	NA	NA
RDX	NA	67.8 - 124.8	0 - 30	61.9 - 133.7	0 - 30	NA	NA	NA	NA
Tetryl	NA	49.7 - 115.6	0 - 30	48.1 - 122.4	0 - 30	NA	NA	NA	NA
m-Dinitrobenzene	NA	79.6 - 118.4	0 - 30	77.9 - 110.5	0 - 30	NA	NA	NA	NA
m-Nitrotoluene	NA	73.9 - 115.5	0 - 30	55.1 - 124.0	0 - 30	NA	NA	NA	NA
o-Nitrotoluene	NA	73.9 - 114.7	0 - 30	72.3 - 109.1	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
p-Nitrotoluene	NA	74.4 - 116.2	0 - 30	55.3 - 125.7	0 - 30	NA	NA	NA	NA
GRO Liquids, SW846 8015A/B VOC - GRO QC only - California Method -									
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	57.6 - 126.9	NA
Gasoline Range Organics	NA	NA	NA	75.2 - 119.5	0 - 20	59.4 - 128.4	0 - 20	NA	NA
Bioassay Technitium-99, DOE EML HASL 300 -									
Technetium-99	NA	NA	NA	75 - 125	NA	NA	NA	15 - 125	-
Total Recoverable Hydrocarbons Water, SW846 9070/ SM 5520F -									
Total Petroleum Hydrocarbons	0 - 20	NA	NA	NA	0 - 20	NA	NA	NA	NA
Total Rec. Petro. Hydrocarbons	0 - 20	NA	NA	64.7 - 90.5	0 - 20	NA	NA	NA	NA
VOA Solids, Volatiles QC only - SW846 8260B - SW846 8260A -									
1,1,1,2-Tetrachloroethane	NA	NA	NA	41.3 - 156.2	0 - 30	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	71.5 - 145.0	0 - 30	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	65.1 - 125.8	0 - 30	NA	NA	NA	NA
1,1,2-Trichloroethane	NA	NA	NA	71.5 - 125.0	0 - 30	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	78.0 - 120.6	0 - 30	NA	NA	NA	NA
1,1-Dichloroethylene	NA	NA	NA	52.8 - 137.7	0 - 30	60.6 - 124.3	0 - 20	NA	NA
1,1-Dichloropropene	NA	NA	NA	89.1 - 128.3	0 - 30	NA	NA	NA	NA
1,2,3-Trichlorobenzene	NA	NA	NA	88.5 - 125.4	0 - 30	NA	NA	NA	NA
1,2,3-Trichloropropane	NA	NA	NA	79.4 - 123.8	0 - 30	NA	NA	NA	NA
1,2,4-Trichlorobenzene	NA	NA	NA	84.0 - 131.2	0 - 30	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	54.1 - 167.0	0 - 30	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	NA	NA	NA	77.6 - 128.7	0 - 30	NA	NA	NA	NA
1,2-Dibromoethane	NA	NA	NA	87.5 - 126.6	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	84.4 - 113.4	0 - 30	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	58.4 - 137.7	0 - 30	NA	NA	NA	NA
1,2-Dichloropropane	NA	NA	NA	53.8 - 135.4	0 - 30	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	70.0 - 118.7	0 - 30	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	87.2 - 115.8	0 - 30	NA	NA	NA	NA
1,3-Dichloropropane	NA	NA	NA	79.4 - 120.0	0 - 30	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	84.1 - 113.9	0 - 30	NA	NA	NA	NA
2,2-Dichloropropane	NA	NA	NA	58.7 - 191.7	0 - 30	NA	NA	NA	NA
2-Butanone	NA	NA	NA	64.6 - 137.4	0 - 30	NA	NA	NA	NA
2-Chloroethylvinyl ether	NA	NA	NA	61.0 - 145.0	NA	NA	NA	NA	NA
2-Chlorotoluene	NA	NA	NA	84.8 - 117.1	0 - 30	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	59.3 - 134.9	0 - 30	NA	NA	NA	NA
4-Chlorotoluene	NA	NA	NA	54.4 - 160.6	0 - 30	NA	NA	NA	NA
4-Isopropyltoluene	NA	NA	NA	70.0 - 125.8	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	62.7 - 134.4	0 - 30	NA	NA	NA	NA
Acetone	NA	NA	NA	70.1 - 138.5	0 - 30	NA	NA	NA	NA
Acetonitrile	NA	NA	NA	74.4 - 129.1	NA	NA	NA	NA	NA
Acrolein	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Acrylonitrile	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	78.2 - 114.8	0 - 30	62.0 - 115.1	0 - 15.4	NA	NA
Benzyl chloride	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Bromobenzene	NA	NA	NA	87.1 - 113.9	0 - 30	NA	NA	NA	NA
Bromochloromethane	NA	NA	NA	72.0 - 127.8	0 - 30	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	73.1 - 133.6	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	65.9 - 138.6	NA
Bromoform	NA	NA	NA	84.3 - 139.3	0 - 30	NA	NA	NA	NA
Bromomethane	NA	NA	NA	58.9 - 141.9	0 - 30	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	76.9 - 117.4	NA	NA	NA	NA	NA
Carbon tetrachloride	NA	NA	NA	72.1 - 140.5	0 - 30	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	82.4 - 115.6	0 - 30	59.9 - 118.2	0 - 18.9	NA	NA
Chloroethane	NA	NA	NA	72.4 - 129.0	0 - 30	NA	NA	NA	NA
Chloroform	NA	NA	NA	74.8 - 127.9	0 - 30	NA	NA	NA	NA
Chloromethane	NA	NA	NA	56.1 - 134.2	0 - 30	NA	NA	NA	NA
Cyclohexane	NA	NA	NA	76.1 - 128.9	NA	NA	NA	NA	NA
Cyclohexanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dibromochloromethane	NA	NA	NA	86.3 - 128.1	0 - 30	NA	NA	NA	NA
Dibromofluoromethane	NA	NA	NA	NA	NA	NA	NA	67.6 - 141.8	NA
Dibromomethane	NA	NA	NA	83.7 - 126.9	NA	NA	NA	NA	NA
Dichlorodifluoromethane	NA	NA	NA	53.7 - 149.3	0 - 30	NA	NA	NA	NA
Ethylbenzene	NA	NA	NA	79.3 - 120.0	0 - 30	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	78.3 - 130.0	0 - 30	NA	NA	NA	NA
Iodomethane	NA	NA	NA	65.7 - 137.2	NA	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	82.0 - 113.4	0 - 30	NA	NA	NA	NA
Isopropyltoluene	NA	NA	NA	NA	0 - 30	NA	NA	NA	NA
Methyl acetate	NA	NA	NA	71.5 - 130.8	NA	NA	NA	NA	NA
Methylcyclohexane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	76.6 - 108.2	0 - 30	NA	NA	NA	NA
Naphthalene	NA	NA	NA	69.1 - 134.7	0 - 30	NA	NA	NA	NA
Styrene	NA	NA	NA	83.5 - 120.0	0 - 30	NA	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	85.8 - 128.0	0 - 30	NA	NA	NA	NA
Tetrahydrofuran	NA	NA	NA	62.6 - 112.9	0 - 30	NA	NA	NA	NA
Toluene	NA	NA	NA	77.4 - 116.7	0 - 30	56.2 - 120.6	0 - 19.9	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	67.7 - 134.1	NA
Trichloroethylene	NA	NA	NA	86.8 - 121.5	0 - 30	53.4 - 140.1	0 - 18.0	NA	NA
Trichlorofluoromethane	NA	NA	NA	69.2 - 132.2	0 - 30	NA	NA	NA	NA
Trichlorotrifluoroethane	NA	NA	NA	70 - 730	NA	NA	NA	NA	NA
Vinyl acetate	NA	NA	NA	64.1 - 136.9	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	58.7 - 136.9	0 - 30	NA	NA	NA	NA
Xylenes (total)	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
cis-1,2-Dichloroethylene	NA	NA	NA	83.3 - 119.6	0 - 30	NA	NA	NA	NA
cis-1,3-Dichloropropylene	NA	NA	NA	88.9 - 124.7	0 - 30	NA	NA	NA	NA
m,p-Xylenes	NA	NA	NA	80.4 - 118.3	0 - 30	NA	NA	NA	NA
n-Butyl alcohol	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
n-Butylbenzene	NA	NA	NA	88.4 - 125.8	0 - 30	NA	NA	NA	NA
n-Propylbenzene	NA	NA	NA	82.9 - 120.8	0 - 30	NA	NA	NA	NA
o-Xylene	NA	NA	NA	82.8 - 117.9	0 - 30	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	88.3 - 122.2	0 - 30	NA	NA	NA	NA
tert-Butyl methyl ether	NA	NA	NA	69.1 - 107.5	NA	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	82.5 - 127.9	0 - 30	NA	NA	NA	NA
trans-1,2-Dichloroethylene	NA	NA	NA	85.0 - 126.2	0 - 30	NA	NA	NA	NA
trans-1,3-Dichloropropylene	NA	NA	NA	71.3 - 133.1	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
VOA Waters, Volatiles QC only - SW846 8260B SC_NPDES - SW846 8260B DOE-AL - SW846 8260B - SW846 8260 Low Level -									
1,1,1,2-Tetrachloroethane	NA	NA	NA	82.5 - 119.4	0 - 30	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	72.1 - 135.9	0 - 30	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	66.3 - 126.8	0 - 30	NA	NA	NA	NA
1,1,2-Trichloroethane	NA	NA	NA	76.5 - 118.7	0 - 30	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	80.0 - 118.8	0 - 30	NA	NA	NA	NA
1,1-Dichloroethylene	NA	NA	NA	66.2 - 131.9	0 - 30	60.5 - 124.0	0 - 20	NA	NA
1,1-Dichloropropene	NA	NA	NA	84.3 - 126.3	0 - 30	NA	NA	NA	NA
1,2,3-Trichlorobenzene	NA	NA	NA	71.2 - 133.9	0 - 30	NA	NA	NA	NA
1,2,3-Trichloropropane	NA	NA	NA	76.0 - 119.6	0 - 30	NA	NA	NA	NA
1,2,4-Trichlorobenzene	NA	NA	NA	71.4 - 135.7	0 - 30	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	82.1 - 121.6	0 - 30	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	NA	NA	NA	67.5 - 129.0	0 - 30	NA	NA	NA	NA
1,2-Dibromoethane	NA	NA	NA	75.3 - 130.2	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	79.5 - 116.4	0 - 30	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	67.3 - 131.1	0 - 30	NA	NA	NA	NA
1,2-Dichloroethane-d4	NA	NA	NA	NA	NA	NA	NA	70 - 130	NA
1,2-Dichloropropane	NA	NA	NA	75.0 - 119.2	0 - 30	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	81.6 - 120.8	0 - 30	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	79.7 - 121.9	0 - 30	NA	NA	NA	NA
1,3-Dichloropropane	NA	NA	NA	83.1 - 114.4	0 - 30	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
1,4-Dioxane	NA	NA	NA	70 - 130	0 - 30	70 - 130	0 - 20	NA	NA
2,2-Dichloropropane	NA	NA	NA	73.6 - 141.7	NA	NA	NA	NA	NA
2-Butanone	NA	NA	NA	63.5 - 134.4	0 - 30	NA	NA	NA	NA
2-Chloro-1,3-butadiene	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
2-Chloroethylvinyl ether	NA	NA	NA	62.7 - 130.7	NA	NA	NA	NA	NA
2-Chlorotoluene	NA	NA	NA	78.5 - 120.9	0 - 30	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	60.1 - 136.2	0 - 30	NA	NA	NA	NA
2-Nitropropane	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
4-Chlorotoluene	NA	NA	NA	77.8 - 122.4	0 - 30	NA	NA	NA	NA
4-Isopropyltoluene	NA	NA	NA	83.1 - 124.7	0 - 30	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	69.0 - 127.0	0 - 30	NA	NA	NA	NA
Acetone	NA	NA	NA	70.6 - 138.7	0 - 30	NA	NA	NA	NA
Acetonitrile	NA	NA	NA	69.6 - 134.7	NA	NA	NA	NA	NA
Acrolein	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Acrylonitrile	NA	NA	NA	50 - 150	NA	NA	NA	NA	NA
Allyl chloride	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Benzene	NA	NA	NA	77.9 - 116.2	0 - 30	70.8 - 116.3	0 - 20	NA	NA
Benzyl chloride	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Bromobenzene	NA	NA	NA	77.5 - 117.6	0 - 30	NA	NA	NA	NA
Bromochloromethane	NA	NA	NA	75.3 - 124.7	0 - 30	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	77.8 - 126.9	0 - 30	NA	NA	NA	NA
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	68.9 - 137.4	NA
Bromoform	NA	NA	NA	79.2 - 140.8	0 - 30	NA	NA	NA	NA
Bromomethane	NA	NA	NA	60.8 - 144.4	0 - 30	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	67.9 - 119.9	NA	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Carbon tetrachloride	NA	NA	NA	65.7 - 140.8	0 - 30	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	81.5 - 117.8	0 - 30	77.3 - 114.4	0 - 20	NA	NA
Chloroethane	NA	NA	NA	68.2 - 131.9	0 - 30	NA	NA	NA	NA
Chloroform	NA	NA	NA	79.9 - 123.7	0 - 30	NA	NA	NA	NA
Chloromethane	NA	NA	NA	72.0 - 142.4	0 - 30	NA	NA	NA	NA
Cyclohexanone	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Dibromochloromethane	NA	NA	NA	80.9 - 129.3	0 - 30	NA	NA	NA	NA
Dibromofluoromethane	NA	NA	NA	NA	NA	NA	NA	73.7 - 143.8	NA
Dibromomethane	NA	NA	NA	79.6 - 126.5	0 - 30	NA	NA	NA	NA
Dichlorodifluoromethane	NA	NA	NA	68.1 - 141.2	0 - 30	NA	NA	NA	NA
Ethyl acetate	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Ethyl methacrylate	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Ethylbenzene	NA	NA	NA	79.5 - 120.4	0 - 30	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	72.6 - 123.7	0 - 30	NA	NA	NA	NA
Iodomethane	NA	NA	NA	67.9 - 125.7	NA	NA	NA	NA	NA
Isobutyl alcohol	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	72.9 - 115.3	0 - 30	NA	NA	NA	NA
Isopropyltoluene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methacrylonitrile	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Methyl methacrylate	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	72.9 - 111.9	0 - 30	NA	NA	NA	NA
Naphthalene	NA	NA	NA	64.5 - 143.1	0 - 30	NA	NA	NA	NA
Pentachloroethane	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Propionitrile	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Styrene	NA	NA	NA	82.2 - 121.3	0 - 30	NA	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	78.3 - 125.5	0 - 30	NA	NA	NA	NA
Tetrahydrofuran	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Toluene	NA	NA	NA	78.8 - 118.1	0 - 30	72.5 - 116.4	0 - 20	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	75.5 - 129.2	NA
Trichloroethylene	NA	NA	NA	83.2 - 122.4	0 - 30	73.7 - 122.3	0 - 20	NA	NA
Trichlorofluoromethane	NA	NA	NA	65.0 - 142.0	0 - 30	NA	NA	NA	NA
Trichlorotrifluoroethane	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
Vinyl acetate	NA	NA	NA	66.8 - 136.1	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	67.1 - 140.8	0 - 30	NA	NA	NA	NA
Xylenes (total)	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
bis(2-Chloroisopropyl)ether	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
cis-1,2-Dichloroethylene	NA	NA	NA	80.5 - 116.8	0 - 30	NA	NA	NA	NA
cis-1,3-Dichloropropylene	NA	NA	NA	76.8 - 129.4	0 - 30	NA	NA	NA	NA
cis-1,4-Dichloro-2-butene	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA
m,p-Xylenes	NA	NA	NA	78.8 - 119.4	0 - 30	NA	NA	NA	NA
n-Butylbenzene	NA	NA	NA	78.7 - 126.7	0 - 30	NA	NA	NA	NA
n-Propylbenzene	NA	NA	NA	78.1 - 126.0	0 - 30	NA	NA	NA	NA
o-Xylene	NA	NA	NA	80.7 - 118.4	0 - 30	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	83.1 - 123.4	0 - 30	NA	NA	NA	NA
tert-Butyl methyl ether	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	79.2 - 123.6	0 - 30	NA	NA	NA	NA
trans-1,2-Dichloroethylene	NA	NA	NA	77.7 - 124.7	0 - 30	NA	NA	NA	NA
trans-1,3-Dichloropropylene	NA	NA	NA	66.6 - 132.3	0 - 30	NA	NA	NA	NA
trans-1,4-Dichloro-2-butene	NA	NA	NA	50 - 150	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
BNA Solids, SW846 8270C - 8270C Selective Ion Monitoring -									
1,2,4-Trichlorobenzene	NA	23.0 - 102.9	0 - 32.5	26.8 - 100.3	0 - 30	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	10 - 150	0 - 30	24.5 - 97.2	0 - 30	NA	NA	NA	NA
1,2-Diphenylhydrazine	NA	10 - 150	0 - 30	10 - 150	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	10 - 150	0 - 30	22.6 - 96.1	0 - 30	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	16.0 - 95.8	0 - 32.1	24.8 - 97.0	0 - 30	NA	NA	NA	NA
1-Methylnaphthalene	NA	NA	NA	10 - 150	NA	NA	NA	NA	NA
2,4,5-Trichlorophenol	NA	10 - 150	0 - 30	40.7 - 103.6	0 - 30	NA	NA	NA	NA
2,4,6-Tribromophenol	NA	NA	NA	NA	NA	NA	NA	20.7 - 111.3	NA
2,4,6-Trichlorophenol	NA	10 - 150	0 - 30	34.0 - 98.5	0 - 30	NA	NA	NA	NA
2,4-Dichlorophenol	NA	10 - 150	0 - 30	35.3 - 96.7	0 - 30	NA	NA	NA	NA
2,4-Dimethylphenol	NA	10 - 150	0 - 30	22.6 - 98.6	0 - 30	NA	NA	NA	NA
2,4-Dinitrophenol	NA	10 - 150	0 - 30	22.0 - 118.7	0 - 30	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	27.3 - 116.9	0 - 31.4	41.8 - 108.4	0 - 30	NA	NA	NA	NA
2,6-Dinitrotoluene	NA	10 - 150	0 - 30	32.7 - 106.6	0 - 30	NA	NA	NA	NA
2-Chloronaphthalene	NA	10 - 150	0 - 30	32.1 - 95.8	0 - 30	NA	NA	NA	NA
2-Chlorophenol	NA	22.6 - 99.5	0 - 36.0	26.2 - 99.0	0 - 30	NA	NA	NA	NA
2-Fluorobiphenyl	NA	NA	NA	NA	NA	NA	NA	18.6 - 98.8	NA
2-Fluorophenol	NA	NA	NA	NA	NA	NA	NA	20.5 - 96.8	NA
2-Methyl-4,6-dinitrophenol	NA	10 - 150	0 - 30	24.7 - 113.0	0 - 30	NA	NA	NA	NA
2-Methylnaphthalene	NA	10 - 150	0 - 30	34.8 - 97.8	0 - 30	NA	NA	NA	NA
2-Nitrophenol	NA	10 - 150	0 - 30	29.1 - 98.9	0 - 30	NA	NA	NA	NA
3,3'-Dichlorobenzidine	NA	10 - 150	0 - 30	22.7 - 118.2	0 - 30	NA	NA	NA	NA
4-Bromophenylphenylether	NA	10 - 150	0 - 30	31.3 - 113.4	0 - 30	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	27.8 - 110.9	0 - 32.7	30.6 - 106.8	0 - 30	NA	NA	NA	NA
4-Chloroaniline	NA	10 - 150	0 - 30	17.2 - 92.4	0 - 30	NA	NA	NA	NA
4-Chlorophenylphenylether	NA	10 - 150	0 - 30	36.6 - 97.8	0 - 30	NA	NA	NA	NA
4-Nitrophenol	NA	16.3 - 128.0	0 - 36.5	27.3 - 113.8	0 - 30	NA	NA	NA	NA
Acenaphthene	NA	19.1 - 105.7	0 - 32.6	37.3 - 105.3	0 - 30	NA	NA	NA	NA
Acenaphthylene	NA	10 - 150	0 - 30	31.4 - 89.4	0 - 30	NA	NA	NA	NA
Acetophenone	NA	10 - 150	0 - 30	27.6 - 95.3	0 - 30	NA	NA	NA	NA
Aniline	NA	10 - 150	0 - 30	11.1 - 110.3	0 - 30	NA	NA	NA	NA
Anthracene	NA	10 - 150	0 - 30	43.2 - 99.7	0 - 30	NA	NA	NA	NA
Benzidine	NA	10 - 150	0 - 30	10 - 150	NA	NA	NA	NA	NA
Benzo(a)anthracene	NA	10 - 150	0 - 30	41.3 - 107.4	0 - 30	NA	NA	NA	NA
Benzo(a)pyrene	NA	10 - 150	0 - 30	37.4 - 108.3	0 - 30	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	10 - 150	0 - 30	39.6 - 111.8	0 - 30	NA	NA	NA	NA
Benzo(ghi)perylene	NA	10 - 150	0 - 30	28.6 - 122.1	0 - 30	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	10 - 150	0 - 30	40.8 - 115.6	0 - 30	NA	NA	NA	NA
Benzoic acid	NA	10 - 150	0 - 30	23.4 - 107.4	NA	NA	NA	NA	NA
Benzyl alcohol	NA	10 - 150	0 - 30	19.9 - 103.8	NA	NA	NA	NA	NA
Butylbenzylphthalate	NA	10 - 150	0 - 30	34.9 - 117.3	0 - 30	NA	NA	NA	NA
Carbazole	NA	10 - 150	0 - 30	34.2 - 103.5	0 - 30	NA	NA	NA	NA
Chlorobenzilate	NA	NA	0 - 30	NA	NA	NA	NA	NA	NA
Chrysene	NA	10 - 150	0 - 30	43.1 - 106.9	0 - 30	NA	NA	NA	NA
Di-n-butylphthalate	NA	10 - 150	0 - 30	43.4 - 110.5	0 - 30	NA	NA	NA	NA
Di-n-octylphthalate	NA	10 - 150	0 - 30	27.0 - 121.4	0 - 30	NA	NA	NA	NA
Dibenzo(a,h)anthracene	NA	10 - 150	0 - 30	28.1 - 118.8	0 - 30	NA	NA	NA	NA
Dibenzofuran	NA	10 - 150	0 - 30	38.1 - 97.5	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Diethylphthalate	NA	10 - 150	0 - 30	39.3 - 102.2	0 - 30	NA	NA	NA	NA
Dimethylphthalate	NA	10 - 150	0 - 30	39.5 - 96.4	0 - 30	NA	NA	NA	NA
Diphenylamine	NA	10 - 150	0 - 30	41.3 - 99.6	0 - 30	NA	NA	NA	NA
Fluoranthene	NA	10 - 150	0 - 30	42.1 - 112.7	0 - 30	NA	NA	NA	NA
Fluorene	NA	10 - 150	0 - 30	39.7 - 98.0	0 - 30	NA	NA	NA	NA
Hexachlorobenzene	NA	10 - 150	0 - 30	38.6 - 100.6	0 - 30	NA	NA	NA	NA
Hexachlorobutadiene	NA	10 - 150	0 - 30	23.4 - 96.9	0 - 30	NA	NA	NA	NA
Hexachlorocyclopentadiene	NA	10 - 150	0 - 30	18.2 - 110.0	0 - 30	NA	NA	NA	NA
Hexachloroethane	NA	10 - 150	0 - 30	22.2 - 96.2	0 - 30	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	10 - 150	0 - 30	30.8 - 115.9	0 - 30	NA	NA	NA	NA
Isophorone	NA	10 - 150	0 - 30	33.0 - 93.6	0 - 30	NA	NA	NA	NA
N-Methyl-N-nitrosomethylamine	NA	10 - 150	30-Mar	10 - 150	NA	NA	NA	NA	NA
N-Nitrosodipropylamine	NA	20.0 - 102.0	0 - 32.4	23.9 - 98.7	0 - 30	NA	NA	NA	NA
Naphthalene	NA	10 - 150	0 - 30	26.9 - 99.6	0 - 30	NA	NA	NA	NA
Nitrobenzene	NA	10 - 150	0 - 30	26.6 - 99.5	0 - 30	NA	NA	NA	NA
Nitrobenzene-d5	NA	NA	NA	NA	NA	NA	NA	21.1 - 100.9	NA
Pentachlorophenol	NA	19.8 - 109.4	0 - 30.4	25.2 - 110.5	0 - 30	NA	NA	NA	NA
Phenanthrene	NA	10 - 150	0 - 30	43.4 - 98.7	0 - 30	NA	NA	NA	NA
Phenol	NA	15.7 - 101.5	0 - 33.4	30.3 - 98.0	0 - 30	NA	NA	NA	NA
Phenol-d5	NA	NA	NA	NA	NA	NA	NA	19.2 - 101.4	NA
Pyrene	NA	22.5 - 119.1	0 - 32.0	33.1 - 109.3	0 - 30	NA	NA	NA	NA
Pyridine	NA	NA	NA	10 - 150	NA	NA	NA	NA	NA
bis(2-Chloroethoxy)methane	NA	10 - 150	0 - 30	24.2 - 92.4	0 - 30	NA	NA	NA	NA
bis(2-Chloroethyl) ether	NA	10 - 150	0 - 30	19.2 - 96.3	0 - 30	NA	NA	NA	NA
bis(2-Chloroisopropyl)ether	NA	10 - 150	0 - 30	22.5 - 96.4	0 - 30	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	10 - 150	0 - 30	37.3 - 123.2	0 - 30	NA	NA	NA	NA
m,p-Cresols	NA	10 - 150	0 - 30	35.5 - 98.4	0 - 30	NA	NA	NA	NA
m-Nitroaniline	NA	10 - 150	0 - 30	29.2 - 93.2	0 - 30	NA	NA	NA	NA
o-Cresol	NA	10 - 150	0 - 30	32.0 - 97.9	0 - 30	NA	NA	NA	NA
o-Nitroaniline	NA	10 - 150	0 - 30	31.1 - 110.1	0 - 30	NA	NA	NA	NA
p-Nitroaniline	NA	10 - 150	0 - 30	24.6 - 111.9	0 - 30	NA	NA	NA	NA
p-Terphenyl-d14	NA	NA	NA	NA	NA	NA	NA	19.9 - 116.2	NA
PAH HPLC Water, SW846 8310 -									
1-Methylnaphthalene	NA	72.61 - 130	0 - 30	75.494 - 130	0 - 30	NA	NA	NA	NA
2-Methylnaphthalene	NA	44.1 - 113.5	0 - 30	65.9 - 98.0	0 - 30	NA	NA	NA	NA
Acenaphthene	NA	42.0 - 119.8	0 - 30	70.725 - 130	0 - 30	NA	NA	NA	NA
Acenaphthylene	NA	43.2 - 119.4	0 - 30	71.547 - 130	0 - 30	NA	NA	NA	NA
Anthracene	NA	73.617 - 130	0 - 30	85.172 - 130	0 - 30	NA	NA	NA	NA
Benzo(a)anthracene	NA	46.4 - 135.9	0 - 30	85.043 - 130	0 - 30	NA	NA	NA	NA
Benzo(a)pyrene	NA	40.7 - 130.8	0 - 30	71.446 - 130	0 - 30	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	60.6 - 120.3	0 - 30	78.281 - 130	0 - 30	NA	NA	NA	NA
Benzo(ghi)perylene	NA	30.6 - 119.7	0 - 30	33.4 - 99.6	0 - 30	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	38.9 - 133.7	0 - 30	68.2 - 107.9	0 - 30	NA	NA	NA	NA
Chrysene	NA	63.5 - 115.2	0 - 30	82.027 - 130	0 - 30	NA	NA	NA	NA
Decafluorobiphenyl	NA	NA	NA	NA	NA	NA	NA	48.1 - 106.2	NA
Dibenzo(a,h)anthracene	NA	39.1 - 133.2	0 - 30	37.4 - 114.8	0 - 30	NA	NA	NA	NA
Fluoranthene	NA	76.16 - 130	0 - 30	82.396 - 130	0 - 30	NA	NA	NA	NA
Fluorene	NA	64.5 - 104.0	0 - 30	73.658 - 130	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Indeno(1,2,3-cd)pyrene	NA	50.4 - 124.6	0 - 30	43.7 - 111.1	0 - 30	NA	NA	NA	NA
Naphthalene	NA	47.7 - 92.4	0 - 30	56.8 - 89.1	0 - 30	NA	NA	NA	NA
Phenanthrene	NA	72.509 - 130	0 - 30	74.236 - 130	0 - 30	NA	NA	NA	NA
Pyrene	NA	47.6 - 126.8	0 - 30	78.92 - 130	0 - 30	NA	NA	NA	NA
PAH HPLC Solids, SW846 8310 -									
1-Methylnaphthalene	NA	47.2 - 122.3	0 - 30	71.925 - 130	0 - 30	NA	NA	NA	NA
2-Methylnaphthalene	NA	54.8 - 106.4	0 - 30	70.516 - 130	0 - 30	NA	NA	NA	NA
Acenaphthene	NA	54.4 - 103.6	0 - 30	69.673 - 130	0 - 30	NA	NA	NA	NA
Acenaphthylene	NA	54.2 - 102.9	0 - 30	70.119 - 130	0 - 30	NA	NA	NA	NA
Anthracene	NA	54.6 - 115.3	0 - 30	71.827 - 130	0 - 30	NA	NA	NA	NA
Benzo(a)anthracene	NA	38.8 - 136.5	0 - 30	81.574 - 130	0 - 30	NA	NA	NA	NA
Benzo(a)pyrene	NA	43.2 - 114.3	0 - 30	72.857 - 130	0 - 30	NA	NA	NA	NA
Benzo(b)fluoranthene	NA	44.1 - 122.4	0 - 30	83.721 - 130	0 - 30	NA	NA	NA	NA
Benzo(ghi)perylene	NA	38.3 - 116.4	0 - 30	66.5 - 111.9	0 - 30	NA	NA	NA	NA
Benzo(k)fluoranthene	NA	34.7 - 136.8	0 - 30	40.1 - 142.6	0 - 30	NA	NA	NA	NA
Chrysene	NA	47.4 - 123.7	0 - 30	84.303 - 130	0 - 30	NA	NA	NA	NA
Decafluorobiphenyl	NA	NA	NA	NA	NA	NA	NA	47.1 - 114.4	NA
Dibenzo(a,h)anthracene	NA	59.1 - 121.1	0 - 30	84.144 - 130	0 - 30	NA	NA	NA	NA
Fluoranthene	NA	42.6 - 127.6	0 - 30	80.974 - 130	0 - 30	NA	NA	NA	NA
Fluorene	NA	55.8 - 108.3	0 - 30	73.3 - 99.9	0 - 30	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	NA	50.1 - 122.1	0 - 30	83.375 - 130	0 - 30	NA	NA	NA	NA
Naphthalene	NA	40.5 - 114.6	0 - 30	58.6 - 110.3	0 - 30	NA	NA	NA	NA
Phenanthrene	NA	59.7 - 106.6	0 - 30	75.205 - 130	0 - 30	NA	NA	NA	NA
Pyrene	NA	43.5 - 122.7	0 - 30	79.601 - 130	0 - 30	NA	NA	NA	NA
Pest/PCB Solids, SW846 8082 - SW846 8081A - SW846 8081 - SW846 8080 -									
4,4'-DDD	NA	34.3 - 138.2	0 - 33.4	56.2 - 125.6	0 - 30.6	NA	NA	NA	NA
4,4'-DDE	NA	37.6 - 137.3	0 - 32.5	54.2 - 122.2	0 - 21.3	NA	NA	NA	NA
4,4'-DDT	NA	32.7 - 166.0	0 - 33.3	58.6 - 146.6	0 - 27.5	NA	NA	NA	NA
4cmx	NA	NA	NA	NA	NA	NA	NA	50.9 - 113.7	NA
Aldrin	NA	34.1 - 123.6	0 - 30.3	57.7 - 109.2	0 - 21.6	NA	NA	NA	NA
Aroclor-1016	NA	30.0 - 149.3	0 - 30.0	56.7 - 115.1	0 - 25.7	NA	NA	NA	NA
Aroclor-1260	NA	30.0 - 137.4	0 - 29.3	57.6 - 109.8	0 - 23.7	NA	NA	NA	NA
Aroclor-Total	NA	NA	NA	NA	0 - 30	NA	NA	NA	NA
Chlordane (tech.)	NA	-	0 -	70 - 130	NA	NA	NA	NA	NA
Decachlorobiphenyl	NA	NA	NA	NA	NA	NA	NA	51.4 - 121.1	NA
Dieldrin	NA	34.4 - 128.6	0 - 31.0	55.1 - 112.7	0 - 30	NA	NA	NA	NA
Endosulfan I	NA	30.0 - 134.0	0 - 31.7	31.0 - 91.7	0 - 30	NA	NA	NA	NA
Endosulfan II	NA	50 - 150	0 - 30	30.0 - 112.1	0 - 30	NA	NA	NA	NA
Endosulfan sulfate	NA	27.8 - 117.6	0 - 33.8	55.6 - 113.2	0 - 32.6	NA	NA	NA	NA
Endrin	NA	36.7 - 142.3	0 - 32	55.1 - 125.6	0 - 22.1	NA	NA	NA	NA
Endrin aldehyde	NA	29.9 - 97.8	0 - 36.0	40.5 - 104.1	0 - 30	NA	NA	NA	NA
Endrin ketone	NA	30.8 - 124.8	0 - 35.1	50.3 - 122.9	0 - 30	NA	NA	NA	NA
Heptachlor	NA	25.4 - 140.3	0 - 30	54.9 - 118.8	0 - 28.5	NA	NA	NA	NA
Heptachlor epoxide	NA	50 - 150	0 - 30	30.0 - 134.8	0 - 36.8	NA	NA	NA	NA
Methoxychlor	NA	50 - 150	0 - 30	52.3 - 125.9	0 - 25.1	NA	NA	NA	NA
Toxaphene	NA	50 - 150	0 - 30	40.2 - 154.8	NA	NA	NA	NA	NA
alpha-BHC	NA	34.7 - 122.4	0 - 29.5	55.8 - 112.1	0 - 30	NA	NA	NA	NA
alpha-Chlordane	NA	29.8 - 144.8	0 - 29.6	54.5 - 125.3	0 - 30	NA	NA	NA	NA
beta-BHC	NA	34.4 - 125.6	0 - 30.6	54.6 - 111.7	0 - 18.0	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
delta-BHC	NA	34.5 - 128.9	0 - 34.4	53.7 - 118.2	0 - 20.4	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	33.7 - 128.7	0 - 32.3	54.2 - 115.4	0 - 30	NA	NA	NA	NA
gamma-Chlordane	NA	31.4 - 131.8	0 - 32.3	56.7 - 112.3	0 - 30	NA	NA	NA	NA
EDB/DBCP Water, SW846 8011 - EPA 504.1 -									
1,2-Dibromo-3-chloropropane	NA	35.2 - 132.2	0 - 28.0	65.7 - 134.3	0 - 30	NA	NA	NA	NA
1,2-Dibromoethane	NA	49.9 - 132.5	0 - 37.2	64.4 - 145.2	0 - 30.0	NA	NA	NA	NA
Herb Solids, SW846 8151A -									
2,4,5-T	NA	33.6 - 145.0	0 - 29.3	31.8 - 155.9	0 - 30	NA	NA	NA	NA
2,4,5-TP	NA	41.4 - 143.5	0 - 36.0	46.2 - 144.8	0 - 29.5	NA	NA	NA	NA
2,4-D	NA	26.5 - 152.8	0 - 34.5	35.2 - 147.3	0 - 30	NA	NA	NA	NA
2,4-DB	NA	58.4 - 140.3	0 - 30	50 - 150	0 - 30	NA	NA	NA	NA
2,4-Dichlorophenylacetic acid	NA	NA	NA	NA	NA	NA	NA	42.6 - 128.9	NA
Dalapon	NA	50 - 150	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
Dicamba	NA	51.4 - 144.2	0 - 30	48.4 - 140.6	0 - 30	NA	NA	NA	NA
Dichlorprop	NA	50 - 150	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
Dinoseb	NA	50 - 150	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
MCPA	NA	50 - 150	0 - 30	70 - 130	NA	NA	NA	NA	NA
MCPP	NA	50 - 150	0 - 30	70 - 130	0 - 30	NA	NA	NA	NA
Herb Waters, SW846 8151A - SM 6640B -									
2,4,5-T	NA	51.1 - 151.3	0 - 25.7	65.7 - 144.6	0 - 30	NA	NA	NA	NA
2,4,5-TP	NA	61.3 - 142.9	0 - 24.1	69.3 - 135.4	0 - 29.2	NA	NA	NA	NA
2,4-D	NA	46.2 - 150.2	0 - 27.4	57.8 - 138.6	0 - 30	NA	NA	NA	NA
2,4-DB	NA	33.662 - 150	0 - 31.4	63.0 - 157.7	0 - 30	NA	NA	NA	NA
2,4-Dichlorophenylacetic acid	NA	NA	NA	NA	NA	NA	NA	56.2 - 121.3	NA
Dalapon	NA	50 - 150	0 - 30	50 - 130	0 - 30	NA	NA	NA	NA
Dicamba	NA	57.1 - 130.4	0 - 30	55.0 - 146.6	0 - 30	NA	NA	NA	NA
Dichlorprop	NA	50 - 150	0 - 30	50 - 130	0 - 30	NA	NA	NA	NA
Dinoseb	NA	50 - 150	0 - 30	50 - 130	0 - 30	NA	NA	NA	NA
MCPA	NA	50 - 150	0 - 30	50 - 130	0 - 30	NA	NA	NA	NA
MCPP	NA	50 - 150	0 - 30	50 - 130	0 - 30	NA	NA	NA	NA
GRO Solids, SW846 8015A/B VOC - SW846 8015A/B PREP - GRO QC only - California Method Prep - California Method -									
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	57.5 - 124.3	NA
Gasoline Range Organics	NA	-	-	72.9 - 118.0	0 - 20	51.4 - 130.0	0 - 31.4	NA	NA
Sulfite Soils, SM 4500 SO3 (2-) B - EPA 377.1 Modified -									
Sulfite	0 - 17.2	75 - 125	0 - 30	75 - 125	0 - 30	75 - 125	0 - 30	NA	NA
Salinity Water, SM 2520B -									
Salinity	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Sulfite Waters, SM 4500 SO3 (2-) B - EPA 377.1 -									
Sulfite	0 - 15	NA	NA	NA	NA	NA	NA	NA	NA
Acidity Waters, SM 2310B - EPA 305.1 -									
Acidity	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Color Water, SM 2120E - EPA 110.2 -									
Color	0 - 0	NA	NA	100 - 100	-	NA	NA	NA	NA
Color @ pH 7.6	0 - 0	NA	NA	NA	NA	NA	NA	NA	NA
Hardness as CaCO3 Water, EPA 130.2 -									
Hardness as CaCO3	0 - 10	90 - 110	0 - 30	90 - 110	0 - 30	80 - 120	-	NA	NA
Corrosivity Solid, SW846 9045C - EPA 150.1 -									
Corrosivity	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Corrosivity 2	0 - 10	NA	NA	95 - 105	-	NA	NA	NA	NA
Turbidity Waters, EPA 180.1									
Turbidity	0 - 20	NA	NA	86.4 - 117.9	0 - 20	NA	NA	NA	NA
MBAS Waters, EPA 425.1 SC_NPDES - EPA 425.1 -									
MBAS	0 - 20	70 - 130	NA	85.754 - 115	0 - 30	63.1 - 127.7	NA	NA	NA
Ferrous Iron Water, SM 3500-Fe-D -									
Ferrous Iron	0 - 20	-	NA	90.5 - 110.1	-	54.7 - 134.6	-	NA	NA
Residual Chlorine Water, SM 4500CL_G - EPA 330.5 -									
Chlorine, Residual	0 - 20	-	NA	85 - 115	0 - 20	91.4 - 124.2	NA	NA	NA
Hex. Cr Waters, SW846 7196A -									
Hexavalent Chromium	0 - 36.0	75 - 125	0 - 30	87.3 - 111.5	0 - 20	75.4 - 116.9	0 - 10	NA	NA
pH Water, SW846 9040B - EPA 150.1 -									
Corrosivity	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
pH	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
pH Solid, SW846 9045C - OLM 4.2 CLP pH -									
pH	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Ortho-PO4 Water, EPA 365.2									
Ortho-phosphate	0 - 23.6	-	-	90 - 110	0 - 10	71.3 - 113.8	-	NA	NA
Specific Conductance Water, SW846 9050A - SM 18_2510B - EPA 120.1 -									
Conductivity	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Specific Conductance	0 - 10	NA	NA	95 - 105	NA	NA	NA	NA	NA
SPC/SPCF Waters, ASTM D 1385 -									
Hydrazine	0 - 20	77.6 - 118.0	NA	85.2 - 114.6	NA	74.7 - 125.4	NA	NA	NA
Fluoride Water, EPA 340.2 -									
Fluoride	0 - 10	80 - 120	NA	85 - 115	0 - 20	85 - 115	NA	NA	NA
Acid Soluble Sulfides, SW846 9034 -									
Acid Soluble Sulfides	0 - 40	24.4 - 120.4	0 - 20	66.5 - 110.2	0 - 20	25 - 125	NA	NA	NA
Total Sulfides Water, EPA 376.2 -									
Total Sulfide	0 - 16.8	-	-	80 - 120	0 - 20	72.4 - 107.9	-	NA	NA
Moisture Solid, SW846 3550 - ASTM E 203 - ASTM D 2216 - ASTM 2216 -									
Karl Fischer Moisture	0 - 30	NA	NA	95 - 105	0 - 20	NA	NA	NA	NA
Moisture	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Total Alkalinity Solid, EPA 310.1 Modified -									
Alkalinity, Total as CaCO3	0 - 20	75 - 120	-	85.5 - 114.2	-	NA	NA	NA	NA
Boiling Point Waters, ASTM D 1120-94 -									
Boiling Point	0 - 5	NA	NA	-	NA	NA	NA	NA	NA
Total Alkalinity Water, SM 4500 CO2 D - SM 2320B - EPA 310.1 -									
Alkalinity, Total as CaCO3	0 - 20	70 - 130	0 - 20	90 - 110	-	NA	NA	NA	NA
Bicarbonate alkalinity (CaCO3)	0 - 20	-	-	-	-	NA	NA	NA	NA
Carbon dioxide, Free	0 - 20	-	-	-	-	NA	NA	NA	NA
Carbon dioxide, Total	0 - 20	-	-	-	-	NA	NA	NA	NA
Carbonate alkalinity (CaCO3)	0 - 20	-	-	-	-	NA	NA	NA	NA
Hydroxide alkalinity as CaCO3	0 - 20	-	-	-	-	NA	NA	NA	NA
Releasable Sulfide, SW846 Chpt. 7.3.4-TIT - SW846 7.3.4 Modified -									
Reactive Releasable Sulfide	0 - 63.7	NA	NA	Oct-80	-	NA	NA	NA	NA
COD Water, HACH 8000 - EPA 410.4 -									
COD	0 - 26.2	-	-	85 - 115	-	85 - 115	0 - 20	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Hex. Cr Solid, SW846 7196A									
Hexavalent Chromium	0 - 25.8	50 - 125	0 - 30	75 - 115	0 - 20	NA	NA	NA	NA
Acid Soluble Sulfides Solid, SW846 9034 - SW846 9030 A -									
Acid Soluble Sulfides	0 - 50	10.8 - 48.6	-	65 - 105	-	NA	NA	NA	NA
Moisture Water, ASTM E 203									
Karl Fischer Moisture	0 - 20	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Carbonate Alk. in Water, SM 2320B -									
Carbonate alkalinity (CaCO3)	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Setaflash 200 Waters, SW846 1020A -									
Setaflash-200	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Setaflash 140 Waters, SW846 1020A -									
Setaflash-140	0 - 15	NA	NA	95 - 105	-	NA	NA	NA	NA
Setaflash 140 Solids, SW846 1020A -									
Setaflash-140	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Setaflash 200 Solid, SW846 1020A -									
Setaflash-200	0 - 10	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA
Flashpoint CC 140 Water, SW846 1010 -									
Flashpoint-140	0 - 10	NA	NA	95 - 105	-	NA	NA	NA	NA
Flashpoint-200	0 - 10	NA	NA	95 - 105	-	NA	NA	NA	NA
Flashpoint CC 200 Water, SW846 1010 -									
Flashpoint-140	0 - 10	NA	NA	95 - 105	0 - 5	NA	NA	NA	NA
Flashpoint-200	0 - 10	NA	NA	95 - 105	0 - 5	NA	NA	NA	NA
Flashpoint CC Solids, SW846 1010 -									
Flashpoint-140	0 - 10	NA	NA	95 - 105	0 - 20	NA	NA	NA	NA
Flashpoint-200	0 - 10	NA	NA	95 - 105	0 - 20	NA	NA	NA	NA
Heating Value Solid, ASTM D 5468 - ASTM D 240-87 -									
Heating Value	0 - 20	NA	NA	90 - 110	NA	NA	NA	NA	NA
Heating Value Waters, ASTM D 240-87 -									
Heating Value	0 - 20	NA	NA	90 - 110	NA	NA	NA	NA	NA
Total Halogens Solid, ASTM D 808 -									
Total Halogens	0 - 50	NA	NA	80.8 - 115.7	NA	NA	NA	NA	NA
Total Halogens Water, ASTM D 808 -									
Total Halogens	0 - 20	NA	NA	79.0 - 115.4	0 - 20	NA	NA	NA	NA
Specific Gravity Water, ASTM D 5057 -									
Specific Gravity	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Density, ASTM D 5057 -									
Density	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Kinematic Vis. Waters, ASTM D2161 & 2983 Modified - ASTM 2983 MODIFIED KINEMATIC - ASTM 2983 MODIFIED ABSOLUTE -									
Viscosity, Absolute	0 - 15	NA	NA	80 - 120	-	NA	NA	NA	NA
Viscosity, Kinematic	0 - 15	NA	NA	80 - 120	-	NA	NA	NA	NA
BOD5 Waters, SM 18-5210B - EPA 405.1									
BOD, 5 DAY	0 - 15	NA	NA	84.6 - 115.4	NA	NA	NA	NA	NA
BOD, 5 DAY Carbonaceous	0 - 15	NA	NA	84.6 - 115.4	NA	NA	NA	NA	NA
EOX Solids, SW846 9023 -									
Extractable Organic Halogens	0 - 38.8	70 - 130	-	80 - 120	-	NA	NA	NA	NA
TOX/AOX Waters, SW846 9020B - EPA 1650 -									
Absorbable Organic Halogens	0 - 20	NA	NA	80 - 120.	-	85.9 - 127.4	0 - 20	NA	NA
Total Organic Halogens	0 - 20	NA	NA	80 - 120	-	79.8 - 132.4	-	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
TOC Solids, SW846 9060 Modified Prep - SW846 9060 Modified - EPA 415.1 Modified Prep - EPA 415.1 Modified -									
Total Organic Carbon	0 - 25	-	-	80 - 120	-	66.2 - 120.6	-	NA	NA
Total Carbon Solids, SW846 9060 Modified Prep - SW846 9060 Modified - EPA 415.1 Modified Prep - EPA 415.1 Modified -									
Total Carbon	0 - 20	-	NA	80 - 120	-	80 - 120	-	NA	NA
Total Carbon Waters, SW846 9060 - EPA 415.1 -									
Total Carbon	0 - 15	NA	NA	86.3 - 113.9	-	75 - 125	NA	NA	NA
Diss. Org. Carbon Waters, EPA 415.1 -									
Diss. Org. Carbon	0 - 15	NA	NA	90.6 - 110.2	NA	80.0 - 120.8	-	NA	NA
TOC Waters, SW846 9060 - EPA 415.1 -									
Total Organic Carbon	0 - 20	-	-	85 - 115	-	80 - 120	-	NA	NA
PO4 Waters, EPA 365.4 Prep - EPA 365.4 -									
Phosphorus, Total as PO4	0 - 20	80 - 115	-	80 - 115	-	-	NA	NA	NA
PO4 Solids, EPA 365.4 Modified Prep - EPA 365.4 Modified -									
Phosphorus, Total as PO4	0 - 20	75 - 125	NA	80 - 120	-	-	NA	NA	NA
NH3 Waters, EPA 350.1 -									
Nitrogen, Ammonia	0 - 20	75 - 125	-	90 - 110	-	-	NA	NA	NA
NH3 Solids, EPA 350.1 Modified -									
Nitrogen, Ammonia	0 - 20	75 - 125	NA	90 - 110	-	NA	NA	NA	NA
TKN Waters, EPA 351.2 -									
Nitrogen, Total Kjeldahl	0 - 20	75 - 125	-	90 - 110	-	NA	NA	NA	NA
TKN Solids, EPA 351.2 Modified -									
Nitrogen, Total Kjeldahl	0 - 20	75 - 125	-	90 - 110	-	-	NA	NA	NA
NOX Waters, EPA 353.1 SC_NPDES - EPA 353.1 -									
Nitrogen, Nitrate/Nitrite	0 - 20	NA	NA	90 - 110	-	80 - 120	-	NA	NA
NOX Solids, EPA 353.1 MODIFIED -									
Nitrogen, Nitrate/Nitrite	0 - 20	75 - 125	NA	90 - 110	0 - 20	-	NA	NA	NA
TNRCC Solids, TNRCC Method 1005 -									
ETPH	NA	62 - 204	0 - 25	63 - 153	0 - 25	NA	NA	NA	NA
TPH (C6-C36)	NA	75 - 125	0 - 25	75 - 125	0 - 25	NA	NA	NA	NA
TRPH (C8-C40)	NA	62 - 204	0 - 25	63 - 153	0 - 25	NA	NA	NA	NA
Trifluorotoluene	NA	NA	NA	NA	NA	NA	NA	52.2 - 151.9	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	52.4 - 151.0	NA
TNRCC Waters, TNRCC Method 1005 -									
ETPH	NA	41 - 101	0 - 20	55 - 118	0 - 20	NA	NA	NA	NA
TPH (C6-C36)	NA	75 - 125	0 - 20	75 - 125	0 - 20	NA	NA	NA	NA
TRPH (C8-C40)	NA	41 - 101	0 - 20	55 - 118	0 - 20	NA	NA	NA	NA
Trifluorotoluene	NA	NA	NA	NA	NA	NA	NA	57.0 - 133.1	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	55.4 - 137.1	NA
Pest/PCB Waters, SW846 8082 - SW846 8081A SC_NPDES - SW846 8081A - SW846 8081 - SW846 8080 -									
4,4'-DDD	NA	42.7 - 136.9	0 - 20.2	59.3 - 129.6	0 - 24.1	NA	NA	NA	NA
4,4'-DDE	NA	43.5 - 126.8	0 - 22.7	56.3 - 121.4	0 - 24.3	NA	NA	NA	NA
4,4'-DDT	NA	50.6 - 155.8	0 - 21.7	68.9 - 148.7	0 - 25.1	NA	NA	NA	NA
4cmx	NA	NA	NA	NA	NA	NA	NA	33.3 - 126.4	NA
Aldrin	NA	40.5 - 120.0	0 - 22.7	50.9 - 112.3	0 - 28.5	NA	NA	NA	NA
Aroclor-1016	NA	36.1 - 136.9	0 - 30.2	58.4 - 131.7	0 - 22.3	NA	NA	NA	NA
Aroclor-1260	NA	30.7 - 116.9	0 - 28.7	54.3 - 111.6	0 - 19.9	NA	NA	NA	NA
Chlordane (tech.)	NA	34.3 - 150.8	0 - 27.8	48.0 - 145.2	NA	NA	NA	NA	NA
Decachlorobiphenyl	NA	NA	NA	NA	NA	NA	NA	30.0 - 135.1	NA
Dieldrin	NA	41.9 - 121.9	0 - 21.1	52.6 - 119.1	0 - 24.5	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Endosulfan I	NA	27.3 - 108.2	0 - 24.9	32.3 - 87.7	0 - 26.3	NA	NA	NA	NA
Endosulfan II	NA	30.0 - 111.8	0 - 29.5	47.7 - 107.7	0 - 35.8	NA	NA	NA	NA
Endosulfan sulfate	NA	36.7 - 131.0	0 - 30.8	45.7 - 123.9	NA	NA	NA	NA	NA
Endrin	NA	42.0 - 135.5	0 - 20.2	57.0 - 130.6	0 - 25.6	NA	NA	NA	NA
Endrin aldehyde	NA	36.0 - 108.7	0 - 31.6	48.4 - 120.0	0 - 24.6	NA	NA	NA	NA
Endrin ketone	NA	43.9 - 140.8	0 - 33.8	41.8 - 132.0	0 - 19.9	NA	NA	NA	NA
Heptachlor	NA	41.3 - 134.7	0 - 26.4	59.9 - 123.2	0 - 26.5	NA	NA	NA	NA
Heptachlor epoxide	NA	42.6 - 158.2	0 - 22.4	62.1 - 122.6	0 - 26.6	NA	NA	NA	NA
Methoxychlor	NA	49.4 - 152.9	0 - 27.7	53.1 - 138.4	0 - 23.4	NA	NA	NA	NA
Toxaphene	NA	33.2 - 139.0	0 - 31.5	56.2 - 131.4	NA	NA	NA	NA	NA
alpha-BHC	NA	45.9 - 127.0	0 - 31.1	59.3 - 117.8	0 - 24.3	NA	NA	NA	NA
alpha-Chlordane	NA	49.2 - 139.0	0 - 18.3	63.0 - 128.4	0 - 20.7	NA	NA	NA	NA
beta-BHC	NA	38.1 - 128.6	0 - 24.6	46.3 - 123.9	0 - 24.1	NA	NA	NA	NA
delta-BHC	NA	30.5 - 136.6	0 - 26.3	54.4 - 126.1	0 - 26.9	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	45.7 - 132.4	0 - 22.3	53.9 - 127.7	0 - 25.2	NA	NA	NA	NA
gamma-Chlordane	NA	46.8 - 125.8	0 - 22.1	55.4 - 119.0	0 - 20.2	NA	NA	NA	NA
Oil & Grease Waters, SW846 9070 - EPA 413.1 -									
Oil & Grease	0 - 30	70 - 130	NA	76.1 - 106.3	0 - 13.2	NA	NA	NA	NA
TPH Gravimetric Solid, SW846 9071A/ SM 5520F -									
Total Petroleum Hydrocarbons	0 - 30	56.7 - 112.9	0 - 30	68.3 - 102.6	0 - 20	-	-	NA	NA
Oil & Grease Soils, SW846 9071A -									
Oil & Grease	0 - 20	76.6 - 111.0	0 - 20	88.5 - 106.2	0 - 20	NA	NA	NA	NA
Volatile Suspended Solids Water, EPA 160.2/160.4 -									
Volatile Suspended Solids	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Total Phenols Solid, SW846 9066 -									
Phenol	0 - 30	70 - 130	NA	-	-	70 - 130	NA	NA	NA
Total Phenol	0 - 30	70 - 130	NA	75 - 110	0 - 30	70 - 130	NA	NA	NA
Reactive CN in Solids, SW846 7.3.3 Prep - SW846 7.3.3 -									
Reactive Releasable Cyanide	0 - 46.2	NA	NA	0 - 27.5	0 - 30	NA	NA	NA	NA
CN-Cl Water, SW846 9012A - EPA 335.1 -									
Cyanide, Amenable to CL	0 - 20	43.4 - 139.4	NA	90 - 110	0 - 30	NA	NA	NA	NA
2002 1664 HEM/SGT-HEM, EPA 1664 -									
Silica Gel Treated n-Hexane Extractable Material	NA	-	-	64 - 132	0 - 20	NA	NA	NA	NA
n-Hexane Extractable Material	NA	-	-	78 - 114	0 - 20	NA	NA	NA	NA
CN-Cl Solids, SW846 9012A									
Cyanide, Amenable to CL	0 - 30	45 - 135	NA	90 - 110	-	NA	NA	NA	NA
CN-WAD Waters, SM 4500-CN-I - ASTM D 2036 Prep - ASTM D 2036 -									
Cyanide, Weak Acid Dissociable	0 - 40	85.4 - 124.7	NA	85 - 115	-	NA	NA	NA	NA
CN-REAC in Waters, SW846 7.3.3 Prep - SW846 7.3.3 -									
Reactive Releasable Cyanide	0 - 50	-	NA	0 - 30	-	NA	NA	NA	NA
Percent Ash @ 550C in Water, SM 2540E									
Percent Ash 550C	0 - 15	NA	NA	NA	NA	NA	NA	NA	NA
Percent Ash @ 550C	0 - 15	NA	NA	NA	NA	NA	NA	NA	NA
Percent Ash at 550C in Solid, SM 2540G -									
Percent Ash 550C	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Percent Ash @ 550C	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Percent Ash at 750C in Solid, ASTM D 482 - ASTM D 3174 MODIFIED -									
Percent Ash 750C	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Solids Water, EPA 160.4 -									
Volatile Solids	0 - 20	NA	NA	NA	NA	NA	NA	NA	NA
Volatile Solids Solid, SM 2540G -									
Volatile Solids	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Free Cyanide Waters, ASTM 4282 Modified -									
Cyanide, Free	0 - 20	-	NA	90 - 110	-	NA	NA	NA	NA
Total Cyanide Waters, SW846 9012A - SW846 9010B Prep - ILM 4.0 CLP Cyanide - EPA 335.3 -									
Cyanide, Total	0 - 25	85.5 - 119.5	-	90 - 110	-	NA	NA	NA	NA
Total Solids Water, SM 2540B - EPA 160.3									
Total Solids	0 - 10	NA	NA	95 - 105	-	NA	NA	NA	NA
Total Solids Solid, SM 2540G									
Total Solids	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Total Phenols Liquid, SW846 9066 - EPA 420.2 -									
Total Phenol	0 - 30	75.2 - 119.4	0 - 20	90 - 110	0 - 20	75 - 125	0 - 20	NA	NA
Total Dissolved Solids Water, SM 2540C - EPA 160.1 -									
Total Dissolved Solids	0 - 10	NA	NA	95 - 105	0 - 5	NA	NA	NA	NA
IC Waters, SW846 9056 - GEL TATB Method - GEL Prep Method - EPA 314.0 DOE-AL - EPA 314.0 - EPA 300.0 - 26A-40									
Bromide	0 - 25	-	NA	90 - 110	-	76.3 - 131.1	0 - 15	NA	NA
Chloride	0 - 20	-	NA	90 - 110	-	80.2 - 124.6	0 - 15	NA	NA
Fluoride	0 - 20	-	NA	90 - 110	-	80 - 120	0 - 15	NA	NA
Nitrate	0 - 20	-	NA	90 - 110	-	77.0 - 114.9	0 - 15	NA	NA
Nitrite	0 - 20	-	NA	90 - 110	-	80 - 120	0 - 15	NA	NA
Ortho-phosphate	0 - 25	-	NA	90 - 110	-	80 - 120	0 - 15	NA	NA
Oxalate	0 - 20	-	NA	80 - 120	-	79.9 - 109.3	NA	NA	NA
Perchlorate	0 - 20	-	NA	90 - 110	-	86.0 - 126.1	0 - 15	NA	NA
Sulfate	0 - 20	-	NA	90 - 110	-	75.0 - 129.8	0 - 15	NA	NA
TATB	0 - 20	-	0 - 20	90 - 110	-	80 - 120	0 - 20	NA	NA
IC Solids, SW846 9056 - SW846 5050 PREP - GEL TATB Method - GEL Prep Method - EPA 314.0 - EPA 300.0 PREP - EPA									
Chloride	0 - 20	80.8 - 114.9	-	87.236 - 110	-	80 - 120	-	NA	NA
Chlorine	0 - 20	NA	NA	80 - 110	-	85 - 110	-	NA	NA
Fluoride	0 - 20	60.0 - 100.6	-	86.3 - 110.4	-	80 - 120	-	NA	NA
Fluorine	0 - 20	NA	NA	65.5 - 139.3	-	80.0 - 119.0	-	NA	NA
Nitrate	0 - 20	68.3 - 124.8	-	86.047 - 110	-	65 - 135	-	NA	NA
Nitrite	0 - 20	67.3 - 121.2	-	86.474 - 110	-	65 - 135	-	NA	NA
Ortho-phosphate	0 - 20	75 - 125	-	85.4 - 112.1	-	82.6 - 114.9	-	NA	NA
Oxalate	0 - 15	85.7 - 111.2	-	90.41 - 110	-	NA	-	NA	NA
Perchlorate	0 - 39	56.1 - 148.6	-	83.0 - 115.9	-	80 - 120	-	NA	NA
Sulfate	0 - 20	75 - 125	NA	88.6 - 110	-	80 - 120	-	NA	NA
Sulfur	0 - 20	NA	NA	66.0 - 133.7	-	70.5 - 127.4	-	NA	NA
TATB	0 - 20	68.5 - 121.3	NA	80 - 120	-	80 - 120	-	NA	NA
CN Total in Solids, SW846 9012A - SW846 9010B Prep -									
Cyanide, Total	0 - 30	73.1 - 126.4	-	78.5 - 121.7	-	-	NA	NA	NA
Specific Gravity Solid, ASTM D 5057 -									
Specific Gravity	0 - 10	NA	NA	NA	NA	NA	NA	NA	NA
Total Suspended Solids Water, EPA 160.2 -									
Total Suspended Solids	0 - 20	NA	NA	95 - 105	0 - 10	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
DRO Solids, SW846 8015A/B SVOC - California Method -									
Diesel Range Organics	NA	29.9 - 143.4	0 - 26.6	50.3 - 148.7	0 - 30	NA	NA	NA	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	33.4 - 127.7	NA
GEL FID/Solvent Scan Soil, SW846 8015A/B SVOC - GEL FID Method -									
1,1,1-Trichloroethane	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
1-Methoxy-2-propanol	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
2-Butanone	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Butoxyethanol	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
2-Ethoxyethanol	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Acetate	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
Acetone	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Benzene	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Chloroform	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Cyclohexanol	0 - 30	NA	NA	47.2 - 132.2	NA	NA	NA	NA	NA
Cyclohexylamine	0 - 30	NA	NA	54.5 - 109.4	NA	NA	NA	NA	NA
Diethylamine	0 - 30	NA	NA	71.085 - 130	NA	NA	NA	NA	NA
Diethylene glycol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Diisobutylamine	0 - 30	NA	NA	78.932 - 130	NA	NA	NA	NA	NA
Dimethylaniline	0 - 30	NA	NA	79.805 - 130	NA	NA	NA	NA	NA
Ethanol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Ethyl acetate	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Ethylbenzene	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Ethylene glycol	0 - 30	NA	NA	63.8 - 139.6	NA	NA	NA	NA	NA
Hexane	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Isobutyl alcohol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Isopropyl Alcohol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methanol	0 - 30	NA	NA	65.7 - 131.8	NA	NA	NA	NA	NA
Methylene chloride	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Nonylamine	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Propylene glycol	0 - 30	NA	NA	63.6 - 140.8	NA	NA	NA	NA	NA
Toluene	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Triethylene glycol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
Xylenes (total)	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
m,p-Xylenes	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
n-Amyl acetate	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
n-Butyl acetate	0 - 30	NA	NA	NA	NA	NA	NA	NA	NA
n-Butyl alcohol	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
n-Propanol	0 - 30	NA	NA	78.945 - 130	NA	NA	NA	NA	NA
o-Xylene	0 - 30	NA	NA	70 - 130	NA	NA	NA	NA	NA
GEL FID/Solvent Scan Water, SW846 8015A/B SVOC - GEL FID Method -									
1,1,1-Trichloroethane	0 - 30	NA	NA	88.0 - 126.4	0 - 30	NA	NA	NA	NA
1,4-Dioxane	0 - 30	-	-	70 - 130	0 - 30	NA	NA	NA	NA
1-Methoxy-2-propanol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Butanone	0 - 30	NA	NA	59.0 - 138.2	0 - 30	NA	NA	NA	NA
2-Butoxyethanol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Ethoxyethanol	0 - 30	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
2-Methyl-1,3-dioxolane	0 - 30	-	-	70 - 130	0 - 30	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
4-Methyl-2-pentanone	0 - 30	NA	NA	69.0 - 129.7	0 - 30	NA	NA	NA	NA
Acetate	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Acetone	0 - 12.3	NA	NA	70.0 - 120.1	0 - 30	NA	NA	NA	NA
Benzene	0 - 30	NA	NA	73.2 - 149.1	0 - 30	NA	NA	NA	NA
Chloroform	0 - 30	NA	NA	70.0 - 120.1	0 - 30	NA	NA	NA	NA
Cyclohexanone	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Diethyl ether	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Diethylene glycol	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Ethane	NA	NA	NA	55.6 - 140.0	0 - 20.4	NA	NA	NA	NA
Ethanol	0 - 30	NA	NA	66.7 - 137.8	0 - 30	NA	NA	NA	NA
Ethene	NA	NA	NA	55.8 - 124.9	0 - 30	NA	NA	NA	NA
Ethyl acetate	0 - 30	-	-	75.6 - 124.6	0 - 30	NA	NA	NA	NA
Ethylbenzene	0 - 30	NA	NA	72.2 - 130.6	0 - 30	NA	NA	NA	NA
Ethylene glycol	0 - 24.0	NA	NA	73.1 - 129.0	0 - 30	NA	NA	NA	NA
Hexane	0 - 18.3	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Isobutyl alcohol	0 - 30	NA	NA	47.2285 - 130	0 - 30	NA	NA	NA	NA
Isopropyl Alcohol	0 - 35.3	-	-	51.41 - 130	0 - 30	NA	NA	NA	NA
Isopropyl acetate	0 - 30	-	-	70 - 130	0 - 30	NA	NA	NA	NA
Isopropyl ether	0 - 30	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Methane	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
Methanol	0 - 16.5	NA	NA	52.1 - 141.2	0 - 30	NA	NA	NA	NA
Methylene chloride	0 - 17.9	NA	NA	46.13 - 130	0 - 30	NA	NA	NA	NA
Propylene glycol	0 - 30	NA	NA	81.884 - 130	0 - 30	NA	NA	NA	NA
Toluene	0 - 30	NA	NA	80.5 - 133.1	0 - 30	NA	NA	NA	NA
Triethylene glycol	0 - 30	NA	NA	66.2 - 138.1	0 - 30	NA	NA	NA	NA
Xylenes (total)	NA	NA	NA	70 - 130	0 - 30	NA	NA	NA	NA
m,p-Xylenes	0 - 30	NA	NA	76.8 - 133.1	0 - 30	NA	NA	NA	NA
n-Amyl acetate	0 - 30	-	-	70 - 130	0 - 30	NA	NA	NA	NA
n-Butyl acetate	0 - 30	NA	NA	87.9 - 122.8	0 - 30	NA	NA	NA	NA
n-Butyl alcohol	NA	NA	NA	52.085 - 130	0 - 30	NA	NA	NA	NA
o-Xylene	0 - 30	NA	NA	72.7 - 145.2	0 - 30	NA	NA	NA	NA
Florida Pro/Conn. Solids, Florida Pro - Connecticut Method -									
ETPH	NA	62 - 204	0 - 25	60.796 - 153	0 - 25	NA	NA	NA	NA
Nonatriacontane (C39)	NA	NA	NA	NA	NA	NA	NA	47.8 - 117.9	NA
TPH (C6-C36)	NA	75 - 125	0 - 25	60.796 - 153	0 - 25	NA	NA	NA	NA
TRPH (C8-C40)	NA	62 - 204	0 - 25	38.9 - 122.9	0 - 25	NA	NA	NA	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	51.7 - 131.1	NA
Florida Pro/Conn. Waters, Florida Pro - Connecticut Method -									
ETPH	NA	41 - 101	0 - 20	55 - 118	0 - 20	NA	NA	NA	NA
Nonatriacontane (C39)	NA	NA	NA	NA	NA	NA	NA	39.5 - 108.9	NA
TPH (C6-C36)	NA	41 - 101	0 - 20	55 - 118	0 - 20	NA	NA	NA	NA
TRPH (C8-C40)	NA	54.846 - 125	0 - 37.1	58.051 - 130	0 - 20	NA	NA	NA	NA
Trifluorotoluene	NA	NA	NA	NA	NA	NA	NA	70 - 130	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	57.9 - 123.5	NA
DRO Waters, SW846 8015A/B SVOC - California Method -									
Diesel Range Organics	NA	43.6 - 140.5	0 - 29.1	47.4 - 144.9	0 - 19.8	NA	NA	NA	NA
o-Terphenyl	NA	NA	NA	NA	NA	NA	NA	27.5 - 132.7	NA
VOA TCLP, SW846 8260B -									
1,1-Dichloroethylene	NA	NA	NA	72.3 - 124.1	-	58.8 - 125.9	0 - 20	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
1,2-Dichloroethane	NA	NA	NA	72.8 - 124.8	-	67.3 - 124.7	0 - 20	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	78.3 - 122.7	-	71.2 - 119.6	0 - 20	NA	NA
2-Butanone	NA	NA	NA	59.6 - 138.1	-	56.9 - 122.5	0 - 20	NA	NA
Benzene	NA	NA	NA	78.0 - 118.2	-	71.4 - 118.8	0 - 20	NA	NA
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	70.6 - 140.1	NA
Carbon tetrachloride	NA	NA	NA	60.7 - 147.2	-	50.2 - 142.8	0 - 20	NA	NA
Chlorobenzene	NA	NA	NA	84.4 - 117.1	-	77.3 - 117.2	0 - 20	NA	NA
Chloroform	NA	NA	NA	84.4 - 120.0	-	70.6 - 124.6	0 - 20	NA	NA
Dibromofluoromethane	NA	NA	NA	NA	NA	NA	NA	79.1 - 138.7	NA
Tetrachloroethylene	NA	NA	NA	78.5 - 134.7	-	67.0 - 133.3	0 - 20	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	80.4 - 131.6	NA
Trichloroethylene	NA	NA	NA	81.9 - 126.7	-	60.2 - 142.6	0 - 20	NA	NA
Vinyl chloride	NA	NA	NA	62.2 - 150.9	-	42.2 - 147.1	0 - 20	NA	NA
VOA 524/8260LL Water, SW846 8260 Low Level - EPA 524.2 -									
1,1,1,2-Tetrachloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,1,1-Trichloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,1,2-Trichloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,1-Dichloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,1-Dichloroethylene	NA	NA	NA	70 - 130	NA	63.8 - 122.7	0 - 13.3	NA	NA
1,1-Dichloropropene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2,3-Trichlorobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2,3-Trichloropropane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2,4-Trichlorobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2,4-Trimethylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2-Dibromo-3-chloropropane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2-Dibromoethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2-Dichlorobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,2-Dichloroethane-d4	NA	NA	NA	NA	NA	NA	NA	86.0 - 114.0	NA
1,2-Dichloropropane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,3,5-Trimethylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,3-Dichlorobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,3-Dichloropropane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,4-Dichlorobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
1,4-Dioxane	NA	NA	NA	70 - 130	NA	70 - 130	-	NA	NA
2,2-Dichloropropane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Butanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Chlorotoluene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
2-Hexanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4-Chlorotoluene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4-Isopropyltoluene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Acetone	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Benzene	NA	NA	NA	70 - 130	NA	80.3 - 123.5	0 - 10.8	NA	NA
Bromobenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Bromochloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Bromodichloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA

Parameter	Duplicate	MS	MSD	LCS	LCSD	PS	PSD	Yield	Blank
Bromofluorobenzene	NA	NA	NA	NA	NA	NA	NA	72.6 - 122.7	NA
Bromoform	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Bromomethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Carbon disulfide	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Carbon tetrachloride	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Chlorobenzene	NA	NA	NA	70 - 130	NA	81.7 - 119.6	0 - 12.8	NA	NA
Chloroethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Chloroform	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Chloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dibromochloromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dibromofluoromethane	NA	NA	NA	NA	NA	NA	NA	81.4 - 125.6	NA
Dibromomethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Dichlorodifluoromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Hexachlorobutadiene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Isopropylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Methylene chloride	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Styrene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Tetrachloroethylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Toluene	NA	NA	NA	70 - 130	NA	78.8 - 125.9	0 - 12.9	NA	NA
Toluene-d8	NA	NA	NA	NA	NA	NA	NA	72.6 - 112.1	NA
Trichloroethylene	NA	NA	NA	70 - 130	NA	78.1 - 121.5	0 - 15.4	NA	NA
Trichlorofluoromethane	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
Vinyl chloride	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
cis-1,2-Dichloroethylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
cis-1,3-Dichloropropylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
n-Butylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
n-Propylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
o-Xylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
sec-Butylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
tert-Butylbenzene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
trans-1,2-Dichloroethylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA
trans-1,3-Dichloropropylene	NA	NA	NA	70 - 130	NA	NA	NA	NA	NA

APPENDIX F: ESSENTIAL QUALITY CONTROL REQUIREMENTS

At GEL, we enforce strict adherence to quality control measures. Quality control measures for each type of analysis are delineated in the associated standard operating procedure and include those specified in the identified analytical method. Client requests for additional quality control agreed to by us will be communicated to the laboratory by the project manager and performed accordingly.

All quality control measures are assessed and evaluated on an on-going basis. We use these measures to establish statistically derived quality control acceptance criteria. The acceptance criterion is used to evaluate whether the analytical process is in control, and to assist us in establishing the validity of the data. Our procedures for handling out of control situations are written in the analytical standard operating procedure.

Method-specific quality measures are described in the appropriate standard operating procedure. Essential but general quality control requirements are summarized in the sections below for chemical testing, including inorganic and organic analyses, microbiological analyses, and radiochemical testing.

F1 Chemical Testing

This section includes our quality control requirements for inorganic and organic analyses, and discusses:

Negative controls
Positive controls
Analytical variability and reproducibility
Method evaluation
Method detection limits
Data reduction
Quality of standards and reagents
Selectivity
Constant and consistent test condition

F1.1 Negative controls

We implement a negative control at least once per analytical batch of samples having the same matrix, and where, if applicable, the same extraction or preparation method is employed. The negative control is a method blank that we use to determine the presence of contamination. If discovered, we must investigate the source of contamination and take measures to correct, minimize or eliminate the source if:

1. The concentration of target analyte exceeds the established practical quantitation limit and exceeds a concentration greater than 1/10 of the measured concentration of any sample in the analytical batch;
2. The concentration of a target analyte in the method blank exceeds that present in the samples and is greater than 1/10 of the specified regulatory limit.

If a method blank is indicative of contamination, we must assess each sample in that batch against the above criteria to determine if the data is acceptable. Any sample associated with a contaminated method blank shall be reprocessed for analysis, or we will report the results with appropriate data qualifiers.

F1.2 Positive Control -Method Performance

F1.2.1 Laboratory Control Sample (LCS)

Purpose:	The LCS is used to evaluate the performance of the total analytical system, including all preparation and analysis steps. Results of the LCS are compared to established criteria and, if found to be outside of these criteria, indicates that the analytical system is "out of control". Any affected samples associated with an out of control LCS shall be reprocessed for re-analysis or the results reported with appropriate data qualifying codes.
Frequency:	The LCS is analyzed at a minimum of 1 per preparation batch. Exceptions would be for those analytes for which no spiking solutions are available such as total suspended solids, total dissolved solids, total volatile solids, total solids, pH, color, odor, temperature, dissolved oxygen or turbidity. In those instances for which no separate preparation method is used (example: volatiles in water) the batch shall be defined as environmental samples that are analyzed together with the same method

and personnel, using the same lots of reagents, not to exceed the analysis of 20 environmental samples.

Composition: The LCS is a controlled matrix, known to be free of analytes of interest, spiked with known and verified concentrations of analytes. NOTE: the matrix spike may be used in place of this control as long as the acceptance criteria are as stringent as for the LCS. Alternatively the LCS may consist of a media containing known and verified concentrations of analytes or as Certified Reference Material (CRM). All analyte concentrations shall be within the calibration range of the methods. The following shall be used in choosing components for the spike mixtures:

The components to be spiked shall be as specified by the mandated test method or other regulatory requirement or as requested by the client. In the absence of specified spiking components the laboratory shall spike per the following:

For those components that interfere with an accurate assessment such as spiking simultaneously with technical chlordane, toxaphene and PCBs, the spike should be chosen that represents the chemistries and elution patterns of the components to be reported.

For those test methods that have extremely long lists of analytes, a representative number may be chosen. The analytes selected should be representative of all analytes reported. The following criteria shall be used for determining the minimum number of analytes to be spiked.

a) For methods that include 1-10 targets, spike all components;
b) For methods that include 11-20 targets, spike at least 10 or 80%, whichever is greater;
c) For methods with more than 20 targets, spike at least 16 components .

Note: Unless otherwise noted in project quality assurance plans or if components interfere with an accurate assessment, all Dept. of Defense projects will have LCS, MS, and MSD that contain all target analytes.

Evaluation Criteria and Corrective Action: The results of the individual batch LCS are calculated in percent recovery. The laboratory shall document the calculation for percent recovery. The individual LCS is compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory determines internal criteria or utilizes client specified assessment criteria.

A LCS that is determined to be within the criteria effectively establishes that the analytical system is in control and validates system performance for the samples in the associated batch. Samples analyzed along with a LCS determined to be "out of control" should be considered suspect and the samples reprocessed and re-analyzed or the data reported with appropriate data qualifying codes.

F1.2.2 Sample Specific Controls

The laboratory must document procedures for determining the effect of the sample matrix on method performance. These procedures relate to the analyses of matrix specific Quality Control (QC) samples and are designed as data quality indicators for a specific sample using the designated test method. These controls alone are not used to judge laboratory performance. Examples of matrix specific QC include: Matrix Spike (MS); Matrix Spike Duplicate (MSD); sample duplicates; and surrogate spikes.

F1.2.3 Matrix Spike; Matrix Spike Duplicates:

Purpose: Matrix specific QC samples indicate the effect of the sample matrix on the precision and accuracy of the results generated using the selected method. The information from these controls is sample/matrix specific and would not normally be used to determine the validity of the entire batch.

Frequency: The frequency of the analysis of matrix specific samples shall be determined as part of a systematic planning process (e. g. Data Quality Objectives) or as specified by the required mandated test method.

Composition: The components to be spiked shall be as specified by the mandated test method. Any permit specified analytes, as specified by regulation or client requested analytes shall also be included. If there are no specified components, the laboratory shall spike per the following:

For those components that interfere with an accurate assessment such as spiking simultaneously with technical chlordane, toxaphene and PCBs, the spike should be chosen that represents the chemistries and elution patterns of the components to be reported.

For those test methods that have extremely long lists of analytes, a representative number may be chosen using the following criteria for choosing the number of analytes to be spiked. However, the laboratory shall insure that all targeted components are included in the spike mixture over a 2 year period.

a) For methods that include 1-10 targets, spike all components;
b) For methods that include 11-20 targets, spike at least 10 or 80%, whichever is greater;
c) For methods with more than 20 targets, spike at least 16 components.

Evaluation Criteria and Corrective Action: The results from matrix spike/matrix spike duplicate are primarily designed to assess the precision and accuracy of analytical results in a given matrix and are expressed as percent recovery (% R) and relative percent difference (RPD).

Results are compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory should determine internal criteria and document the method used to establish the limits. For matrix spike results outside established criteria corrective action shall be documented or the data reported with appropriate data qualifying codes.

F1.2.4 Matrix Duplicates:

Purpose: Matrix duplicates are defined as replicate aliquots of the same sample taken through the entire analytical procedure. The results from this analysis indicate the precision of the results for the specific sample using the selected method. The matrix duplicate provides a usable measure of precision only when target analytes are found in the sample chosen for duplication.

Frequency: The frequency of the analysis of matrix duplicates may be determined as part of a systematic planning process (e. g. Data Quality Objectives) or as specified by the mandated test method.

Composition: Matrix duplicates are performed on replicate aliquots of actual samples. The composition is usually not known.

Evaluation Criteria and Corrective Action The results from matrix duplicates are primarily designed to assess the precision of analytical results in a given matrix and are expressed as relative percent difference (RPD) or another statistical treatment (e. g., absolute differences). The laboratory shall document the calculation for relative percent difference or other statistical treatments.

Results are compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory shall determine internal criteria and document the method used to establish the limits. For matrix duplicates results outside established criteria corrective action shall be documented or the data reported with appropriate data qualifying codes.

F1.2.5 Surrogate Spikes:

Purpose Surrogates are used most often in organic chromatography test methods and are chosen to reflect the chemistries of the targeted components of the method. Added prior to sample preparation/extraction, they provide a measure of recovery for every sample matrix.

Frequency Except where the matrix precludes its use or when not available, surrogate compounds are added to all samples, standards, and blanks for all appropriate test methods.

Composition: Surrogate compounds are chosen to represent the various chemistries of the target analytes in the method. They are often specified by the mandated method and are deliberately chosen for their being unlikely to occur as an environmental contaminant. Often this is accomplished by using deuterated analogs of select compounds.

Evaluation Criteria and Corrective The results are compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory determines internal criteria and documents the method used to establish the limits.

Action: the method used to establish the limits.

Surrogates outside the acceptance criteria must be evaluated for the effect indicated for the individual sample results. The appropriate corrective action may be guided by the data quality objectives or other site specific requirements. Results reported from analyses with surrogate recoveries outside the acceptance criteria include appropriate data qualifiers.

F1.3 Method Evaluation

The following procedures, as described in the other sections of the QAP, are in place in order to ensure the accuracy of the reported result:

Procedure for initial demonstration of analytical capability performed initially (prior to the analysis of any samples) and if there is a significant change in instrument type, personnel, matrix or test method. Refer to Section 8.

Procedures for initial and continuing calibration protocols as specified in Section 7.

Procedures for utilizing proficiency test samples to evaluate the ability of a procedure and/or analyst laboratory to produce accurate data as specified in Section 3.

F1.4 Method Detection Limits

Method detection limits (MDLs) are determined as descried in GL-LB-E-001 for the Determination of Method Detection Limits. This procedure is based on that established in 40 CFR Part 136, Appendix B.

Where possible, MDL studies are conducted for both aqueous and solid matrices using a clean matrix appropriate to the test method (such as laboratory pure reagent water or Ottawa sand.) MDL studies for the majority of routine parameters are conducted by:

analyzing seven replicates of the lowest calibration standard
determining the standard deviation of the seven replicates
multiplying the standard deviation by 3.143 (based on six degrees of freedom and representing a 99% confidence level) to obtain the calculated MDL.

If the MDL study is being conducted for a new method or target analyte, the following steps are taken:

the MDL is estimated based on information provided in the method or analytical experience
a standard with a concentration three to five times the estimated MDL is prepared and analyzed seven times
the MDL is calculated as above based on the standard deviation and degreases of freedom
the MDL is evaluated for reasonableness by verification through analysis of a prepared standard solution two to three times the calculated MDL.

MDL studies are not performed for any target analyte for which spiking solutions are not available such total volatile solids, pH, color, odor, temperature dissolved oxygen or turbidity.

Practical quantitation limits (PQLs) are determined by either multiplying the MDL by 5 TO 10 or are equal to that of the lowest calibration standard. Concentrations of a target analyte determined to be greater that its PQL are defined as quantitative results. All quantitative reported results are bracketed by calibration or calibration verification standards.

All MDL studies conducted by the laboratory are submitted to the Quality team for an independent review. Upon acceptance of the MDL study, the MDLs reported to clients via our computer system are updated unless otherwise specified by contract. PQLs are also updated as directed by the new MDLs or changes to procedures.

All data pertaining to the study and the calculation of the MD(s) is stored on compact discs. The compact discs are maintained as quality records in the Quality department.

F1.5 Data Reduction

The procedures for data reduction, such as use of linear regression, are documented in the individual analytical standard operating procedures. GEL's policy governing the manual integration of chromatographic data is detailed in GL-LB-E-017 for Procedure and Policy for Manual Integration. Understanding of the procedures used for data reduction is an important part of an analyst demonstrating proficiency in an analytical procedure. All analysts who may potentially perform manual integrations of chromatographic data are also trained to GL-LB-E-017.

Manual integrations of chromatographic peaks can only be performed in accordance with this GL-LB-E-017. This ensures that the integrations are done in a consistent and technically justifiable manner while meeting the requirements set forth under the Good Automated Laboratory Practices.

F1.6 Quality of Standards and Reagents

The quality of standards used in instrument calibration or quality control samples and reagents used in sample preparation and/or analysis must meet the criteria described in Section 7. In methods where the purity is not specified, analytical grade reagents are used. Reagents of lesser purity than those specified by the test method are never used. Upon receipt and prior to use the labels on the container are checked to verify that the purity of the reagents meets the documented requirements of the particular test method.

The quality of water sources is monitored and documented as described Section 4. The quality of water used in sample preparation or analysis meets the method-specified requirements. The type of water available in the laboratory is described in Section 4.

F1.7 Selectivity

Absolute and relative retention times aid in the identification of components in chromatographic analyses and to evaluate the effectiveness of a column in separating constituents. The procedures governing retention time widows are documented in the applicable analytical SOP and meet all regulatory and method requirements.

In addition to retention time windows, the acceptance criterion for mass spectral training is also documented in the appropriate analytical SOP. In all cases, the acceptance criteria meet or exceed those specified in the analytical methods.

Unless stipulated in writing by the client, confirmations are performed to verify the compound identification of positive results detected on a sample from a location that has not been previously tested by our laboratory. Such confirmations are performed on a second column for organic tests such as pesticides, herbicides, or acid extractable or when recommended by the analytical test method except when the analysis involves the use of a mass spectrometer. All conformation is documented.

F1.8 Constant and Consistent Test Conditions

GEL's implementation of standard operating procedures that specify quality criteria including initial and continuing calibrations assures that our test instruments consistently operate within the specifications required of the application for which the equipment is used.

In addition to the specifications applied to instrumentation, glassware used for sample preparation or analyses is cleaned in a manner that reduced the potential for positive or negative interferences. Glassware is prepared in accordance with GL-LB-E-003 for Glassware Preparation.

This SOP details the procedures used to clean the following groups of glassware:

- That used for the determination of metals with a special section for bottles to be used for the determination of mercury by either EPA 7470 or 7471A.
- Reusable bottles and plasticware
- Bottles sued for the determination of biochemical oxygen demand
- Glassware used in the determination of organic compounds
- That used for the determination of methylene blue active substances
- Glassware used in the determination of total organic halides
- Glassware used in the analyses of samples for total kjeldahl nitrogen and total phosphorous
- Generic glassware used in all other analyses

If the method specifies that the glassware be stored in a particular manner, this requirement is documented in the appropriate analytical SOP.

Section F2 Microbiology

The quality control elements included in this section apply to microbiological analyses performed at GEL. The analyses include the determination of both total and fecal coliforms and standard plate counts.

Discussed in this section are:

- Negative controls

Positive controls
Test variability and reproducibility
Method evaluation
Test performance
Data reduction
Quality of standards, reagents, and media
Selectivity
Test conditions

F2.1 Negative Controls

We demonstrate that the cultured samples have not been contaminated during sampling handling and analysis or environmental exposure by the use of negative controls. These negative controls include both sterility checks of media and method blanks.

All blanks and non-inoculated controls specified by the test methods are prepared and analyzed at the frequency stated in the method and in the corresponding standard operating procedure.

A minimum of one non-inoculated control is prepared and analyzed is analyzed with analytical batches containing only one sample. If the analytical batch contains multiple samples, a series of method blanks is prepared. This series includes least one beginning and ending negative control with additional controls inserted after every 10 samples.

If the method blanks show evidence of contamination, the data obtained for the associated samples is not reported and the client is advised that resampling will be necessary.

Prior to initial use, each lot of media is subjected to a sterility check by analyzing an aliquot of sterile buffer water. If there is any evidence of contamination, the media is not utilized for the analysis of samples and is either returned to the supplier or disposed of in accordance with the Laboratory Waste Management Plan.

F2.2 Positive Controls

Positive controls are used to demonstrate that the medium can support the growth of the target organism and that it produces the specified or expected reaction to that organism. Prior to the initial and then on a monthly basis each lot of media is tested using least one pure culture of with a known positive reaction. If the positive reaction does not occur, the media is not used for sample analysis and is either returned to the supplier or disposed of according to the Laboratory Waste Management Plan.

F2.3 Test Variability and Reproducibility

We demonstrate reproducibility of our data by analyzing sample duplicates for least 5% of the suspected positive samples. Each analyst performing microbiological analyses makes parallel analyses on at least one positive sample per month.

For analysis requiring sample volumes of less than 100mL or where the clients submit duplicate sample aliquots, a sample duplicates is analyzed with each analytical batch.

F2.4 Method Evaluation

Our ability to perform a specified analysis successfully for its intended purpose is demonstrated and documented in meeting at a minimum the acceptance criteria specified by the method, by the EPA, and by state programs under which we are certified. The acceptance criteria demonstrate that the test method as performed at GEL provides correct and expected results with respect to specified detection capabilities, selectivity, and reproducibility.

Proficiency of the analysis is demonstrated prior to the test method through the use of positive and negative controls. The validation of microbiological test methods is conducted under the same conditions as those for routine analysis.

All validation data is recorded in a logbook specified by the appropriate SOP. We maintain the data as long as the analysis is being conducted and for a minimum of five years after the retirement of an analytical method.

F2.5 Test Performance

Test performance is demonstrated for all growth and recovery media used by the appropriate growth and reaction of target organisms to the test media through the use of positive controls as discussed in F2.2.

F2.6 Data Reduction

All data is calculated and subjected to data reduction and statistical interpretations as specified by the method's SOP. These specifications incorporate those found in the associated analytical method.

For test methods specifying colony counts, such as membrane filter or colony counting, then the ability of individual analysts to count colonies is verified at least once per month. This verification includes having two or more analysts count colonies from the same plate.

F2.7 Quality of Standards, Reagents and Media

In addition to the performance of positive and negative controls, we ensure that the quality of the reagents and media meets or exceeds the requirements specified in the analytical methods. The commercially dehydrated powders used to prepare certain culture media as well as the media that is purchased ready for use are both subjected to positive and negative controls. In addition, all reagents, commercial dehydrated powders and media are used within the shelf life of the product as documented in Section 8.

We retain all manufacturer supplied "quality specification statements" which may contain such information as shelf life of the product, storage conditions, sampling regimen/rate, sterility check including acceptability criteria, performance checks including the organism used, their culture collection reference and acceptability criteria, date of issue of specification, or statements assuring that the relevant product batch meets the product specifications.

All media and buffers are prepared using deionized water that has been demonstrated to be free from bacterial contamination. The deionized water used for microbiological analyses and the monitoring of the deionized water is discussed in Section 4.

Media, solutions and reagents are prepared, used and stored in accordance with appropriate SOP. As described in 2.2, all laboratory media are be evaluated at least monthly to ensure they support the growth of specific microbial cultures. In addition, selective media are checked to ensure they suppress the growth of non-target organisms.

The laboratory detergent is be checked by use of the inhibitory residue test to ensure that its residues do not inhibit or promote growth of microorganisms.

F2.8 Selectivity

We perform all confirmation and verifications tests specified by the test method according to the procedures outlined in our SOPs.

In order to demonstrate traceability and selectivity, we use reference cultures of microorganisms obtained from a recognized national collection. We do not subculture bacterial working stocks. The storage and maintenance of all working and reference stocks are specified in the applicable analytical SOP.

F2.9 Test Conditions

We monitor background levels by the use of method blanks and other negative controls. The acceptable background counts for each analysis and how to deal with situations in which these levels are exceeded are specified in the applicable SOP.

Walls, floors, ceilings and work surfaces of our microbiological laboratory are non-absorbent and easy to clean and disinfect. Measures are taken to avoid accumulation of dust by the provision of sufficient storage space and daily cleaning of exposed surfaces.

The temperature measuring devices such as liquid-in-glass thermometers used in incubators, autoclaves and other equipment are of the appropriate quality to achieve the specification in the test method.

The graduation of the temperature measuring devices is appropriate for the required accuracy of measurement. Each device is calibrated at least annually to national or international standards for temperature in accordance with GL-QS-E-007 for Thermometer Calibration.

The temperatures of incubators, refrigerators, autoclaves, and waterbaths are monitored and documented in accordance with GL-LB-E-004 for Temperature Monitoring and Documentation Requirements for Refrigerators, Freezers, Ovens, Incubators, and Other Similar Devices. While in use, each piece of equipment is maintained in the temperature range specified by the applicable SOP and test method.

Records of autoclave operations including temperature and time are maintained for every cycle.

Volumetric equipment such as automatic dispensers, air displacement pipets and disposal pipets are all used in the microbiology laboratory. This equipment is routinely checked for accuracy as discussed in Section 7.

Conductivity meters, pH meters, and other similar measurement instruments are calibrated according to the methods specified requirements detailed in the SOP.

Mechanical timers are checked regularly against electronic timing devices to ensure accuracy.

Section F3 Radiochemical Analysis

This section describes the general quality control applied to radiochemical analysis. The specific quality control criteria applied to each analysis are delineated in the corresponding SOP.

Discussed in this section are:

Negative controls
Positive controls
Test variability/reproducibility
Tracers and carriers
Method evaluation
Radiation measurement system calibration
Data reduction
Quality of standards and Reagents
Test Conditions

F3.1 Negative Controls

Method blanks serve as the primary negative controls providing a means of assessing the existence and magnitude of contamination introduced via the analytical scheme. A method blank is analyzed at a frequency of one per preparation or analytical batch and is one of the quality control measures to be used to assess batch acceptance.

The activity level determined for each target in the method blank is assessed against the specific acceptance criteria specified in the applicable SOP. These criteria are based on a designated sample aliquot size and include appropriate calculations to compare the blank to activity levels determined for different sizes of sample aliquots.

The activity level of any target analyte in the method blank should be less than or equal to the contract required detection limit. The method blank may exceed this limit if the activity is less than 5% that of the lowest sample activity in the batch.

If the method blank acceptance criteria is not met, the specified corrective action and contingencies delineated in the SOPs are followed. Any failures of method blanks to meet the acceptance criteria are documented in the laboratory report and through GEL's nonconformance reporting system specified in GL-QS-E-004 for the Documentation of Nonconformance Reporting and Dispositioning and Control of Nonconforming Items.

The activity levels determined for method blanks are not subtracted from those obtained for the samples in the associated preparation or analytical batch. Correction factors such as instrument background and analyte presence in the tracer may, however, be applied to all analyzed samples including both client samples and internal quality control samples.

F3.2 Positive Controls

Positive controls routinely employed in radiochemical analyses include both laboratory control samples (LCS) and matrix spikes (MS.)

The laboratory standards used to prepare LCS and MS are from a different source than those used in instrument calibration. The activity levels of target analytes in the LCS and MS exceed ten times the prior detection limit and are less than one hundred times this detection limit. If a radiochemical method, however, has more than one reportable analyte isotope, the LCS and MS need to only include one of the analyte isotopes.

Gamma spectroscopy is the exception to this guideline requiring the LCS and MS to contain isotopes representing the low, medium, and high-energy range of the analyzed gamma spectra.

F3.2.1 Laboratory Control Sample (LCS)

Laboratory control samples are analyzed at a minimum of once per preparation or analytical batch containing twenty or less samples.

The recovery of target analytes in the LCS is compared to the acceptance criteria (75% - 125%) specified in the applicable analytical SOP. If the recovery of the LCS does not fall within the acceptance range, the corrective actions and contingency steps specified in the SOP are implemented. These steps include the completion of an internal nonconformance report in accordance with GL-QS-E-004 and noting the failure on the laboratory report.

F3.2.2 Matrix Spike (MS)

Matrix spikes are analyzed at a minimum of once per preparation or analytical batch containing twenty samples or less under the following conditions:

The analytical method does not utilize an internal standard or carrier
There is a physical or chemical separation process
There is sufficient sample volume provided for the analysis.

The target analyte recoveries are one of the quality control measures used to assess batch acceptance. The recovery of target analytes in the MS is compared to the acceptance criteria (75% - 125%) specified in the applicable analytical SOP. If the recovery of the MS does not fall within the acceptance range, the data associated with that matrix spike is qualified accordingly.

F3.3 Test Variability/Reproducibility

The reproducibility of measurements is evaluated by the use of matrix duplicates. Matrix duplicates are analyzed once per preparation or analytical batch of twenty samples. The relative percent difference (RPD) obtained between the activity levels obtained for the sample and its duplicate are evaluated against the range in the SOP. This range is 0%- 20% for activities greater than the contract reporting limit. If the RPD exceeds these criteria, the corrective actions addressed in the SOP are implemented.

F3.4 Tracers and Carriers

Two additional quality control measures specific to radiochemical analysis are tracers and carriers. If the analytical method requires a tracer or carrier, each sample result will be associated with a tracer recovery that is calculated and reported. For radiochemistry procedures requiring gravimetric or radiometric recovery (tracer yields), the acceptable limits are 15% - 125%. These limits may vary for specific clients and/or projects. If the applicable limits are not met, the corrective actions delineated in the SOP are implemented.

F3.5 Method Evaluation

GEL evaluates the radiochemical preparation and analytical methods to ensure the accuracy of the reported result. This evaluation includes initial demonstrations of capability as described in Section 8 and the analysis of proficiency test samples as described in Section 3. The suppliers of proficiency test samples conform to the requirements of ANSI N42.22.

F3.6 Radiation Measurement System Calibration

It is not generally necessary or practical to calibrate radiochemical instrumentation each day of use due to its stability and the time-consuming nature of some of the measurements. There are, therefore, significant differences in the calibration requirements for radiochemical instrumentation from that used for chemical analyses.

Calibration differences include but are not limited to the following:

The requirement in Section 7 for the determination of the appropriate number of standards for initial calibration is not applicable to radiochemical methods. If the radiochemical method requires multiple standards for initial calibration, the number of standards is included in the applicable SOP.

If linear regression or non-linear regression is used to fit standard response or calibration standard results to a calibration curve, the correlation coefficient is determined. This differs from Section 7.

The requirement identified in Section 7 for the bracketing of quantitative results by calibration or calibration verification standards is not applicable to radiochemical analyses due to the non-correlated event nature of decay counting instrumentation.

As indicated in Section 7, the LCS may fill the requirements for the performance of an initial calibration and continuing calibration verification standard. The calibration verification acceptance criteria are same as specified for the LCS (75 -125%)

Background calibration measurements are made on a regular basis and monitored using control charts. These values are subtracted from the total measured activity in the determination of the sample activity. The frequency of these measurements is indicated in the table below.

Instrument type	Minimum Frequency
Gamma spectroscopy	Monthly
Alpha spectroscopy	Monthly
Gas-proportional	Day of use
Scintillation counters	Day of use

Instrument calibration shall be performed with reference standards as defined in Section F3.8.

The frequency of calibration shall be addressed in the governing SOPs

F3.7 Data Reduction

All sources of method uncertainties and their propagation must be traceable to reported results. This is performed under the guidance of the ISO "Guide to the Expression of Uncertainty in Measurement" and the NIST Technical Note 1297 on "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results".

F3.8 Quality of Standards and Reagents

The reference standards we use are obtained from the National Institute of Standards and Technology (NIST), EPA, or suppliers providing NIST standards. Reference standards should be accompanied by a certificate of calibration whose content is described in ANSI N42.22 - 1995, Section 8, Certificates. All reagents used shall be analytical reagent grade or better.

F3.9 Test Conditions

GEL adheres to written procedures that minimize the possibility of cross contamination between samples. This prevents incorrect analysis results from the cross contamination. Procedures are in place, for example, to separate known radioactive and nonradioactive samples from the time of sample receipt to analysis and sample disposal.

Instrument performance checks are performed on a regular basis and monitored with control charts. This ensures that the instrument is operating properly and that the calibration has not changed. The same check source used in the preparation of the control chart at the time of calibration is used in the performance checks of the instrument. The sources must provide adequate counting statistics for a relatively short count time and should be sealed or encapsulated to provide loss of activity and contamination of the instrument and laboratory personnel.

Instrument performance checks include checks on the counting efficiency and the relationship between channel number and alpha or gamma ray energy. These checks are performed at the frequency indicated in the table below.

Instrument	Frequency of Counting Efficiency	Frequency of Channel # and Alpha and Gamma Ray Energy
Gamma Spectroscopy	Day of use	Day of use
Alpha Spectroscopy	Monthly	Day of use
Gas proportional	Day of use	Day of use
Scintillation Counters	Day of use	Day of use

APPENDIX G: ETHICS AND DATA INTEGRITY AGREEMENT

THE GEL GROUP INC.

ETHICS and DATA INTEGRITY AGREEMENT

I. I, ______________________________, state that I understand the high standards of integrity required of me with regard to the duties I perform and the data I report in connection with my employment at The GEL Group Inc.

II. I agree that in the performance of my duties at The GEL Group Inc.:

A. I shall not intentionally report data values that are not the actual values obtained;

B. I shall not intentionally report dates and times of data analyses that are not the actual dates and time of data analyses; and

C. I shall not intentionally represent another individual's work as my own.

III. I agree to inform The GEL Group Inc. of any accidental or intentional reporting of non-authentic data by myself in a timely manner.

IV. I agree to inform The GEL Group Inc. of any accidental or intentional reporting of non-authentic data by other employees.

______________________________ (Signature)

______________ (Date)

APPENDIX H: EQUIPMENT LIST

ORGANIC EXTRACTIONS

#	Equipment	Model #	Purchase Date	ID/Serial #
1	Dionex Solvent Extraction	ACE 200	Jan-97	97070827
3	Tekmar Sonic Distribution	600		
1	Analytical Bio-Chemistry Laboratories GPPC System	AP-1000	Feb-93	9231-SI, 9176CO, 9156/122UVD, 1216SCR
8	Zymark Turbovap	Turbovap II	May-96	TV9612N6726, TV9631N6975, TV9628N6939, TV9627N6926, TV0146N10597, TV0146N10596, TV0146N10598, TV0146N10595
2	N-Evaps Organomation	115, 1205	Jun-93, Jun-95	5673, 15076

SEMIVOLATILE ORGANIC ANALYSES

1	LC/MS/MS Water HPLC MicroMass Mass Spectrometer	2795	May-02, May-02	D02SMG212M, QAA212
2	Hewlett Packard HPLC Chemstation	1100	Oct-99	DE91605558
2	Hewlett Packard HPLC Chemstation	1050	Oct-92	3319A00022, 3423A00442
1	Hewlett Packard Gas Chromatograph with Dual Electron Capture Detectors and Dual Autosamplers	5890	Mar-94	3336A51011
6	Hewlett Packard 5973 Gas Chromatograph/Mass Spectrometer	5973	May-97	US70810371, US72010604, US82311233, US82311481, US82311417, US82311610
4	Hewlett Packard Gas Chromatograph-FID	5890	Feb-91, Aug-98	3033A33351
1	Head Space Autosampler	CTC-HS500	Jun-94	30362
6	Hewlett Packard Gas Chromatograph-ECD	6890	Aug-97, Nov-97 Mar-98, Jul-98	US00010134, US00009591, US00023402, US00023068, US10133016, US00028911

VOLATILE ORGANIC ANALYSES

1	Hewlett Packard Gas Chromatograph/Mass Spectrometer with OI 4560 Purge and Arcon Autosampler	5973	Oct-99	US91911845
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer with 014560/Arcon Autosampler	5973	Nov-98	US82311236
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer Chemstation with OI 4560/Arcon Autosampler	5972	May-93	3341A00976
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer Chemstation with OI 4560/Arcon Autosampler	5972	Jun-93	3251A00145
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer Chemstation with 014560/Arcon Autosampler	5973	Jan-98	US72010562

#	Equipment	Model #	Purchase Date	ID/Serial #
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer Chemstation with OI 4560/Arcon Autosampler	5973	Mar-99	US82311536
1	Tracor Gas Chromatograph with a Photoionization Detector and a Flame Ionization Detector and Tekmar LCS 2000 with Arcon Autosampler	540	Nov-90	891691
1	Hewlett Packard Gas Chromatograph/Mass Spectrometer Chemstation with 014560/Arcon Autosampler	5972	Feb-94	3418A01517
1	Hewlett Packard Apollo 9000 Series 735 Platforms running: Ingress 6.3, Target 3.12 HPUX 9.05, and Envision 3.20		Feb-94	6239A02398
1	PE Nelson 2600 Series Gas Chromatography Software System Operating on 386 PC Computers	NEC 386 SX/2	Nov-90	333572879

METALS ANALYSES

#	Equipment	Model #	Purchase Date	ID/Serial #
2	Perkin Elmer Mercury Analyzer	Fims 400, Fims 100	Nov-97, Jul-01	4179, 1538
1	PS Analytical Atomic Fluorescence Mercury Analyzer	10.035	Aug-02	024
2	Perkin Elmer Inductively Coupled Plasma Mass Spectrometer	ELAN 6100	Dec-01, Apr-02	187000, G2730107
2	Optima 4300DV Spectrometer	4300DV	Apr-02, Apr-02	077N1030502, 077N2061001
1	Thermo-Jarrell Ash Simultaneous Inductively Coupled Plasma Trace Analyzer w/ Autosampler and Ultrasonic Nebulizer	61E Trace	Jan-95	489890

GENERAL CHEMISTRY

#	Equipment	Model #	Purchase Date	ID/Serial #
1	Dohrman Total Organic Carbon Analyzer	DC190	May-93	9302211
1	OI Analytical, TOC 1010	1010	Jul-99	18935710267
2	Horizon Speed Vap II	9000, 9000	Oct-01, Apr-02	01-337, 01-340
5	Environmental Express Midi Still	N/A	Mar-02, Mar-02	2022, 2023, 2017, 602, MC-100
2	Lachat QuikChem 8000	8000	Jul-01, Jul-02	A83000-1910, A83000-2077
1	ThermoSpectronic	20D+	Nov-03	3DUD255001
2	Mitsubishi Total Organic Halogen Analyzers	TOX-10-C, TOX-10-C	Jul-84, Jan-90	43R00334, 43R31429
1	Dionex Ion Chromatograph	DX 500	Oct-99	99050260
2	Dionex Ion Chromatograph	Series 4500I	Jun-89, Mar-93	873450, 930613
1	Bran & Luebbe/Technicon Automated Chemistry Segmented Flow Autoanalyzer	TRACCS 800	Mar-90	165-A011-02
1	Turbidimeter	Micro100	Jun-03	205205

#	Equipment	Model #	Purchase Date	ID/Serial #
1	Dohrman DX 2000 TOX/EOX	DX2000	Feb-94	9309876
1	EM Science Karl Fischer Moisture Analyzer	EV-5	Jan-86	83109-01
1	Tecator Kjeltec System w/Distiller and Block Digestor	1026, 1015	Jan-93, Jan-93	10002767
2	Bran & Luebbe Block Digestor	BD-20/40	Mar-90	GG0869033, GG0619005
1	Midi Vap Cyan-Ten Midi Cyanide Distillation	MC-100	Jul-93	MCVA1390797
1	Sequoia Turner Spectrophotometer	340	Oct-93	007611TF
2	HACH COD Reactor	COD Reactor	Jan-94	911005731C, 9807000017919
1	Orion Conductivity Meter	160	Jan-94	32241041
1	Expandable Ionanalyzer	EA940	Jan-90	2060
1	Setaflash Flashpoint Analyzer	01SF	Dec-93	2779
1	Parr 1261 Calorimeter	Parr 1261	Jan-89	289
1	Sartorius Balance	GEL #B005		3410156
2	Sartorius Analytical Balance	GEL #B-010, GEL #B-012		30505030, 40245216
RADIOCHEMISTRY/BIOASSAY				
1	Tennelec Automatic Proportional Counters	LB5100W	Aug-92	14740
1	Tennelec Automatic Proportional Counters	LB4100	Sep-92	14741
3	Tennelec LB-4100 Proportional Counter w/48 Detectors	LB4100	Mar-93, Jun-93, Dec-98	18483, 21938
4	Beckman Liquid Scintillation Counters	LS600/LL, LS6500, LS6500	Jun-93, Jun-93, Apr-94	7065155, 7067083, 7067404
1	Canberra Scintillation Detector (NaI)	G0470 Relative Efficiency 100%	Mar-99	
2	Wallac Liquid Scintillation Counters	Guardian/Quantallus	Mar-97, Dec-98	4040127, 2200082
2	PGT Germanium Detectors for Gamma Spectroscopy System	NIGC3019 Relative Efficiency 100%	May-97, May-97	2211, 2245
4	Canberra Germanium Detectors for Gamma Spectroscopy System	GC3019 Relative Efficiency 100%	Nov-97, Nov-97, May-97, May-97	1922864, 2461, 2605, 2464
7	Canberra Germanium Detectors for Gamma Spectroscopy System	GC3519 Relative Efficiency 100%	Dec-91, Dec-91, Jan-94, Nov-97, May-97, May-97	5933088, 11912863, 12922955, 1943199, 1943234, 7933154, 11912876
3	Canberra & Ortec High Efficiency Germanium Detectors for Gamma Spectroscopy System	GC4018 Relative Efficiency 40-45%	May-97, Nov-98, Nov-98	1933074, 30-TN10348, 37-TN11260A

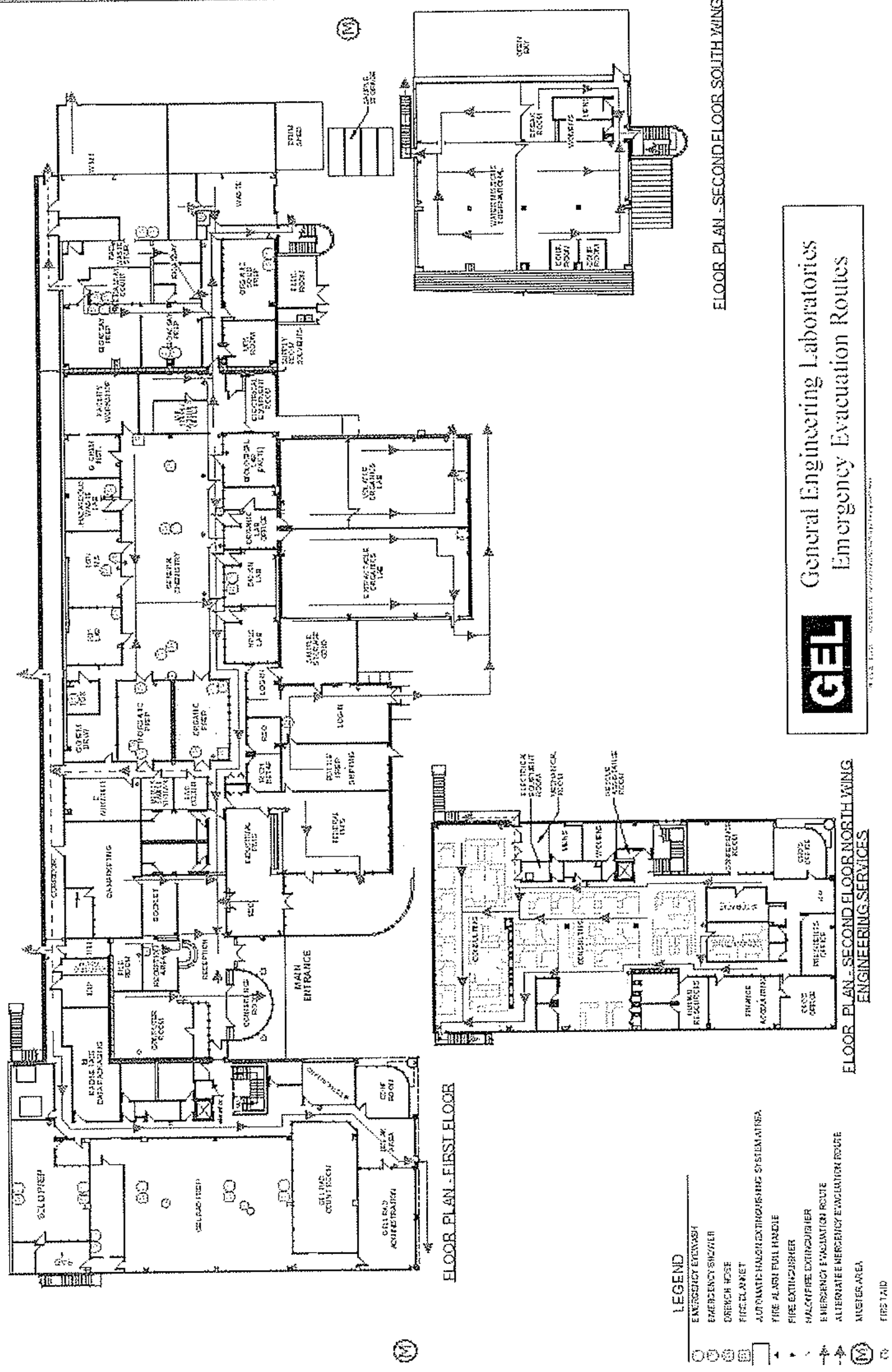
#	Equipment	Model #	Purchase Date	ID/Serial #
2	Canberra & Ortec High Efficiency Germanium Detectors for Gamma Spectroscopy System	GC8021 90210P Relative Efficiency 80-90%	Aug-94, Nov-98	8943324, 30-TP30546A
1	Canberra GX 3519 Extended Range High Efficiency Germanium Detector for Gamma Spectroscopy System	GR3520	Aug-93	8932581
1	Canberra GCW 3522 Germanium Well Detector for Gamma Spectroscopy System	GCW3523	Apr-94	3941466
3	Canberra Low Energy Germanium Detector for X-Ray Spectroscopy System	GL2020/S	Feb-95, Jan-95, Mar-98	129 22782, 195 4119, 3984452
1	Canberra Alpha/Gamma Data Management System	XG3100B	Feb-92	G-4470
1	Digital Vax Station 4000/90 Computer System for Alpha/Gamma Data Management System	VS49-K-AA	Dec-94	AB43500 OWN
2	DEC Alpha Work Stations for Alpha/Gamma Data Management System	600 AV, 600 AV	Nov-98, Nov-98	N183806280, N188806229
112	Canberra Alpha Spectrometers for Alpha Spectroscopy System (Environmental)	7401	1992 to 1995	Varied
24	Canberra Alpha PIPS Detectors for Alpha Spectroscopy System (Bioassay)	7401	1993 to 1995	Varied
6	Ludlum Scalers for Radium 226 Analysis/Lucas Cells	2000	Dec-00, May-92, Jun-93, Oct-93, Dec-98, Dec-00	101846, 86493, 104617, 140731, 078964, 125015
1	Protean Automatic Proportional Counter	WPC 9550	Mar-02	0021910
4	Protean Multi-Detector (16) Proportional Counter	MDS-16	Apr-02	10751-4
2	Laser Kinetic Phosphorimeter	KPA-11, KPA-11	Mar-94	91-45050014, 9445050064
1	Laser Kinetic Phosphorimeter	KPA-10	Apr-95	89-0505-0035
84	Canberra Alpha Analist Spectrometer w/PIRS Detectors	7200	1988-2002	Varied
LABORATORY INFORMATION MANAGEMENT SYSTEMS				
1	SUN Ultra Enterprise 3000, Solaris 2.5.1, 6 CPUs, (new carlos) 512 MB RAM, 50 GB Disk (mirrored, 100 Mbps Eth card, Oracle 7)	N/A	Apr-98	SUN-E3-167
1	SUN Ultra Enterprise 3000, Solaris 2.6, 6 CPUs, (prodsvr01) 512 MB RAM, 25 GB Disk (mirrored, 100 Mbps Eth card, Oracle 8I, Rad Tower)	N/A	Apr-98	SUN-E3-167
1	Windows NT Server, NT4, 2 CPU 256 MB RAM 10 GB Disk (rad_server), 100 Mbps Eth card, ORACLE7	N/A	Aug-98	PC Server Class
1	HP9000 Dclass, HP-UX 10.20, 2 cpu, 256 MB RAM, (hpclp1) 50GB Disk (mirrored and RAID%), Raid tower, 100 Mbps Eth card, Target Software	N/A	Nov-97	A3480A

#	Equipment	Model #	Purchase Date	ID/Serial #
1	HP9000 Dclass, HP-UX 10.20, 2 cpu, 256 MB RAM, (kilroy) 50GB Disk (mirrored and RAID5), Raid tower, 100 Mbps Eth card, Target Software	N/A	Nov-97	A3480A
1	SUN Ultra Enterprise 4500, Salaris 9 20 CMUs, 6 GB RAM, 720 GB Disk (mirrored RAID 5), Oracle 9, 100 Mbps Ethernet card	E4500	Feb-03	941H35EF
1	Rave - Ultra AX-MP 2 CPU's, 1024 MB RAM, 60 GB Disk (mirrored)	E450	Oct-99	257703
1	Rave - Ultra AX-MP 2 CPU's, 1024 MB RAM, 60 GB Disk (mirrored)	E250	Mar-00	302971
1	SUN Sparc-5 225 MB, 5 GB	N/A		521F00XX
1	SUN Sparc-5 225 MB, 10 GB	N/A		434F2457

UNIVERSAL POWER SUPPLY

#	Equipment	Model #	Purchase Date	ID/Serial #
1	International Power Machines Durable Power 300	FE-Series	May-99	BP-FE-81

APPENDIX I: FACILITIES WITH EVACUATION ROUTES



APPENDIX J: STANDARD OPERATING PROCEDURES & ANALYTICAL METHODS

SOP#	SOP TITLE	METHODS
GL-ADM-E-001	Preparation, Authorization, Change, and Release of SOPs	N/A
GL-ADM-E-002	Process, Review, and Distribution of CofAs and COA Packages	N/A
GL-ADM-E-003	Courier Service	N/A
GL-AP-E-001	Invoicing Analytical Lab Numbers	N/A
GL-CO-E-001	Revising General Engineering Laboratories Catalog of Analytical Services	N/A
GL-CO-E-002	Delegated Authorization to Commit the Company	N/A
GL-CO-E-003	Request for Proposal (RFP)/Contract Review	N/A
GL-CS-E-002	Internal Review of Contractually Required Quality Criteria for Clien Package Delivery	N/A
GL-CS-E-004	Distribution and Utilization of the Project Management Alpha LIMS Manual	N/A
GL-CS-E-005	Electronic Data Deliverables	N/A
GL-CS-E-006	Subcontracting Analytical Services	N/A
GL-CS-E-007	Creation of Standard Test Products	N/A
GL-CS-M-001	Project Management ALPHA LIMS Manual	N/A
GL-DC-E-001	Document Control	N/A
GL-FC-E-001	Facility Security	N/A
GL-FC-E-002	Testing Emergency Eyewash and Shower Equipment	N/A
GL-FC-E-003	Fume Hood Face Velocity Performance Checks	N/A
GL-FC-E-004	Inspection of Fire Extinguishers	N/A
GL-FS-E-001	Field pH	N/A
GL-FS-E-002	Field Specific Conductance	N/A
GL-FS-E-003	Field Dissolved Oxygen	N/A
GL-FS-E-004	Field Total and Free Residual Chlorine	N/A
GL-FS-E-005	CME-45 B Drilling Rig	N/A
GL-FS-E-006	Hydrolab Datasonde 4a Operation	N/A
GL-GC-E-001	Total Dissolved Solids	160.1, 2540C
GL-GC-E-002	Fluoride Determination by Ion Selective Electrode	340.2, SM 4500F-B, SM 4500F-C
GL-GC-E-004	Standards - Definitions and Preparation	N/A
GL-GC-E-007	Total Organic Halogen (TOX) on Liquid Samples Using the Mitsubishi TOX-10 Analyzer	1650C, 9020B
GL-GC-E-008	pH	150.1, 9040B, 9041A, 9045C, 4500 H
GL-GC-E-009	Conductivity	120.1, 9050, SM 2510B
GL-GC-E-010	Paint Filter Test	9095A
GL-GC-E-011	Total Solids	160.3, 2540B, 2540G
GL-GC-E-012	Total Suspended Solids	160.2
GL-GC-E-017	Gravimetric Total Petroleum Hydro Carbons (TPH) in Liquids	9070A(Mod), SM 5520F
GL-GC-E-018	Determination of Oil and Grease and Total Recoverable Petroleum Hydrocarbons (TPH) in Solid Matrices	9071A, SM 5520E, SM 5520F
GL-GC-E-019	Ammonia Determination by Traacs 800 Methodology	350.1
GL-GC-E-020	Oil and Grease Liquids	413.1, 9070A

SOP#	SOP TITLE	METHODS
GL-GC-E-025	Hardness by Calculation	SM 2340B
GL-GC-E-026	Total Phosphorus	365.4
GL-GC-E-027	Pensky-Martens Closed Cup Flashpoint	1010
GL-GC-E-028	Carbonaceous Biochemical Oxygen Demand (CBOD)	405.1, SM 5210
GL-GC-E-029	Corrosivity Toward Steel	1110(Mod)
GL-GC-E-031	Fecal Coliform by Membrane Filter	9222D
GL-GC-E-032	Carbon Dioxide (Total and Free) by Calculation	310.1, SM 4500-CO2-D
GL-GC-E-033	Alkalinity - Total, Bicarbonate Carbonate, Hydroxide, and Phenolphthalein	310.1(Mod), 2320B
GL-GC-E-034	Fecal Coliform Most Probable Number (5 Tube Dilution)	SM 9221-E1, SM 9221-E
GL-GC-E-035	Volatile Suspended Solids	160.2, 160.4, SM 2540E
GL-GC-E-036	Color Determination by Visual Comparison	110.2, SM 2120B
GL-GC-E-037	Turbidity	2310B, 180.1
GL-GC-E-040	Cyanide Amenable to Chlorination	335.1(Mod), 335.3 (Mod), 9010B, 9012A
GL-GC-E-041	Nitrate/Nitrite Sample Preparation and Analysis Using the Traacs 800 Autoanalyzer	353.1
GL-GC-E-044	Colorimetric Determination of Chromium, Hexavalent	7196A
GL-GC-E-045	Biochemical Oxygen Demand (BOD)	405.1, SM 5210
GL-GC-E-046	Orthophosphate	365.2, SM 4500-PE
GL-GC-E-047	Methylene Blue Active Substance	425.1, 5540C
GL-GC-E-048	Heating Value Determination by Bomb Calorimeter	ASTM D 240-00, 4809-00 (M), E711-87 (M)
GL-GC-E-050	Threshold Odor, Consistent Series EPA 140.1	140.1
GL-GC-E-052	Sulfide (Methylene Blue Method)	376.2(M), HACH 8131
GL-GC-E-053	Heterotrophic Plate Count (Standard Plate Count)	SM 9215
GL-GC-E-054	Total Coliform by Membrane Filter	SM 9222B(M)
GL-GC-E-055	Total Kjeldahl Nitrogen (TKN) Analysis Using the Traacs 800 Autoanalyzer	351.2
GL-GC-E-056	Sulfite	SM 4500-SO3 2-B
GL-GC-E-057	Volatile Solids and % Ash-550-Procedure for Water Samples	160.4, SM 2540E
GL-GC-E-058	Volatile Solids and % Ash-550-Procedure for Solid and Semi-Solid Samples	SM 2540G
GL-GC-E-059	Dissolved Oxygen Analysis by Membrane Electrode Method	4500-O-G
GL-GC-E-061	Chemical Oxygen Demand (COD) - Digestion Reactor Method	410.4, HACH 8000
GL-GC-E-062	Total Carbon and Total Organic Carbon Analysis Using the Dohrmann DC-190 Boat Sampler	9060(M)
GL-GC-E-063	Total Coliform by Most Probable Number (5 Tube Dilution)	SM 9221B(M)
GL-GC-E-064	Density	ASTM D5057
GL-GC-E-065	Specific Gravity	ASTM D5057
GL-GC-E-066	Flashpoint by Setaflash	1020A
GL-GC-E-067	Total Cyanide Sample Preparation	9012A, 9010B, 335.1, 33 335.4, 335.2 CLP-M
GL-GC-E-068	Viscosity	Manufacturer's Method
GL-GC-E-069	Reactive Cyanide and Sulfide	SW-846
GL-GC-E-070	Determination of Kinematic and Dynamic Viscosity Using a Glass	ASTM D 445-82

SOP#	SOP TITLE	METHODS
	Capillary Viscometer	
GL-GC-E-071	Total Phosphorous Sample Preparation	365.4
GL-GC-E-072	Ammonia Sample Preparation	350.1, 350.2
GL-GC-E-073	Free Cyanide Analysis by Microdiffusion	ASTM D 4282
GL-GC-E-074	Extractable Organic Halides (EOX) Using the Dohrmann DX-2000 Analyzer	SW846 9023
GL-GC-E-076	Total Residue Chlorine	SM 4500 ClG, 330.5
GL-GC-E-077	Cyanide Weak Acid Dissociable Sample Preparation and Analysis	335.4, 4500-CN-1
GL-GC-E-078	Total Kjeldahl Nitrogen Preparation Using the Traacs 800 Autoanalyzer	351.2
GL-GC-E-079	Bomb Preparation Method for Solid Waste	5050
GL-GC-E-080	Total Coliform Membrane Filter Analysis by SW-846 Method	9132, 9222B
GL-GC-E-082	Acid-Soluble Sulfides	9030B, 9034
GL-GC-E-086	Ion Chromatography	300.0, SM 4110B, 9056
GL-GC-E-087	Percent Water by Karl Fischer Titration	ASTM E203-96
GL-GC-E-090	Acidity	305.1, 305.2, 2310B
GL-GC-E-091	Wavelength Verification of Sequoia-Turner Spectrophotometers	N/A
GL-GC-E-092	General Chemistry Data Packaging and Validation	N/A
GL-GC-E-093	Total, Total Inorganic and Total Organic Carbon (TOC) using the O Analytical Model 1010 TOC Analyzer	415.1, SW846 9060
GL-GC-E-094	N-Hexane Extractable Material (HEM, Oil and Grease) and Silica GEL Treated N-Hexane	1664, SW846 9070A
GL-GC-E-095	Cyanide Analysis	335.2 CLP-M, 335.1, 335. 335.4, 9010B, 9012A
GL-GC-E-096	Perchlorate by Ion Chromatography	314.0
GL-GC-E-097	Boiling Point	ASTM D 1120 (M)
GL-GC-E-098	Halogens	ASTM D 808-00
GL-GC-E-099	Ferrous Iron	SM 3500-Fe-D
GL-GC-E-100	Total Hardness by Titration	130.2
GL-GC-E-101	Hydrazine	ASTM D 1385-01
GL-GC-E-102	Total Recoverable Phenol Determination by the Lachat QuickCher FIA+ 8000 Series	420.2, 9066
GL-GC-E-103	Total Phosphorus by the Lachat QuickChem FIA+ 8000 Series	365.4
GL-GC-E-104	TKN Analysis using the Lachat QuickChem FIA+8000	351.2
GL-GC-E-105	Volumetric Determination of Settleable Solids	160.5, SM 2540F
GL-GC-E-106	Ammonia Determination by the Lachat Quickchem FIA + 8000 Ser	350.1 Rev2
GL-HR-E-002	Employee Training	N/A
GL-HR-E-003	Maintenance of Training Records	N/A
GL-IMS-E-001	Software Modification	N/A
GL-IMS-E-002	Computer Software Development and Maintenance	N/A
GL-IMS-E-004	Verification and Validation of Software	N/A
GL-IMS-E-005	Computer Services	N/A
GL-IMS-E-006	Method Backup for Computer Controlled Instrumentation	N/A
GL-LB-E-001	Determination of Method Detection Limits	N/A
GL-LB-E-002	Balances	N/A

SOP#	SOP TITLE	METHODS
GL-LB-E-003	Glassware Preparation	N/A
GL-LB-E-004	Temperature Monitoring and Documentation Requirements for Refrigerators, Ovens, Incubators, and Other Similar Devices	N/A
GL-LB-E-005	Data Review/Validation	N/A
GL-LB-E-006	Toxicity Characteristic Leaching Procedure Preparation	1311
GL-LB-E-007	Laboratory Standards Documentation	N/A
GL-LB-E-008	Basic Requirements for the Use and Maintenance of Laboratory Notebooks, Logbook, Forms and Other Record Keeping Devices	N/A
GL-LB-E-009	Run Logs	N/A
GL-LB-E-010	Maintenance and Use of Air Displacement Pipets	N/A
GL-LB-E-012	Verifying the Maintenance of Sample Integrity	N/A
GL-LB-E-013	CLP/CLP-Like Data Package Assembly, Revision and Archiving	N/A
GL-LB-E-015	Control of Laboratory Standards	N/A
GL-LB-E-016	DI Water System	N/A
GL-LB-E-017	Procedure and Policy for Manual Integration	N/A
GL-LB-E-018	Instrument Clock Verification	N/A
GL-LB-E-020	Tuning of High Intensity Ultra-Sonic Processor	N/A
GL-LB-E-022	Generation of Swipe Data	N/A
GL-LB-E-023	Waste Extraction Test (Wet)	N/A
GL-LB-E-024	Synthetic Precipitation Leaching Procedure	1312
GL-LB-E-025	Modified Elutriate	N/A
GL-LB-E-026	Container Suitability Testing	N/A
GL-LB-G-001	Laboratory Waste Management Plan	N/A
GL-LB-N-001	Safety, Health and Chemical Hygiene Plan	N/A
GL-MA-E-006	Acid Digestion of Total Recoverable or Dissolved Metals in Surfac and Groundwater Samples for Analysis by ICP or ICP-MS	3005A, 200 Series
GL-MA-E-008	Acid Digestion of Total Metals in Aqueous Samples and Extracts f Analysis by ICP or ICP-MS	3010A, 200 Series
GL-MA-E-009	Acid Digestion of Sediments, Sludges, and Soils	3050B
GL-MA-E-010	Mercury Analysis Using the Perkin Elmer Automated Mercury Analyzer	245.1, 245.2, 245.5, 245. CLP-M, 7470A, 7471A, S 3112B
GL-MA-E-012	Inorganic CLP Sample Digestions	ILMO 4.0, CLP
GL-MA-E-013	Determination of Metals by ICP with the Thermo Jarrell Ash ICAP- 61E Trace Spectrometer	EPA 200.7, SW-846 6010 and 200.7 CLP-M
GL-MA-E-014	Determination of Metals by ICP-MS with the Hewlett-Packard Mod 4500 Spectrometer	6020, 200.8
GL-MA-E-015	Microwave Based Atmospheric Pressure Acid Digestion of Total Recoverable and Dissolved Metals	SW-846 3051
GL-MA-E-016	Sample Preparation for Total Recoverable Elements by EPA 200.	EPA 200 series 200.7, 20
GL-MA-E-017	Metals Data Validation	N/A
GL-MA-E-018	Mercury Analysis using the PS Analytical Millenium Automated Mercury Analyzer	EPA 1631
GL-MA-E-019	Low Level Mercury Sampling by EPA Method 1669	EPA 1669
GL-OA-E-001	Establishing Retention Time Windows for Gas Chromatographic Analysis	8000

SOP#	SOP TITLE	METHODS
GL-OA-E-002	Organic Standards Preparation and Traceability	N/A
GL-OA-E-003	Non-Volatile Total Petroleum Hydrocarbons by Flame Ionization Detector	8000B, 3510B, 8015B, 3550B, CA Method
GL-OA-E-004	Volatile Total Petroleum Hydrocarbons by Flame Ionization Detect	5030B, 8000B, 8015B, C Method
GL-OA-E-007	Dioxins and Furans	8280
GL-OA-E-009	Semivolatile Analysis by Gas Chromatograph/Mass Spectrometer	8270C, EPA 625
GL-OA-E-010	Extraction of Semivolatile and Nonvolatile Organic Compounds fro Soil, Sludge, and Other Miscellaneous Samples	8270C, 8081, 8081A, 808 8015A, 8310, FL-PRO, C ETPH
GL-OA-E-011	Chlorophenoxy Acid Herbicides	8151A
GL-OA-E-013	Extraction of Semivolatile and Nonvolatile Organic Compounds fro Groundwater, Wastewater, and Other Aqueous Samples	608, 625, 8270B, 8081, 8081A, 8082, 8015A, 801 8310
GL-OA-E-015	Extraction of Herbicides from Groundwater, Wastewater, and othe Aqueous Samples	8151A
GL-OA-E-020	Percent Moisture	3550
GL-OA-E-021	Volatile Organic Aromatic Compounds by Gas Chromatograph an Photoionization Detector	8021A, 602
GL-OA-E-022	Volatile Organic Compounds by Gas Chromatograph/Mass Spectrometer	524.2
GL-OA-E-024	Cleanup and Extraction of Polyurethane Foam Cartridge (PUF) for Semivolatile Analysis	TO-4, TO-13, 8270(M), 608(M)
GL-OA-E-026	Volatile Organic Compounds (VOC) by Gas Chromatograph/Mass Spectrometer	624
GL-OA-E-027	Extraction of Herbicides from Soil and Sludge Samples	8151A
GL-OA-E-030	Polynuclear Aromatic Hydrocarbons	8000B, 8310
GL-OA-E-033	Nitroaromatics and Nitramines by High Performance Liquid Chromatography (HPLC)	8330, 8000B
GL-OA-E-036	Florosil Cleanup of Organochlorine Pesticide Solvent Extracts	3510C, 3550B
GL-OA-E-037	Sulfuric Acid/Permanganate Cleanup of PCB Solvent Extract	3550B, 3610C, 8082
GL-OA-E-038	Volatile Organic Compounds (VOC) by GC/MS by Methods 8260B/5030B/5035	8260A, 8260B, 5030A, 5030B, 5035
GL-OA-E-039	Volatile Organics in Soil and Water Samples by Method 5035	5035
GL-OA-E-040	Polychlorinated Biphenyls by Method 8082	8000B, 8082, 608
GL-OA-E-041	Organochlorine Pesticides and Chlorinated Hydrocarbons by Methods 8081A/8121	8000B, 8080, 8081, 8081 8121, 608
GL-OA-E-043	Organotins	N/A
GL-OA-E-044	Organics Data Validation	N/A
GL-OA-E-045	Sulfur Clean-up	3660B
GL-OA-E-046	Common Industrial Solvents, Glycols and Various Organic Compounds by FID	8000A, 3510B, 8015A, 3550A, CA Method
GL-OA-E-047	Gel Permeation Cleanup of Solvent Extracts	3640A, 3510C, 3550B
GL-OA-E-048	FL-PRO (Petroleum Range Organics by GC-FID	3510C, 3550B, 8000B, 8015B, FL-PRO
GL-OA-E-049	Silica Gel Cleanup Using Solid Phase Silica Gel Extraction Cartridges	3550B, 3510C
GL-OA-E-050	Extraction of Semi and Non Volatile Organic Compounds from Oil	N/A

SOP#	SOP TITLE	METHODS
GL-OA-E-051	Dioxins and Furans by 8280A	8280A
GL-OA-E-052	TPH by GC-FID TNRCC Method 1005	TNRCC Method 1005
GL-OA-E-053	Analysis of 1,4-Dioxane by GC/MS	SW 846 8260B
GL-OA-E-054	Gasoline Range Organics Using Flame Ionization Detection Per Alaska Method AK101	AK101
GL-OA-E-055	DRO/RRO by GC-FID AK 102, AK 103	AK102, 103
GL-OA-E-056	Low Level Analysis by LC/MS/MS by Method 8321 Modified	8321 (M)
GL-OA-E-057	Sample Preparation for Perchlorate using LC/MS/MS	314.0, 8321A (M)
GL-OA-E-058	VOA Refrigerator Blanks	N/A
GL-OA-E-059	1,2-Dibromomethane EDB and 1,2-Dibromo-3-Chloroproane (DBC in Water by ECD by 504 or 8011	504, 8011
GL-OA-E-060	Screening of Semivolatile Organic Compounds by GC/MS and GC/ECD	N/A
GL-QS-B-001	Quality Assurance Plan	N/A
GL-QS-E-001	Conduct of Quality Audits	N/A
GL-QS-E-002	Conducting Corrective Action	N/A
GL-QS-E-003	Training, Qualifying, and Certifying Quality Assurance Audit Personnel	N/A
GL-QS-E-004	Documentation of Nonconformance Reporting and Dispositioning and Control of Nonconforming Items	N/A
GL-QS-E-005	Review of Monitoring Device Logs	N/A
GL-QS-E-007	Thermometer Calibration	N/A
GL-QS-E-008	Quality Records Management and Disposition	N/A
GL-QS-E-011	Method Validation	N/A
GL-QS-E-012	NCR Database Operation	N/A
GL-QS-E-013	Handling of Proficiency Evaluation Samples	N/A
GL-RAD-A-001	Determination of Gross Alpha And Gross Non-Volatile Beta in Wat	900.0, 9310
GL-RAD-A-001	Determination of Gross Alpha And Gross Non-Volatile Beta in Soil	900.0 (M), 9310
GL-RAD-A-001	Determination of Gross Alpha in Water by Coprecipitation	520/5-84-006 Method 00-
GL-RAD-A-002	Determination of Tritium	906.0
GL-RAD-A-003	Determination of Carbon-14 in Water, Soil, Vegetation and Other Solid Matrices	N/A
GL-RAD-A-004	Determination of Strontium 89/90 in Water, Soil, Milk, Filters, Vegetation and Tissues	905.0 (M), DOE RP501 (N HASL-300 (M)
GL-RAD-A-005	Determination of Technitium-99	HASL-300(M), DOE RP55 (M)
GL-RAD-A-006	Determination of Iodine-129	901.1(M), HASL-300(M)
GL-RAD-A-007	Determination of Radon-222 in Water	SM 7500 Rn-B (M)
GL-RAD-A-008	Determination of Radium-226	903.1 (M)
GL-RAD-A-009	Determination of Radium-228 in Water	904.0 (M), Ra-05 (M)
GL-RAD-A-009	Determination of Total Alpha Emitting Radium and Radium-228 in Soil	HASL-300 (M)
GL-RAD-A-010	Total Alpha Radium Isotopes in Water	900.1 (M)
GL-RAD-A-011	Isotopic Determination of Americium, Curium, Plutonium, and Uranium	DOE RP800 (M), HASL-3 (M)
GL-RAD-A-012	Isotopic Determination of Thorium	DOE RP800 (M), HASL-3

SOP#	SOP TITLE	METHODS
		(M)
GL-RAD-A-013	Determination of Gamma Isotopes in Water and Soil	900.1 (M), HASL-300 (M)
GL-RAD-A-014	Determination of Total Radioactivity in Contact Waste	N/A
GL-RAD-A-015	Digestion for Soils and Sand	N/A
GL-RAD-A-016	Determination of Radiometric Polonium	N/A
GL-RAD-A-017	Determination of Iodine-131 in Water	902.0, SM 7500-IB
GL-RAD-A-018	Determination of Lead-210 in Liquid and Solid Matrices	N/A
GL-RAD-A-019	Determination of Phosphorus-32 in Soil and Water	N/A
GL-RAD-A-020	Determination of Promethium-147 in Soil and Water	N/A
GL-RAD-A-021	Soil Sample Preparation for the Determination of Radionuclides	N/A
GL-RAD-A-021	Soil Sample Ashing for the Determination of Radionuclides	N/A
GL-RAD-A-022	Determination of NI-59 and NI-63 in Soil and Water	N/A
GL-RAD-A-023	Total Uranium Environmental and Bioassay Samples by Kinetic Phosphorescence	ASTM D 5174
GL-RAD-A-025	Determination of Iron-55 in Liquid and Solid Matrices by Gamma Spectroscopy Counting	N/A
GL-RAD-A-026	Preparation of Special Matrices for the Determination of Radionuclides	N/A
GL-RAD-A-028	Radium-226 in Drinking Water by EPA Method 903.1	903.1
GL-RAD-A-029	Determination of Strontium-89/90 in Drinking Water by EPA Metho 905.0	905.0
GL-RAD-A-030	Determination of Radium-228 in Aqueous Samples by EPA Metho 904.0 and 9320	904.0, 9320
GL-RAD-A-031	Determination of Selenium and Tellurium	N/A
GL-RAD-A-032	Isotopic Determination of Neptunium	N/A
GL-RAD-A-033	Determination of Chlorine-36	N/A
GL-RAD-A-035	Isotopic Determination of Plutonium-241	DOE RP800 (M), HASL-3 (M)
GL-RAD-A-036	Isotopic Determination of Americium, Curium, and Plutonium in Large Soil Samples	DOE RP800 (M), HASL-3 (M)
GL-RAD-A-038	Determination of Thorium/Uranium	DOE RP800 (M), HASL-3 (M)
GL-RAD-A-040	Determination of Fe-55 in Liquid and Solid Matrices by Liquid Scintillation Counter	N/A
GL-RAD-A-041	Determination of Total Activity in Solids and Liquids	N/A
GL-RAD-A-042	Americium, Curium, Plutonium and Uranium in Liquid Samples by Vacuum Box Method	N/A
GL-RAD-A-043	Determination of Plutonium, Uranium and Thorium	N/A
GL-RAD-A-044	Total Alpha Radium in Aqueous Samples (EPA 903.0 and 9315)	903.0, 9315
GL-RAD-A-045	Isotopic Determination of Plutonium, Uraniium, Americium, Curium and Thorium	HASL-300 (M)
GL-RAD-A-046	Isotopic Determination of Ra-224 and Ra-226 by Alpha Spectrome	N/A
GL-RAD-B-001	Sequential Determination of Isotopic Americium, Curium, Californium, Plutonium, Strontium and Uranium in Urine	N/A
GL-RAD-B-002	Determination of Polonium-210, Radium-226, and Radium-228 in Urine	N/A
GL-RAD-B-003	Determination of Isotopic Thorium and Uranium in Urine Samples	N/A

SOP#	SOP TITLE	METHODS
GL-RAD-B-004	Determination of Lead-210 in Bioassay Samples	N/A
GL-RAD-B-005	Management of Blank Populations	N/A
GL-RAD-B-008	Determination of Gross Alpha Activity in Nasal Swipes	N/A
GL-RAD-B-009	Bioassay Countroom Alpha Spectroscopy System	N/A
GL-RAD-B-010	Sequential Determination of Thorium, Plutonium and Uranium in Fecal Samples	N/A
GL-RAD-B-011	Determination of Tritium in Urine	906.0
GL-RAD-B-012	Ashing of Fecal Samples	N/A
GL-RAD-B-013	Sequential Determination of Americium and Plutonium in Fecal Samples	N/A
GL-RAD-B-014	Preparation of Synthetic Urine and Fecal Material	N/A
GL-RAD-B-015	Determination of Protactinium in Urine	N/A
GL-RAD-B-016	Determination of Technetium-99 in Urine	N/A
GL-RAD-B-017	Determination of Neptunium in Urine	N/A
GL-RAD-B-018	Operation of the Manual and Automatic Chemcheck KPA	N/A
GL-RAD-B-019	Total Uranium in Bioassay Samples by Kinetic Phosphorence	N/A
GL-RAD-B-020	NI-59 and NI-63 in Urine	N/A
GL-RAD-B-021	Wallac 1220 Quantalus Liquid Scintillation Counter	N/A
GL-RAD-D-002	Analytical Methods Validation for Radiochemistry	N/A
GL-RAD-D-003	Data Review, Validation, and Data Package Assembly	N/A
GL-RAD-I-001	Gamma Spectroscopy System Operations	N/A
GL-RAD-I-004	Beckman LS-6000/6500 Operating Procedure	N/A
GL-RAD-I-006	LB4100 Gross Alpha/Beta Counter Operating Instructions	N/A
GL-RAD-I-007	Ludlum Model 2000 Lucas Cell Counter Operating Instructions	N/A
GL-RAD-I-008	VAX/VMS Quality Control Software Program	N/A
GL-RAD-I-009	The Alpha Spectroscopy System	N/A
GL-RAD-I-010	Counting Room Instrumentation Maintenance and Performance Checks	N/A
GL-RAD-I-011	Operation of the Chemchek Kinetic Laser Phosphorimeter	N/A
GL-RAD-I-012	Managing Statistical Data in the Radiochemistry Laboratory	N/A
GL-RAD-I-013	Column Preparation	N/A
GL-RAD-I-014	WALLAC Guardian Model 1414-003	N/A
GL-RAD-I-015	WPC 9550 Gross Alpha/Beta Counter Operating Instructions	N/A
GL-RAD-I-016	Multi-Detector Counter Operating Instructions	N/A
GL-RAD-M-001	Preparation of Radioactive Standards	N/A
GL-RAD-M-003	Magnetic Backup of Hard Drives for Alpha and Gamma Spectroscopy	N/A
GL-RAD-S-001	Radiation Survey Procedures	N/A
GL-RAD-S-002	Radiation Related Emergency Procedures	N/A
GL-RAD-S-003	Inventory and Tracking of Radioactive Material	N/A
GL-RAD-S-004	Radioactive Material Handling Procedure	N/A
GL-RAD-S-006	Radiation Worker Training	N/A
GL-RAD-S-007	Receiving of Radioactive Samples	N/A
GL-RAD-S-008	Shipping of Radioactive Samples and Sample Residues	N/A
GL-RAD-S-009	Dosimetry Procedures	N/A

SOP#	SOP TITLE	METHODS
GL-RAD-S-010	Handling of Biological Materials	N/A
GL-RAD-S-012	Radiation Safety Relative to the NITON XL-309 Lead-Based Paint Analyzer	N/A
GL-RAD-S-013	Air Sampling for Radioactivity	Guide 825
GL-RC-E-001	Receipt and Inspection of Material and Services	N/A
GL-RC-E-002	Material Requisition Form Procedure	N/A
GL-RC-E-003	Sample Bottle Preparation and Shipment	N/A
GL-SR-E-001	Sample Receipt, Login, and Storage	N/A
GL-SR-E-002	Return of Samples	N/A
GL-SR-E-003	Inspection, Cleaning and Screening of Sample Coolers	N/A

APPENDIX K: SAMPLE STORAGE AND PRESERVATION REQUIREMENTS

Parameter	Container[1]	Preservation	Holding Time[2]
Inorganics			
Acidity	P,G	4°C	14 days
Alkalinity	P,G	4°C	14 days
Demand (BOD)	P,G	4°C	48 hours
Bromide	P,G	None	28 days
Chemical Oxygen Demand (COD)	P,G	4°C, H_2SO_4 to pH<2	28 days
Chlorine by Bomb	P,G	None	None
Chloride	P,G	None	28 days
Color	P,G	4°C	48 hours
Conductivity	P,G	4°C	28 days
Corrosivity by pH	P	None	Immediate
Corrosivity to Steel	P	None	None
Cyanide amenable to chlorination	P,G	4°C, NaOH to pH>12, 0.6g ascorbic acid [3]	14 days [4]
Cyanide, total	P,G	4°C, NaOH to ph>12, 0.6g ascorbic acid [3]	14 days [4]
Dissolved Oxygen	G (bottle and tap)	None	Immediate
Fixed and Volatile Solids	P,G	4°C	7 days
Flashpoint	P,G	None	None
Fluoride	P	None	28 days
Hardness	P,G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months
Heating Value	P	None	None
Hydrazine	G	HC1 to pH<2	Immediate
Percent (%) Moisture	P	4°C	None
Ammonia Nitrogen	P,G	4°C, H_2SO_4 to pH<2	28 days
Nitrate	P,G	4°C	48 hours
Nitrite	P,G	4°C	48 hours
Nitrate/Nitrite	P,G	4°C, H_2SO_4 to pH<2	28 days
Total Kjeldahl and Organic Nitrogen	P,G	4°C, H_2SO_4 to pH<2	28 days
Odor	G	4°C, Zero headspace	Immediate
Oil and Grease	G	4°C, HC1 or H_2SO_4 to pH<2	28 days
Orthophosphate	P,G	Filter immediately, 4°C	48 hours
Total Phenols	G	4°C, H_2SO_4 to pH<2	28 days
pH	P,G	None	Immediate
Total Phosphorus	P,G	4°C, H_2SO_4 to pH<2	28 days
Residual Chlorine	P,G	None	Immediate
Salinity	P	None	28 days
Specific Gravity	P	4°C	7 days
Sulfate	P,G	4°C	28 days
Sulfide	P,G	4°C, add ZNAce and NaOH to pH>9	7 days
Sulfite	P,G	None	Immediate
Sulfur by Bomb	G	None	None
Surfactants	P,G	4°C	48 hours
Settleable Solid	P,G	4°C	48 hours
Total Dissolved Solid	P,G	4°C	7 days
Total Solid	P,G	4°C	7 days
Total Suspended Solid	P,G	4°C	7 days
Volatile Solid	P,G	4°C	7 days
Total Organic Carbon	P,G	4°C,HCl or H_2SO_4 to pH<2	28 days
Total Organic Halides	G	4°C, H_2SO_4 to pH<2	28 days
Total Petroleum Hydrocarbons	G	4°C, H_2SO_4 to pH<2	28 days
Turbidity	P,G	4°C	48 hours
Metals (except chromium VI and mercury)	P	4°C,HNO_3 to pH<2	6 months

Parameter	Container[1]	Preservation	Holding Time[2]
Chromium VI - Aqueous	P	4°C	24 hours
Chromium VI - Solids	P	4°C	7 days for extraction
Mercury - Wastewater and Drinking water	P,G	4°C,HNO_3 to pH<2	28 days
Mercury - Others	G	4°C,HNO_3 to pH<2	28 days
Bacteriology			
Coliform, fecal	P,G	4, 0.008% $Na_2S_2O_3$ [3]	6 hours
Standard Plate Count	P,G	4°C, 0.008% $Na_2S_2O_3$	24 hours
Coliform, total - Wastewater	P,G	4°C, 0.008% $Na_2S_2O_3$	6 hours
Coliform, total - Groundwater	P,G	4°C, 0.008% $Na_2S_2O_3$	24 hours
Organics			
Base/Neutral and Acid Extractables - Water	Amber G, teflon-lined cap	4°C 0.008% sodium thiosulfate solution	7 days for extraction 40 days after extraction for analysis
Base/Neutral and Acid Extractables - Solid and Waste	G, teflon-lined cap	4°C	14 days for extraction 40 days after extraction for analysis
Base/Neutral and Acid Extractables - Concentrated Waste	G, teflon-lined cap	None	7 days for extraction 40 days after extraction for analysis
BTEX - Solid and sludge	G, teflon-lined septum	4°C	14 days
BTEX - Water	G, teflon-lined septum	4°C, 0.008% $Na_2S_2O_3$, zero headspace	14 days
TPH-GRO	G, teflon-lined cap	4°C, HCl to pH s, zero headspace	14 days
TPH-DRO	G, teflon-lined cap	4°C	14 days
Volatiles - Groundwater	G, teflon-lined cap	4°C, HCl to pH s, zero headspace	14 days
Chlorinated Herbicides - Water	Amber G, teflon-lined cap	4°C 0.008% sodium thiosulfate solution	7 days for extraction 40 days after extraction for analysis
Chlorinated Herbicides - Solid and Waste	G, teflon-lined cap	4°C	14 days for extraction 40 days after extraction
Volatiles - Drinking Water	G, teflon-lined cap	4°C, 0.008% $Na_2S_2O_3$[3], zero headspace	14 days
Volatiles (excluding 2 chloroethylvinylether) - Wastewater	Encore Sampler	4°C, zero head-space, HC1 to pH 2	14 days
Volatiles - Wastewater	G, teflon-lined cap	4°C, 0.008% $Na_2S_2O_3$[3], zero headspace	7 days
Volatiles - Solid and Sludge -	Encore Sampler	4°C	14 days
Volatiles - Concentrated Waste	G, teflon-lined septum	None	14 days
Industrial Solvents	G, teflon-lined septum	4°C	None
Organochlorine Pesticides and PCBs	Amber G, teflon-lined cap	4°C 0.008% sodium thiosulfate solution	7 days for extraction 40 days after extraction for analysis
PCBs in Oil	G, teflon-lined cap	None	7 days for extraction 40 days after extraction for analysis
Dioxin	G, teflon-lined cap	4°C	7 days for extraction 40 days after extraction for analysis
Total Petroleum Hydrocarbon	G, teflon-lined septum	4°C	14 days
Coliform, total - Drinking water	P,G	4°C, 0.008% $Na_2S_2O_3$	30 hours
Radiochemistry			
Carbon-14 - Water and Soil	P	4°C	6 months
Gamma Isotopes - Water	P	HNO_3 to pH-2	6 months

Parameter	Container[1]	Preservation	Holding Time[2]
Gamma Isotopes - Soil	P	None	6 months
Gross Alpha and Beta - Water	P	HNO_3 to pH-2	6 months
Gross Alpha and Beta - Soil	P	None	6 months
Iodine-129 - Water and Soil	P	None	6 months
Iodine -131 - Water	P	None	6 months
Neptunium - Water	P	HNO_3 to pH-2	6 months
Neptunium - Soil, Vegetation, and Air Filters	P	None	6 months
Plutonium - Water	P	HNO_3 to pH-2	6 months
Plutonium - Soil, Vegetation, and Air Filters	P	None	6 months
Thorium - Water	P	HNO_3 to pH-2	6 months
Thorium - Soil, Vegetation, and Air Filters	P	None	6 months
Uranium - Water	P	HNO_3 to pH-2	6 months
Uranium - Soil, Vegetation, and Air Filters	P	None	6 months
Americium - Water	P	HNO_3 to pH-2	6 months
Americium - Soil, Vegetation, and Air Filters	P	None	6 months
Curium - Water	P	HNO_3 to pH-2	6 months
Curium - Soil, Vegetation, and Air Filters	P	None	6 months
Lead-210 - Water	P	HNO_3 to pH-2	6 months
Nickel-59 - Water and Soil	P	None	6 months
Nickel-63 - Water and Soil	P	None	6 months
Phosphorus-32 -Water	P	HNO_3 to pH-2	6 months
Phosphorus-32 -Soil	P	None	6 months
Polonium -Water	P	HNO_3 to pH-2	6 months
Polonium -Soil	P	None	6 months
Promethium-147 -Water	P	HNO_3 to pH-2	6 months
Promethium-147 -Soil	P	None	6 months
Radium-223 - Water	P	None	6 months
Radium-224 - Water	P	None	6 months
Radium-226 - Water	P	HNO_3 to pH-2	6 months
Radium-228 - Water	P	HNO_3 to pH-2	6 months
Radon-222 - Water	40ml volatile bottle	4°C, Zero headspace	7 days
Radon-222 - Soil	P	4°C	6 months
Strontium-89/90 -Water	P	HNO_3 to pH-2	6 months
Strontium-89/90 -Soil	P	None	6 months
Technetium-99 -Water	P	HNO_3 to pH-2	6 months
Technetium-99 -Soil	P	None	6 months
Total Alpha Radium -Water	P	HNO_3 to pH-2	6 months
Total Alpha Radium -Soil	P	None	6 months
Total Uranium -Water	P	HNO_3 to pH-2	6 months
Tritium - Water, Soil, Vegetation, and Air Filters	P	4°C	6 months
Iron 55 -Water	P	HNO_3 to pH-2	6 months
Iron 55 -Soil	P	None	6 months
Total Uranium -Soil	P	None	6 months

[1] P = Polyethylene; G = Glass

[2] Samples should be analyzed as soon as possible after collection. The holding times listed are maximum times that samples may be held before analysis and be considered valid.

[3] Used only in the presence of residual chlorine.

[4] Maximum holding time is 24 hours when sulfide is present. All samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If present, remove by adding cadmium nitrate powder until a negative spot test is obtained. Filter sample and add NaOH to pH12.

APPENDIX C

SAMPLING SCHEDULE

Revised 8/05/03

TABLE 3
Section I POC Groundwater Monitoring Network

Unit	Well Number	Sampling Interval
Opaline claystone	OC-3	annual*
	OC-4	annual*
	OC-5	annual*
	OC-6	annual*
	OC-9	annual*
	OC-10	annual*
	OC-11	annual*
	OC-12	annual*
	OC-13	annual*
	OC-14	annual*
	OC-15	annual*
	OC-16	annual*
Transitional	MW-5A	quarterly
	MW-6TR	quarterly
	MW-8TR	quarterly
	MW-9A	quarterly
	MW-16TR	quarterly
	MW-31TR	quarterly
	MW-33	quarterly
	MW-41T	quarterly
	MW-42TR	quarterly
	MW-43T	quarterly
	MW-45T	quarterly
	MW-71T	quarterly
	MW-73T	quarterly
	MW-131T	quarterly
	MW-132T	quarterly
	MW-133T	quarterly
	MW-134T	quarterly
	PSDL-9TR	quarterly
	PSDL-21	quarterly
	SL-1	quarterly
	SL-3	quarterly
	SL-2	quarterly
Secondary	MW-5BSR	annual
	MW-7SR	annual
	MW-9	annual
	MW-10	annual

* Wells will initially be sampled for four consecutive quarters.

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TABLE 3
Section I POC Groundwater Monitoring Network

Unit	Well Number	Sampling Interval
Secondary	MW-11	annual
	MW-12	annual
	MW-13	annual
	MW-14	annual
	MW-15	annual
	MW-17	annual
	MW-35S	annual
	MW-36SR	annual
	MW-37SR	annual
	MW-38SR	annual
	PSDL-9ASR	annual
Primary	SL-13	annual
	SL-14PR	annual
	MW-39P	annual
	MW-40P	annual
	MW-44P	annual
	MW-46P	annual
	MW-47P	annual
UBC-A	UBC-10	annual
	UBC-11	annual
	UBC-12	annual
	UBC-13	annual
	UBC-14	annual
	UBC-53	annual

* Wells will initially be sampled for four consecutive quarters.

Revised 8/05/03

TABLE 4
Section II POC Groundwater Monitoring Network

Unit	Well Number	Sampling Interval
Opaline claystone	OC-2	annual*
	OC-7	annual*
	OC-8	annual*
Transitional	MW-19A	quarterly
	MW-20A	quarterly
	MW-22TR	quarterly
	MW-23ATR	quarterly
	MW-24TR	quarterly
	MW-26ATR	quarterly
	MW-27BTR	quarterly
	MW-28A	quarterly
	MW-29	quarterly
	MW-30	quarterly
	MW-48TR	quarterly
	MW-49T	quarterly
	MW-50T	quarterly
	MW-51T	quarterly
	MW-52T	quarterly
	MW-54T	quarterly
	MW-61T	quarterly
	MW-80TR	quarterly
	MW-81T	quarterly
	MW-89T	quarterly
	MW-127T	quarterly
Secondary	MW-18B	annual
	MW-20B	annual
	MW-21	annual
	MW-23SR	annual
	MW-25SR	annual
	MW-26B	annual
	MW-27AR	annual
	MW-28B	annual
	MW-57S	annual
	MW-59S	annual

* Wells will initially be sampled for four consecutive quarters.

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TABLE 4
Section II POC Groundwater Monitoring Network

Unit	Well Number	Sampling Interval
Secondary	MW-60SR	annual
	MW-62S	annual
	MW-63SR	annual
	MW-82S	annual
	MW-86SR	annual
	MW-90SR	annual
	MW-128S	annual
	MW-129S	annual
	SL-19SR	annual
	SL-20SR	annual
Primary	MW-99P	annual
	MW-18APR	annual
	MW-53P	annual
	MW-55P	annual
	MW-56P	annual
	MW-58P	annual
	MW-64P	annual
	MW-87P	annual
	MW-91PR	annual
	MW-100P	annual
	SL-21PR	annual
	SL-22	annual
	SL-23	annual
	SL-24	annual
UBC-A	PBC-4	annual
	UBC-15AR	annual
	UBC-16	annual
	UBC-17	annual
	UBC-18	annual
	UBC-22AR	annual
	UBC-23	annual
	UBC-30	annual
	UBC-51	annual
	UBC-52	annual

Wells will initially be sampled for four consecutive quarters.

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TABLE 5
Section III POC Groundwater Monitoring Network

UNIT	Well Number	Sampling Interval
Transitional	MW-81T	Quarterly
	MW-89T	Quarterly
	SL-8	Quarterly
	MW-101T	Quarterly
	MW-114T	Quarterly
	MW-115T	Quarterly
	MW-116T	Quarterly
	MW-117T	Quarterly
	MW-136T	Quarterly
Secondary	MW-82S	annual
	MW-86SR	annual
	MW-90SR	annual
	MW-102S	annual
	MW-135S	annual
	SL-9	annual
	SL-19SR	annual
Primary	MW-64P	annual
	MW-87P	annual
	MW-91PR	annual
	MW-99P	annual
	MW-103P	annual
	MW-124P	annual
	MW-125P	annual
	MW-130P	annual
	UBC-3	annual
UBC-A	UBC-2A1R	annual
	UBC-4	annual
	UBC-23	annual
	UBC-24	annual
	UBC-26	annual
	UBC-29AR	annual
	UBC-31	annual
	UBC-34	annual
	UBS-35	annual
	UBC-48	annual
	UBC-49	annual

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TABLE 6
Background GroundWater Monitoring Network

Unit	Well Number	Sampling Interval
Transitional	MW-96T	annual
	MW-98TR	annual
	MW-126T	annual
Secondary	PSDL-17A	annual
	MW-1	annual
	MW-92SR	annual
Primary	MW-93PR	annual
	MW-94PR	annual
	MW-95P	annual
UBC-A	UBC-25	annual
	UBC-27	annual
	UBC-28AR	annual

Old Background Well *

Transitional	MW-97T

* This well is no longer sampled, however, available groundwater quality data may be used, in part, for statistical evaluation.

Old Background Wells **

Primary	MW-2
	MW-4
	MW-4A
	PSDL-6
UBC-A	PBC-1
	CBC-18

** These wells have been abandoned, however, available groundwater quality data may be used, in part, for statistical evaluation.

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TABLE 7
Ground Water Monitoring Network UBC-B Zone

Unit	Well Number	Sampling Interval
UBC-B	UBC-1	quarterly*
	UBC-5	quarterly*
	UBC-6	quarterly*
	UBC-8	quarterly*
	UBC-9	quarterly*
	UBC-17B	quarterly*
	UBC-18B	quarterly*

* Wells will be sampled for four quarters only, to establish baseline data.
UBC-B wells will only be routinely sampled when UBC-A wells detect contamination.

Table 8. Water Level Measurement Schedule

Well ID	Frequency	TOC Elevation (ft)
B 25	Quarterly	153.65
BM 1	Quarterly	158.66
BM 2	Quarterly	156.53
CBC 4	Quarterly	103.17
CBC 8	Quarterly	116.49
CBC 11 A	Quarterly	155.83
CBC 20	Quarterly	172.49
LSUBC 1 A	Quarterly	132.02
MW 1	Quarterly	166.84
MW 3	Quarterly	168.89
MW 5 A	Quarterly	129.19
MW 5 B	Quarterly	129.54
MW 5 BSR	Quarterly	130.20
MW 5	Quarterly	128.17
MW 6 TR	Quarterly	128.72
MW 7 SR	Quarterly	128.65
MW 8 TR	Quarterly	128.17
MW 9 A	Quarterly	126.04
MW 9	Quarterly	125.03
MW 10	Quarterly	125.82
MW 11	Quarterly	126.65
MW 12	Quarterly	121.40
MW 13	Quarterly	119.66
MW 14	Quarterly	121.74
MW 15	Quarterly	123.01
MW 16 TR	Quarterly	122.13
MW 17	Quarterly	120.75
MW 18 APR	Quarterly	130.87
MW 18 B	Quarterly	130.40
MW 19 A	Quarterly	129.82
MW 20 A	Quarterly	130.63
MW 20 B	Quarterly	130.46
MW 21	Quarterly	131.98
MW 22 TR	Quarterly	133.28
MW 23 ATR	Quarterly	132.28
MW 23 SR	Quarterly	132.28
MW 24 TR	Quarterly	135.27
MW 25 SR	Quarterly	135.58
MW 26 ATR	Quarterly	135.52
MW 26 B	Quarterly	135.64
MW 27 A	Quarterly	135.02
MW 27 AR	Quarterly	136.23
MW 27 BTR	Quarterly	135.69
MW 28 A	Quarterly	136.30
MW 28 B	Quarterly	136.32
MW 29	Quarterly	136.48
MW 30	Quarterly	138.17
MW 31 TR	Quarterly	121.43
MW 31	Quarterly	121.18
MW 32	Quarterly	131.16
MW 33	Quarterly	129.06
MW 34	Quarterly	140.50
MW 35 S	Quarterly	130.74
MW 36 SR	Quarterly	129.96
MW 37 SR	Quarterly	130.99
MW 38 SR	Quarterly	133.19
MW 39 P	Quarterly	129.07
MW 40 P	Quarterly	125.29
MW 41 T	Quarterly	125.99
MW 42 T	Quarterly	126.42
MW 42 TR	Quarterly	126.29
MW 43 T	Quarterly	122.63
MW 44 P	Quarterly	122.45
MW 45 T	Quarterly	122.84
MW 46 P	Quarterly	122.64
MW 47 P	Quarterly	121.89
MW 48 T	Quarterly	138.60
MW 48 TR	Quarterly	138.73
MW 49 T	Quarterly	131.95
MW 50 T	Quarterly	129.92
MW 51 T	Quarterly	131.21
MW 52 T	Quarterly	131.35
MW 53 P	Quarterly	133.15
MW 54 T	Quarterly	133.65
MW 55 P	Quarterly	133.79
MW 56 P	Quarterly	135.42
MW 57 S	Quarterly	137.32
MW 58 P	Quarterly	140.07
MW 59 S	Quarterly	141.25
MW 60 S	Quarterly	144.23
MW 60 SR	Quarterly	145.13
MW 61 T	Quarterly	141.12
MW 62 S	Quarterly	157.99

Table 8. Water Level Measurement Schedule

Well ID	Frequency	TOC Elevation (ft)
MW 63 S	Quarterly	158.62
MW 63 SR	Quarterly	162.42
MW 64 P	Quarterly	138.45
MW 71 T	Quarterly	130.44
MW 72 P	Quarterly	131.32
MW 73 T	Quarterly	130.65
MW 77 P	Quarterly	146.11
MW 78 T	Quarterly	145.79
MW 80 T	Quarterly	158.84
MW 80 TR	Quarterly	162.38
MW 81 T	Quarterly	141.63
MW 82 S	Quarterly	141.55
MW 86 S	Quarterly	166.69
MW 86 SR	Quarterly	166.54
MW 87 P	Quarterly	166.81
MW 89 T	Quarterly	153.05
MW 90 S	Quarterly	160.30
MW 90 SR	Quarterly	160.10
MW 91 P	Quarterly	160.40
MW 91 PR	Quarterly	160.19
MW 92 S	Quarterly	177.25
MW 92 SR	Quarterly	177.58
MW 93 P	Quarterly	177.20
MW 93 PR	Quarterly	177.27
MW 94 P	Quarterly	178.01
MW 94 PR	Quarterly	177.81
MW 95 P	Quarterly	175.35
MW 96 T	Quarterly	175.78
MW 97 T	Quarterly	161.82
MW 98 T	Quarterly	177.20
MW 98 TR	Quarterly	177.65
MW 99 P	Quarterly	154.27
MW 100 P	Quarterly	144.72
MW 101 T	Quarterly	167.96
MW 102 S	Quarterly	167.72
MW 103 P	Quarterly	167.42
MW 114 T	Quarterly	168.76
MW 115 T	Quarterly	168.84
MW 116 T	Quarterly	168.72
MW 117 T	Quarterly	168.71
MW 124 P	Quarterly	149.59

Well ID	Frequency	TOC Elevation (ft)
MW 125 P	Quarterly	143.75
MW 126 T	Quarterly	177.15
MW 127 T	Quarterly	129.83
MW 128 S	Quarterly	129.58
MW 129 S	Quarterly	130.85
MW 130 P	Quarterly	141.96
MW 131 T	Quarterly	128.62
MW 132 T	Quarterly	128.54
MW 133 T	Quarterly	130.58
MW 134 T	Quarterly	132.94
MW 135 S	Quarterly	142.91
MW 136 T	Quarterly	149.35
MW T1	Quarterly	138.35
OC 2	Quarterly	123.47
OC 3	Quarterly	120.93
OC 4	Quarterly	126.38
OC 5	Quarterly	128.70
OC 6	Quarterly	128.48
OC 7	Quarterly	140.56
OC 8	Quarterly	140.74
OC 9	Monthly**	128.04
OC 10	Monthly**	127.07
OC 11	Monthly**	124.70
OC 12	Monthly**	122.16
OC 13	Monthly**	119.78
OC 14	Monthly**	130.60
OC 15	Monthly**	128.77
OC 16	Monthly**	129.86
P 42 B	Quarterly	156.24
P 42 T	Quarterly	156.19
P 112 A	Quarterly	154.45
P 112 B	Quarterly	154.57
P 112 C	Quarterly	154.58
P 112 D	Quarterly	154.54
P 114 A	Quarterly	149.17
P 114 B	Quarterly	148.28
P 114 C	Quarterly	147.75
P 114 D	Quarterly	147.16
PBC 2	Quarterly	149.40
PBC 3	Quarterly	134.58
PBC 4	Quarterly	131.47

**New wells - water levels will be measured monthly for first year and quarterly thereafter

Table 8. Water Level Measurement Schedule

Well ID	Frequency	TOC Elevation (ft)
PBC 6	Quarterly	110.71
PSDL 1	Quarterly	156.93
PSDL 4	Quarterly	102.58
PSDL 5	Quarterly	111.14
PSDL 7	Quarterly	106.13
PSDL 8	Quarterly	114.56
PSDL 9 A	Quarterly	120.64
PSDL 9 ASR	Quarterly	119.76
PSDL 9 TR	Quarterly	119.79
PSDL 9	Quarterly	119.83
PSDL 11	Quarterly	155.15
PSDL 12	Quarterly	106.08
PSDL 13	Quarterly	143.53
PSDL 14 A	Quarterly	142.78
PSDL 14	Quarterly	142.60
PSDL 16	Quarterly	158.98
PSDL 17 A	Quarterly	157.64
PSDL 17	Quarterly	158.16
PSDL 20	Quarterly	172.92
PSDL 21 A	Quarterly	124.50
PSDL 21	Quarterly	125.39
PW 4	Quarterly	127.39
SL 1	Quarterly	120.29
SL 2	Quarterly	123.50
SL 3	Quarterly	121.14
SL 4	Quarterly	106.75
SL 5	Quarterly	107.11
SL 6	Quarterly	122.82
SL 7	Quarterly	123.66
SL 8	Quarterly	143.23
SL 9	Quarterly	143.96
SL 11	Quarterly	119.87
SL 12	Quarterly	119.90
SL 13	Quarterly	125.98
SL 14 PR	Quarterly	127.98
SL 15	Quarterly	158.31
SL 16	Quarterly	129.61
SL 19 SR	Quarterly	155.65
SL 19	Quarterly	156.34
SL 20 SR	Quarterly	152.96
SL 21 PR	Quarterly	152.63
SL 22	Quarterly	135.22
SL 23	Quarterly	131.33
SL 24	Quarterly	130.87
UBC 1	Quarterly	106.44
UBC 2 A1R	Quarterly	121.20
UBC 2	Quarterly	121.41
UBC 3	Quarterly	144.96
UBC 4	Quarterly	123.11
UBC 5	Quarterly	107.49
UBC 6	Quarterly	123.64
UBC 8	Quarterly	120.79
UBC 9	Quarterly	119.93
UBC 10	Quarterly	127.72
UBC 11	Quarterly	125.60
UBC 12	Quarterly	123.67
UBC 13	Quarterly	122.87
UBC 14	Quarterly	122.73
UBC 15 AR	Quarterly	130.58
UBC 15	Quarterly	131.11
UBC 16	Quarterly	130.07
UBC 17 B	Quarterly	134.24
UBC 17	Quarterly	132.29
UBC 18 B	Quarterly	135.58
UBC 18	Quarterly	133.97
UBC 19	Quarterly	131.49
UBC 21	Quarterly	146.14
UBC 22 AR	Quarterly	130.82
UBC 22	Quarterly	132.02
UBC 23	Quarterly	141.25
UBC 24	Quarterly	167.20
UBC 25	Quarterly	178.24
UBC 26	Quarterly	160.67
UBC 27	Quarterly	177.30
UBC 28 AR	Quarterly	175.03
UBC 28	Quarterly	174.50
UBC 29 AR	Quarterly	154.60
UBC 29	Quarterly	154.13
UBC 30	Quarterly	137.52
UBC 31	Quarterly	167.10
UBC 34	Quarterly	143.69
UBC 35	Quarterly	149.54
UBC 48	Quarterly	168.86
UBC 49	Quarterly	168.54
UBC 51	Quarterly	135.59
UBC 52	Quarterly	140.95
UBC 53	Quarterly	128.25
WT 1	Dry	142.32
WT 8	Monthly	156.71
WT 10	Monthly	107.96
WT 11	Monthly	101.21
WT 12	Monthly	100.27
WT 15	Monthly	110.57
WT 16	Monthly	105.90
WT 20	Monthly	130.62
WT 23	Monthly	121.79
WT 24	Monthly	119.47
WT 26	Monthly	140.07
WT 27	Monthly	122.06
WT 30	Monthly	106.05
WT 32	Monthly	140.81

APPENDIX D

SAMPLING LOG FORM

GROUNDWATER SAMPLING LOG

WELL ID ____________________

TIME _______________

WEATHER CONDITIONS ____

TEMPERATURE (°C or °F) ____ PURGE

DATE __________________________________ SAMPLE DATE ____________________________________

TOTAL DEPTH (ft.) _____________________ (taken from well log)

DEPTH TO STATIC WATER COLUMN (ft.) __________________________________

CALCULATED WELL VOLUME (1 casing volume) (gal.)____

CALCULATED MAXIMUM VOLUME OF WATER TO BE PURGED (5 casing volumes) (gal.) ______________

ACTUAL VOLUME OF WATER PURGED (approx. gal./dryness) _________________________________

CALCULATED FLOW RATE (gal/min) ____

CALCULATED PUMPING TIME (length of time in minutes) ____

ACTUAL PUMPING TIME (length of time in minutes) ____

CHECK-BACK TIME ______________________

TIME PURGING BEGINS __________________

TIME PURGING ENDS ____________________

RECOVERY TIME (if needed) ______________

PH CALIBRATION DURING PURGING (4, 7, 10) (circle two) ACTUAL READING ___________________pH

CALIBRATION DURING SAMPLING (4, 7, 10) (circle two) ACTUAL READING _________DATE______TIME

SAMPLES (same time on sample bottles) ____________________________________

TIME	pH	CONDUCTIVITY	TEMPERATURE	NOTES

ADDITIONAL NOTES:

PRESERVATION:

Samples Iced In Field (>45°F) Yes ☐ No ☐
VOC (HCl) Yes ☐ No ☐
Metals (HNO_3) Yes ☐ No ☐
Rinsate Blank Yes ☐ No ☐

Sulfide (Zn acetate and NaOH) Yes ☐ No ☐
Cyanide (NaOH) Yes ☐ No ☐
Dioxins / Furans (sodium thiosulfate) Yes ☐ No ☐
Field Blank Yes ☐ No ☐

APPENDIX E

CHAIN OF CUSTODY

Project #: ______
GEL Quote #: ______
COC Number [1]: ______
PO Number:

Chain of Custody and Analytical Request

Client Name: Phone #:

Project/Site Name: Fax #:

Address:

Collected by: Send Results To:

						Should this sample be considered:			Sample Analysis Requested [5] (Fill in the number of containers for each test)										
																			<-- Preservative Type (6)
Sample ID	Date Collected (mm-dd-yy)	Time Collected (Military) (hhmm)	QC Code [2]	Field Filtered [3]	Sample Matrix [4]	Radioactive	TSCA Regulated	Total number of containers											Comments Note: extra sample is required for sample specific QC

TAT Requested: Normal: ______ Rush: ______ Specify: ______ (Subject to Surcharge) Fax Results: Yes / No Circle Deliverable: C of A / QC Summary / Level 1 / Level 2 / Level 3 / Level 4

Remarks: Are there any known hazards applicable to these samples? If so, please list the hazards

Chain of Custody Signatures					
Relinquished By (Signed)	Date	Time	Received by (signed)	Date	Time
1			1		
2			2		
3			3		

Sample Shipping and Delivery Details

GEL PM:

Method of Shipment: Date Shipped:

Airbill #:

Airbill #:

1.) Chain of Custody Number = Client Determined
2.) QC Codes: N = Normal Sample, TB = Trip Blank, FD = Field Duplicate, EB = Equipment Blank, MS = Matrix Spike Sample, MSD = Matrix Spike Duplicate Sample, G = Grab, C = Composite
3.) Field Filtered: For liquid matrices, indicate with a - Y - for yes the sample was field filtered or - N - for sample was not field filtered.
4.) Matrix Codes: DW = Drinking Water, GW = Groundwater, SW = Surface Water, WW = Waste Water, W = Water, SO = Soil, SD = Sediment, SL = Sludge, SS = Solid Waste, O = Oil, F = Filter, P = Wipe, U = Urine, F = Fecal, N = Nasal
5.) Sample Analysis Requested: Analytical method requested (i.e. 8260B, 6010B/7470A) and number of containers provided for each (i.e. *8260B* - 3, *6010B/7470A* - 1).
6.) Preservative Type: HA = Hydrochloric Acid, NI = Nitric Acid, SH = Sodium Hydroxide, SA = Sulfuric Acid, AA = Ascorbic Acid, HX = Hexane, ST = Sodium Thiosulfate, If no preservative is added = leave field blank

For Lab Receiving Use Only

Custody Seal Intact?
YES NO

Cooler Temp:
______ *C*

WHITE = LABORATORY YELLOW = FILE PINK = CLIENT

APPENDIX F
ANALYTICAL PARAMETERS

Date: 08/05/03

Table 1A
Volatile Organic Parameters

Constituent	Practical Quantitation Limit (PQL) (ug/l)
Acrolein	20
Acrylonitrile	20
Benzene	5
Bromoform	5
Chlorodibromomethane	10
Chloroform	5
Dichlorobromomethane	5
Methyl Bromide	10
Methyl Chloride	10
Methylene Chloride	5
Carbon Tetrachloride	5
Chlorobenzene	5
Chloroethane	10
2-Chloroethyl vinyl ether	10
1,1-Dichloroethane	5
1,2-Dichloroethane	5
1,1-Dichloroethylene	5
1,2-trans-Dichloroethylene	5
1,2-Dichloropropane	5
1,3-Dichloropropene	5
Ethylbenzene	5
1,1,2,2-Tetrachloroethane	5
Tetrachloroethylene	5
Toluene	5
1,1,1-Trichloroethane	5
1,1,2-Trichloroethane	5
Trichloroethylene	5
Vinyl Chloride	2

Note: Table 1B - Deleted as per Stipulated Agreement (CASE No. 89-135)

Date: 08/05/03

Table 1C
Inorganic Parameters

Constituent	Practical Quantitation Limit (PQL)* (ug/l)	Background Concentration (ug/l)
Arsenic	10	PQL
Barium	100	PQL
Cadmium	5	PQL
Chromium	20	PQL
Lead	15	PQL
Mercury	0.2	PQL
Nickel	50	PQL
Zinc	20	PQL
Chloride	2000	PQL

*(Values are subject to be updated dependent on EPA method modifications.)

Table 1D
Field Parameters

Parameter	Background
Specific Conductance (umhos/cm)	TBD
pH (Standard Units)	TBD
Temperature (Degrees Celsius)	N/A
Water Elevation (Feet Above MSL)	N/A
Turbidity (t.u.)	TBD

TBD - To Be Determined
N/A - Not Applicable

Date: 01/11/93

Table 2
Prediction Limits

Organic Parameters

Constituent	Prediction Limit (ug/l)
Acrolein	40
Acrylonitrile	40
Benzene	12
Bromoform	13
Chlorodibromomethane	21
Chloroform	12
Dichlorobromomethane	13
Methyl Bromide	21
Methyl Chloride	20
Methylene Chloride	40
Carbon Tetrachloride	12
Chlorobenzene	12
Chloroethane	21
2-Chloroethyl vinyl ether	20
1,1-Dichloroethane	12
1,2-Dichloroethane	12
1,1-Dichloroethylene	12
1,2-trans-Dichloroethylene	12
1,2-Dichloropropane	12
1,3-Dichloropropene	13
Ethylbenzene	12
1,1,2,2-Tetrachloroethane	12
Tetrachloroethylene	12
Toluene	12
1,1,1-Trichloroethane	12
1,1,2-Trichloroethane	12
Trichloroethylene	12
Vinyl Chloride	20

Date: 01/11/93

Table 2 (Continued)
Prediction Limits

Inorganic Parameters

Constituent	Prediction Limit (ug/l)
Arsenic	TBD
Barium	TBD
Cadmium	TBD
Chromium	TBD
Lead	TBD
Mercury	TBD
Nickel	TBD
Zinc	TBD
Chloride	N/A

Field Parameters

Constituent	Prediction Limit (ug/l)
Specific Conductance (umhos/cm)	TBD
pH (Standard Units)	TBD
Temperature	N/A
Water Elevation	N/A
Turbidity	N/A

N/A - Not Applicable

TBD - To Be Determined

APPENDIX G

WELL INSPECTION FORM

Pinewood Well Condition Checklist

Well ID	Date	Pads Crck'd / Debris	Undercut / Silting	Lock	Prot. Casing	Comments /Recommendations	Follow Up & Date
B 25							
BM 1							
BM 2							
CBC 4							
CBC 8							
CBC 11 A							
CBC 20							
LSUBC 1 A							
MW 1							
MW 3							
MW 5 A							
MW 5 B							
MW 5 BSR							
MW 5							
MW 6 TR							
MW 7 SR							
MW 8 TR							
MW 9 A							
MW 9							
MW 10							
MW 11							
MW 12							
MW 13							
MW 14							
MW 15							
MW 16 TR							
MW 17							
MW 18 APR							
MW 18 B							
MW 19 A							
MW 20 A							
MW 20 B							
MW 21							
MW 22 TR							
MW 23 ATR							
MW 23 SR							
MW 24 TR							
MW 25 SR							
MW 26 ATR							
MW 26 B							
MW 27 A							
MW 27 AR							
MW 27 BTR							
MW 28 A							
MW 28 B							
MW 29							
MW 30							
MW 31 TR							
MW 31							
MW 32							
MW 33							
MW 34							
MW 35 S							
MW 36 SR							
MW 37 SR							
MW 38 SR							
MW 39 P							
MW 40 P							

Date:______________

Start Time: ______________

Technician: __________________________

Pinewood Well Condition Checklist

Well ID	Date	Pads Crck'd / Debris	Undercut / Silting	Lock	Prot. Casing	Comments /Recommendations	Follow Up & Date
MW 41 T							
MW 42 T							
MW 42 TR							
MW 43 T							
MW 44 P							
MW 45 T							
MW 46 P							
MW 47 P							
MW 48 T							
MW 48 TR							
MW 49 T							
MW 50 T							
MW 51 T							
MW 52 T							
MW 53 P							
MW 54 T							
MW 55 P							
MW 56 P							
MW 57 S							
MW 58 P							
MW 59 S							
MW 60 S							
MW 60 SR							
MW 61 T							
MW 62 S							
MW 63 S							
MW 63 SR							
MW 64 P							
MW 71 T							
MW 72 P							
MW 73 T							
MW 77 P							
MW 78 T							
MW 80 T							
MW 80 TR							
MW 81 T							
MW 82 S							
MW 86 S							
MW 86 SR							
MW 87 P							
MW 89 T							
MW 90 S							
MW 90 SR							
MW 91 P							
MW 91 PR							
MW 92 S							
MW 92 SR							
MW 93 P							
MW 93 PR							
MW 94 P							
MW 94 PR							
MW 95 P							
MW 96 T							
MW 97 T							
MW 98 T							
MW 98 TR							
MW 99 P							
MW 100 P							

Date:____________

Technician: ______________________

Start Time: ____________

Pinewood Well Condition Checklist

Well ID	Date	Pads Crck'd / Debris	Undercut / Silting	Lock	Prot. Casing	Comments /Recommendations	Follow Up & Date
MW 101 T							
MW 102 S							
MW 103 P							
MW 114 T							
MW 115 T							
MW 116 T							
MW 117 T							
MW 124 P							
MW 125 P							
MW 126 T							
MW 127 T							
MW 128 S							
MW 129 S							
MW 130 P							
MW 131 T							
MW 132 T							
MW 133 T							
MW 134 T							
MW 135 S							
MW 136 T							
MW T1							
OC 2							
OC 3							
OC 4							
OC 5							
OC 6							
OC 7							
OC 8							
OC 9							
OC 10							
OC 11							
OC 12							
OC 13							
OC 14							
OC 15							
OC 16							
P 42 B							
P 42 T							
P 112 A							
P 112 B							
P 112 C							
P 112 D							
P 114 A							
P 114 B							
P 114 C							
P 114 D							
PBC 2							
PBC 3							
PBC 4							
PBC 6							
PSDL 1							
PSDL 4							
PSDL 5							
PSDL 7							
PSDL 8							
PSDL 9 A							
PSDL 9 ASR							
PSDL 9 TR							

Date:______________

Technician: ____________________________

Start Time: ______________

Pinewood Well Condition Checklist

Well ID	Date	Pads Crck'd / Debris	Undercut / Silting	Lock	Prot. Casing	Comments /Recommendations	Follow Up & Date
PSDL 9							
PSDL 11							
PSDL 12							
PSDL 13							
PSDL 14 A							
PSDL 14							
PSDL 16							
PSDL 17 A							
PSDL 17							
PSDL 20							
PSDL 21 A							
PSDL 21							
PW 4							
SL 1							
SL 2							
SL 3							
SL 4							
SL 5							
SL 6							
SL 7							
SL 8							
SL 9							
SL 11							
SL 12							
SL 13							
SL 14 PR							
SL 15							
SL 16							
SL 19 SR							
SL 19							
SL 20 SR							
SL 21 PR							
SL 22							
SL 23							
SL 24							
UBC 1							
UBC 2 AIR							
UBC 2							
UBC 3							
UBC 4							
UBC 5							
UBC 6							
UBC 8							
UBC 9							
UBC 10							
UBC 11							
UBC 12							
UBC 13							
UBC 14							
UBC 15 AR							
UBC 15							
UBC 16							
UBC 17 B							
UBC 17							
UBC 18 B							
UBC 18							
UBC 19							

Date:______________

Technician: ______________________________

Start Time: ______________

Table 1. Well Construction Summary Table and Purge Volumes

Well ID	Screened Unit	Installation Date	X Coordinate	Y Coordinate	Top of Screen Elevation	Bottom of Screen Elevation	Well Diameter (inches)	Total Depth (feet)	Ground Surface Elevation	TOC Elevation	Depth to Water (040103)	Groundwater Elevation (040103)	One Well Volume (gallons)	Recovery Time (hours)	Maximum Purge Requirements (gallons)
B 25	TLS	9/29/1981	2146643.20	675413.28	39.38	36.38	1.25	114	150.80	153.65	70.17	83.48			
BM 1	-	5/2/1985	2145953.57	674430.19	95.69	91.69	2	65	156.69	158.66	34.83	123.83			
BM 2	-	5/2/1985	2146254.41	675060.85	108.5	104.5	2	50	154.50	156.53	30.46	126.07			
CBC 4	UBC-A	8/31/1985	2143592.85	677158.31	14.59	4.59	2	95	99.59	103.17	19.70	83.47			
CBC 8	UBC-A	8/26/1985	2145063.34	676104.7	26.96	16.96	2	96	112.96	116.49	35.66	80.83	10.41		52.05
CBC 11 A	UBC-A	9/2/1985	2145694.60	677055.64	29.33	24.33	4	138	152.33	155.83	71.81	84.02			
CBC 20	UBC-A	9/1/1985	2145147.22	676615.42	31.98	21.98	2	147	168.98	172.49	91.41	81.08			
LSUBC 1 A	PSL/UBC-A	11/24/1986	2145583.96	676408	20.75	10.75	2	118	128.75	132.02	52.75	79.27			
MW 1	SSL	8/29/1985	2145851.33	677784.15	48.54	38.54	2	125	163.54	166.84	84.41	82.43	7.15	0	35.77
MW 3	PSL	-	2147066.91	677122.93	27.76	17.76	2	138	166.26	168.89	84.20	84.69			
MW 5 A	TLS	1/23/1987	2145610.52	674906.79	80.87	75.87	2	50	125.87	129.19	26.40	102.79	4.39	7 days	4.39
MW 5 B	SSL	5/13/1991	2145628.54	674904.91	58.29	48.29	4	78	126.29	129.54	44.29	85.25			
MW 5 BSR	SSL	11/21/1995	2145622.43	674904.88	52.27	47.27	4	80	127.27	130.20	45.18	85.02	24.65	2	24.65
MW 5	SSL/TLS	8/14/1985	2145621.12	674893.81	66.63	56.63	2	68	124.63	128.17	35.15	93.02			
MW 6 TR	TLS	2/24/1994	2145535.99	675029.12	69.07	64.07	4	61	125.07	128.72	37.28	91.44	17.87	3	17.87
MW 7 SR	SSL	1/18/1994	2145445.89	675147.9	50.08	45.08	4	80	125.08	128.65	43.18	85.47	26.37	0	131.87
MW 8 TR	TLS	2/10/1994	2145353.70	675270.92	68.25	58.25	4	66	124.25	128.17	38.13	90.04	20.76	0	103.79
MW 9 A	TLS	2/4/1987	2145251.66	675397.52	67.62	62.62	2	60	122.62	126.04	38.43	87.61	4.07	4	4.07
MW 9	SSL	8/21/1985	2145262.00	675381.14	54.22	44.22	2	78	122.22	125.03	38.86	86.17	6.84	0	34.19
MW 10	SSL	8/20/1985	2145166.69	675501.17	56.74	46.74	2	75	121.74	125.82	39.85	85.97	6.39	0	31.97
MW 11	SSL	8/24/1985	2145070.08	675618.03	57.35	47.35	2	75	122.35	126.65	40.67	85.98	6.30	0	31.48
MW 12	SSL	8/22/1985	2144978.16	675734.43	58.92	48.92	2	68	119.15	121.40	35.44	85.96	6.04	0	30.19
MW 13	SSL	8/12/1985	2144936.30	675844.47	60.82	50.82	2	66	116.82	119.66	33.75	85.91	5.72	0	28.60
MW 14	SSL	8/6/1985	2145068.60	675946.67	57.98	47.98	2	70	117.98	121.74	35.66	86.08	6.21	0	31.05
MW 15	SSL	8/7/1985	2145183.68	676048.95	61.08	51.08	2	68	119.08	123.01	30.71	92.30	6.72	24	6.72
MW 16 TR	TLS	3/10/1994	2145301.88	676154.57	74.37	69.37	4	49	118.37	122.13	21.73	100.40	20.26	24	20.26
MW 17	SSL	8/9/1985	2145417.47	676237.42	58.68	48.68	2	68	117.68	120.75	37.51	83.24	5.63	4	5.63
MW 18 APR	PSL	6/27/1994	2144748.46	676444.8	41.04	31.04	4	96	127.04	130.87	49.84	81.03	32.64	0	163.22
MW 18 B	SSL	-	2144752.99	676450.95	64.96	54.96	2	72	126.96	130.40	44.19	86.21	5.09	4	5.09
MW 19 A	TLS	-	2144596.89	676426.19	72.85	67.85	4	58	125.85	129.82	30.41	99.41	20.61	24	20.61
MW 20 A	TLS	-	2144445.94	676423.15	76.68	71.68	4	55	126.68	130.63	34.80	95.83	15.77	24	15.77
MW 20 B	SSL	-	2144460.92	676429.12	65.7	50.7	4	76	126.70	130.46	44.43	86.03	23.07	0	115.35
MW 21	SSL	8/30/1985	2144303.40	676467.93	72.01	62.01	2	64	126.01	131.98	44.15	87.83	4.21	24	4.21
MW 22 TR	TLS	3/9/1994	2144152.72	676491.21	75.5	70.5	4	59	129.50	133.28	44.70	88.58	11.81	0	59.03
MW 23 ATR	TLS	3/8/1994	2144031.90	676576.98	80.68	75.68	4	53	128.68	132.28	43.80	88.48	8.36	0	41.79
MW 23 SR	SSL	3/30/1994	2144025.47	676581.66	65.87	55.87	4	73	128.87	132.28	47.98	84.30	18.56	24	18.56
MW 24 TR	TLS	3/1/1994	2143940.97	676824.16	82.57	77.57	4	54	131.57	135.27	46.39	88.88	7.39	4	7.39
MW 25 SR	SSL	3/29/1994	2143940.73	676832.16	63.82	58.82	4	74	132.82	135.58	55.42	80.16	13.94	72	13.94
MW 26 ATR	TLS	3/4/1994	2143971.99	676980.66	85.83	80.83	4	51	131.83	135.52	42.15	93.37	8.19	24	8.19
MW 26 B	SSL	7/ /89	2143964.60	676978.12	76.05	56.05	4	75	132.05	135.64	48.32	87.32	20.42	72	20.42
MW 27 A	SSL	2/3/1987	2143992.13	677140.14	75.29	70.29	2	62	132.39	135.02	42.73	92.29			
MW 27 AR	SSL	3/22/2001	2143995.49	677113.05	-	61.02	4	71.5	132.52	136.23	45.17	91.06	19.62	24	19.62
MW 27 BTR	TLS	2/24/1994	2144003.88	677112.53	85.22	80.22	4	52	132.22	135.69	40.02	95.67	10.09	72	10.09
MW 28 A	TLS	7/13/1989	2144051.65	677249.61	88.7	83.7	4	49	132.70	136.30	39.74	96.56	8.40	72	8.40
MW 28 B	SSL	7/13/1989	2144047.36	677268.84	74.7	64.7	4	67	132.70	136.32	49.82	86.50	14.24	72	14.24
MW 29	TLS	10/24/1986	2144076.11	677418.44	89.27	84.27	2	49	133.27	136.48	38.02	98.46	2.31	24	2.31
MW 30	TLS	10/22/1986	2144108.96	677563.65	87.5	82.5	2	52.5	135.00	138.17	39.18	98.99	2.69	24	2.69
MW 31 TR	TLS	4/18/1996	2145623.99	676239.96	65.86	60.86	4	57	117.86	121.43	23.57	97.86	24.16	24	24.16
MW 31	TLS	8/6/1987	2145627.16	676232.19	66.08	61.08	4	55	116.08	121.18	23.38	97.80			
MW 32	TLS/SSL	8/10/1987	2145719.61	676110.39	55.94	50.94	2	75	125.94	131.16	47.93	83.23			
MW 33	TLS	8/11/1987	2145921.53	675825.4	67.25	62.25	2	63.5	125.75	129.06	27.70	101.36	6.37	24	6.37
MW 34	TLS	8/13/1987	2146185.29	675657.13	68.43	63.43	2	74	137.43	140.50	37.27	103.23			
MW 35 S	SSL	UNK	2145729.75	676118.25	48	43	4	83	126.00	130.74	45.86	84.88	27.35	24	27.35
MW 36 SR	SSL	4/6/1994	2145913.91	675838.09	49.54	44.54	4	82	126.54	129.96	47.85	82.11	24.53	6	24.53
MW 37 SR	SSL	4/4/1994	2146074.03	675608.58	47.92	42.92	4	84	126.92	130.99	48.08	82.91	26.11	4	26.11
MW 38 SR	SSL	6/29/1994	2146283.47	675387.79	49.53	44.53	4	85	129.53	133.19	47.73	85.46	26.73	3	26.73
MW 39 P	PSL	1/ /90	2145597.00	674921.1	39.47	29.47	4	96	125.47	129.07	47.75	81.32	33.86	0	169.29
MW 40 P	PSL	-	2145171.90	675486.56	34.08	29.08	4	93	122.08	125.29	44.15	81.14	34.00	0	169.98
MW 41 T	TLS	1/18/1991	2145178.05	675493.91	69.63	59.63	4	63	122.63	125.99	37.51	88.48	18.84	24	18.84
MW 42 T	TLS	1/6/1991	2145079.96	675615.91	70.45	65.445	4	57	122.45	126.42	36.04	90.38			
MW 42 TR	TLS	3/15/1996	2145086.18	675609.78	69.35	64.35	4	59	123.35	126.29	35.96	90.33	16.96	24	16.96
MW 43 T	TLS	1/3/1991	2144973.69	675756.85	77.36	72.36	4	48	119.36	122.63	27.54	95.09	14.84	6	14.84
MW 44 P	PSL	/ /90	2144974.55	675744.77	37.89	32.89	4	87	119.89	122.45	41.27	81.18	31.53	0	157.67
MW 45 T	TLS	1/3/1991	2145089.08	675963.58	75.55	70.55	4	49	119.55	122.84	22.43	100.41	19.50	24	19.50
MW 46 P	PSL	2/21/1990	2145077.06	675954.9	32.06	27.06	4	92	119.06	122.64	41.41	81.23	35.37	0	176.87
MW 47 P	PSL	/ /90	2145286.51	676132.32	47.37	37.37	4	82	119.37	121.89	40.54	81.35	28.72	0	143.59
MW 48 T	TLS	4/30/1991	2145326.99	676720.32	75.29	70.29	4	65	135.29	138.60	32.70	105.90			
MW 48 TR	TLS	3/20/1996	2145330.85	676732.14	75.23	70.23	4	65	135.23	138.73	32.97	105.76	23.20	24	23.20
MW 49 T	TLS	5/1/1991	2145180.26	676647.39	68.44	63.44	4	65	128.44	131.95	25.40	106.55	28.15	0	140.75
MW 50 T	TLS	3/26/1991	2145032.25	676601.71	73.8	68.8	4	57	126.80	129.92	22.53	107.39	25.20	72	25.20
MW 51 T	TLS	3/26/1991	2144907.33	676488.09	76.68	71.68	4	56	127.68	131.21	22.43	108.78	24.23	72	24.23
MW 52 T	TLS	3/26/1991	2144290.61	676448.73	78.81	73.81	4	55	128.81	131.35	42.89	88.46	9.57	24	9.57
MW 53 P	PSL	4/27/1990	2144155.73	676501.74	42.47	32.47	4	96	128.47	133.15	52.47	80.68	31.48	0	157.41
MW 54 T	TLS	3/26/1991	2143922.25	676688.93	81.02	76.02	4	54	130.02	133.65	44.88	88.77	8.33	24	8.33
MW 55 P	PSL	6/27/1990	2143919.17	676674.64	50.47	40.47	4	90	130.47	133.79	52.90	80.89	26.39	0	131.97
MW 56 P	PSL	6/27/1990	2143968.19	676961.74	52.02	42.02	4	90	132.02	135.42	54.59	80.83	25.34	0	126.71
MW 57 S	SSL	4/25/1991	2144081.80	677429.54	76.09	66.09	4	74	134.09	137.32	53.43	83.89	11.62	3	11.62
MW 58 P	PSL	6/27/1990	2144114.56	677580.64	51.28	41.28	4	95	136.28	140.07	59.08	80.99	25.93	0	129.65
MW 59 S	SSL	4/30/1991	2144142.71	677701.83	68.64	58.64	4	79	137.64	141.25	58.86	82.39	15.51	3	15.51
MW 60 S	SSL	6/27/1990	2144174.02	677865.22	66.67	56.67	4	85	141.67	144.23	61.89	82.34			
MW 60 SR	SSL	11/15/1995	2144182.44	677862.25	61.77	56.77	4	85	141.77	145.13	62.75	82.38	16.72	2	16.72
MW 61 T	TLS	3/26/1991	2144144.11	677713.34	82.72	77.72	4	60	137.72	141.12	39.78	101.34	15.42	24	15.42
MW 62 S	SSL	6/19/1990	2145414.55	677813.48	64.49	59.49	4	95	154.49	157.99	75.30	82.69	15.15	0	75.75
MW 63 S	SSL	6/7/1990	2145680.26	677775.48	49.31	44.31	4	108	154.31	158.62	76.00	82.62			
MW 63 SR	SSL	5/16/1996	2145699.33	677788.45	45.97	40.97	4	118	158.97	162.42	80.04	82.38	27.04	4	27.04
MW 64 P	PSL	11/10/1992	2145310.26	676708.03	35.8	25.8	4	109	134.80	138.45	56.16	82.29	36.89	0	184.44
MW 71 T	TLS	10/5/1992	2145736.20	676139.81	56.9	51.9	4	75	126.90	130.44	38.50	91.94	26.15	4	26.15
MW 72 P	PSL	12/13/1992	2145876.66	675996.21	28.8	23.8	4	101	124.80	131.32	48.85	82.47			
MW 73 T	TLS	12/14/1992	2145866.75	676002.97	61.69	56.69	4	68	124.69	130.65	36.26	94.39	24.62	4	24.62
MW 77 P	PSL	12/16/1992	2146469.18	675823.7	30.4	25.4	4	117	142.40	146.11	64.88	81.23			
MW 78 T	TLS	12/16/1992	2146459.95	675832.24	58.1	53.1	4	89	142.10	145.79	57.71	88.08			
MW 80 T	TLS	-	2145706.21	677771.35	59.6	54.6	4	100	154.60	158.84	29.44	129.40			
MW 80 TR	TLS	4/15/1996	2145710.07	677785.27	58.97	53.97	4	105	158.97	162.38	79.40	82.98	18.94	24	18.94
MW 81 T	TLS	8/24/1992	2145441.84	676795.14	73.08	68.08	4	70	138.08	141.63	32.04	109.59	27.11	24	27.11
MW 82 S	SSL	10/8/1992	2145431.33	676788.68	55.2	50.2	4	88	138.20	141.55	58.82	82.73	21.24	24	21.24
MW 86 S	SSL	12/19/1992	2145743.59	677323.66	66.19	56.19	4	107	163.19	166.69	83.82	82.87			
MW 86 SR	SSL	5/29/1996	2145735.94	677318.34	54.92	49.92	4	113	162.92	166.54	83.75	82.79	21.46	4	21.46
MW 87 P	PSL	9/28/1992	2145739.92	677306.97	47.31	37.31	4	126	154.89	166.81	84.31	82.50	29.51	0	147.55
MW 89 T	TLS	12/20/1992	2145785.60	677622.5	55.99	50.99	4	98	148.99	153.05	76.59	83.61	21.30	24	21.30
MW 90 S	SSL	11/20/1992	2145782.60	677613.84	52.8	47.8	4	109	156.80	160.30	77.83	82.47			
MW 90 SR	SSL	12/21/1995	2145777.69	677619.28	49.1	44.1	4	116	156.26	160.10	77.63	82.47	25.06	4	25.06
MW 91 P	PSL	10/26/1992	2145780.46	677596.64	45.4	40.4	4	120	156.90	160.40	77.89	82.51			
MW 91 PR	PSL	1/12/1996	2145775.77	677609.87	34.41	29.41	4	127	156.41	160.19	77.77	82.42	34.62	0	173.08
MW 92 S	SSL	10/15/1992	2148008.31	676821.9	28.4	23.4	4	150.5	173.90	177.25	93.16	84.09			
MW 92 SR	SSL	2/3/1995	2148000.32	676819.91	28.17	23.17	4	151	174.17	177.58	93.84	83.74	39.55	0	197.76
MW 93 P	PSL/UBC-A	10/20/1992	2148012.00	676811.85	18.9	13.9	4	160	173.90	177.20	98.39	78.81			

Table 1. Well Construction Summary Table and Purge Volumes

Well ID	Screened Unit	Installation Date	X Coordinate	Y Coordinate	Top of Screen Elevation	Bottom of Screen Elevation	Well Diameter (inches)	Total Depth (feet)	Ground Surface Elevation	TOC Elevation	Depth to Water (040103)	Groundwater Elevation (040103)	One Well Volume (gallons)	Recovery Time (hours)	Maximum Purge Requirements (gallons)
MW 93 PR	PSL	1/27/1995	2148003.88	676809.11	17.43	12.43	4	161	173.43	177.27	93.52	83.75	46.57	0	232.86
MW 94 P	PSL	11/4/1992	2147308.90	677579.38	13.4	8.4	4	166	174.40	178.01	93.94	84.07			
MW 94 PR	PSL	1/24/1995	2147312.57	677584.03	14.47	9.47	4	165	174.47	177.81	120.28	57.53	31.38	72	31.38
MW 95 P	PSL	10/30/1992	2148081.33	676175.54	22.2	17.2	4	156	172.20	175.35	91.29	84.06	43.66	4	43.66
MW 96 T	TLS	1/8/1993	2148083.48	676190.42	42.51	37.51	4	134	171.51	175.78	79.12	96.66	38.62	24	38.62
MW 97 T	TLS	12/16/1992	2147236.21	675532.78	23.1	13.1	4	145	158.10	161.82	78.02	83.80			
MW 98 T	TLS	10/12/1992	2148005.19	676831.62	42.84	37.84	4	136	173.84	177.20	94.57	82.63			
MW 98 TR	TLS	2/8/1995	2147997.25	676829.99	43.17	38.17	4	136	174.17	177.65	95.28	82.37	28.86	24	28.86
MW 99 P	PSL	12/19/1992	2145670.81	677018.09	43.6	33.6	4	117	150.60	154.27	71.68	82.59	31.99	0	159.95
MW 100 P	PSL	7/25/1994	2144169.58	677848.11	52.47	47.47	4	93	140.47	144.72	61.95	82.77	23.05	3	23.05
MW 101 T	TLS	6/22/1995	2146580.31	676683.31	57.46	47.46	4	117	164.46	167.96	85.93	82.03	22.57	24	22.57
MW 102 S	SSL	6/23/1995	2146573.55	676674.81	42.22	37.22	4	127	164.22	167.72	85.41	82.31	29.44	4	29.44
MW 103 P	PSL	6/27/1995	2146572.88	676666.69	31.92	26.92	4	137	163.92	167.42	84.65	82.77	36.47	0	182.35
MW 114 T	TLS	7/30/1996	2146704.50	676814	33.33	23.33	4	142	165.33	168.76	84.19	84.57	39.99	24	39.99
MW 115 T	TLS	7/26/1996	2146711.97	676821.21	17.41	12.41	4	153	165.41	168.84	84.53	84.31	46.95	4	46.95
MW 116 T	TLS	8/3/1996	2146842.07	676955.27	25.88	20.88	4	144.5	165.38	168.72	81.99	86.73	43.00	24	43.00
MW 117 T	TLS	8/12/1996	2146849.81	676961.65	15.4	10.4	4	155	165.40	168.71	84.40	84.31	48.26	4	48.26
MW 124 P	PSL	4/25/2001	2146036.95	676627.08	-	19.86	4	126	145.86	149.59	66.98	82.61	40.98	0	204.88
MW 125 P	PSL	5/1/2001	2145728.24	676748.97	-	20.99	4	119	139.99	143.75	61.24	82.51	40.17	0	200.86
MW 126 T	TLS	2/21/1995	2147328.09	677574.14	41.15	36.15	4	138	174.15	177.15	93.42	83.73	31.07	72	31.07
MW 127 T	TLS	6/30/1995	2144765.56	676447.37	76.73	71.73	4	55	126.73	129.83	29.08	100.75	18.95	24	18.95
MW 128 S	SSL	7/1/1995	2145039.15	676565.58	53.97	48.97	4	77	125.97	129.58	46.32	83.26	22.39	6	22.39
MW 129 S	SSL	7/3/1995	2145178.51	676637.69	54.44	49.44	4	78	127.44	130.85	47.97	82.88	21.84	4	21.84
MW 130 P	PSL	7/24/1997	2145442.66	676806.48	29.27	24.27	4	114	138.27	141.96	59.53	82.43	37.98	0	189.89
MW 131 T	TLS	3/26/2001	2146004.50	675730.74	-	58.94	4	66	124.94	128.62	25.28	103.34	28.99	0	144.97
MW 132 T	TLS	4/9/2001	2146093.85	675582.5	-	60.96	4	64	124.96	128.54	25.18	103.36	27.69	0	138.44
MW 133 T	TLS	4/9/2001	2146207.57	675472.84	-	58.13	4	69	127.13	130.58	26.85	103.73	29.78	24	29.78
MW 134 T	TLS	4/4/2001	2416270.52	675401.77	-	55.52	4	74	129.52	132.94	35.50	97.44	27.37	4	27.37
MW 135 S	SSL	5/2/2001	2145720.21	676756.23	-	42.73	4	97	139.73	142.91	60.40	82.51	25.98	0	129.88
MW 136 T	TLS	5/3/2001	2146045.11	676624.24	-	44.66	4	101	145.66	149.35	66.54	82.81	24.91	4	24.91
MW T1	TLS	-	-	-	-			-	135.62	138.35	39.25	99.10			
OC 2	OC	1/23/1987	2145307.76	676558.9	79.97	74.97	2	45	119.97	123.47	21.25	102.22	4.44	24	4.44
OC 3	OC	1/26/1989	2144973.46	675861.77	85.87	80.87	2	36	116.87	120.93	16.69	104.24	3.81	24	3.81
OC 4	OC	1/28/1987	2145379.39	675178.01	82.38	77.38	2	45	122.38	126.38	26.22	100.16	3.71	24	3.71
OC 5	OC	6/10/1994	2145490.27	675083.09	100.05	95.05	2	30	125.05	128.70	21.78	106.92	1.93	24	1.93
OC 6	OC	6/10/1994	2145487.13	675087.97	84.11	79.11	2	46	125.11	128.48	30.31	98.17	3.11	24	3.11
OC 7	OC	6/10/1994	2144128.22	677630.67	105.98	100.98	2	36	136.98	140.56	28.04	112.52	1.88	24	1.88
OC 8	OC	6/9/1994	2144129.81	677636.78	96.09	91.09	2	46	137.09	140.74	35.44	105.30	2.32	24	2.32
OC 9	OC	1/13/2003	-	-	95.15	85.15	2	40	125.15	128.04	28.22	99.82	2.39	24	2.39
OC 10	OC	1/13/2003	-	-	88.28	78.28	2	46	124.28	127.07	27.24	99.83	3.51	24	3.51
OC 11	OC	1/14/2003	-	-	86.75	76.75	2	45	121.75	124.70	25.52	99.18	3.66	24	3.66
OC 12	OC	1/14/2003	-	-	93.66	83.66	2	35.5	119.16	122.16	18.68	103.48	3.23	24	3.23
OC 13	OC	1/14/2003	-	-	92	82	2	35	117.00	119.78	16.69	103.09	3.44	24	3.44
OC 14	OC	1/14/2003	-	-	82.93	72.93	2	55	127.93	130.60	27.80	102.80	4.87	24	4.87
OC 15	OC	1/14/2003	-	-	88.45	78.45	2	47.5	125.95	128.77	20.01	108.76	4.94	24	4.94
OC 16	OC	1/15/2003	-	-	91.98	81.98	2	45	126.98	129.86	20.01	109.85	4.54	24	4.54
P 42 B	UBC-A	10/16/1992	2146843.73	676621.06	-0.3	-5.3	4	158	152.70	156.24	72.27	83.97			
P 42 T	TLS	10/20/1992	2146848.18	676607.96	14.7	4.7	4	148	152.70	156.19	72.27	83.92			
P 112 A	TLS - Channel	12/10/1993	2146416.78	677692.79	24.26	19.26	2	131	151.26	154.45	68.92	85.53			
P 112 B	TLS - Channel	12/9/1993	2146406.47	677694.36	15.35	10.35	2	140	151.35	154.57	70.11	84.46			
P 112 C	TLS - Channel	12/9/1993	2146396.15	677696.62	-2.57	-7.57	2	159	151.43	154.58	70.42	84.16			
P 112 D	TLS - Channel	12/8/1993	2146385.93	677698.94	-14.61	-19.61	2	170	151.39	154.54	70.36	84.18			
P 114 A	TLS - Channel	12/17/1993	2147041.63	676538.83	29.9	25.9	2	120	145.90	149.17	65.39	83.78			
P 114 B	TLS - Channel	12/17/1993	2147050.77	676532.02	13.86	9.86	2	135	144.86	148.28	65.07	83.21			
P 114 C	TLS - Channel	12/16/1993	2147057.66	676526.4	-6.75	-11.75	2	155	144.25	147.75	63.76	83.99			
P 114 D	TLS - Channel	12/15/1993	2147067.69	676520.47	-20.38	-24.83	2	168	143.62	147.16	63.22	83.94			
PBC 2	UBC-A	3/12/1985	2145209.70	675139.1	18.95	13.95	2	132	146.95	149.40	63.65	85.75			
PBC 3	UBC-A	3/15/1985	2144044.35	677322.74	23.58	19.58	2	113	132.58	134.58	50.90	83.68			
PBC 4	UBC-A	3/18/1985	2144304.42	676448.26	26.75	22.75	2	105	126.75	131.47	50.72	80.75	9.45	0	47.27
PBC 6	UBC-A	4/9/1985	2144015.31	676361.21	31.44	27.44	2	80	107.44	110.71	29.86	80.85			
PSDL 1	TLS	4/4/1985	2146096.12	677745.34	45.79	40.79	4	112	153.79	156.93	61.41	95.52			
PSDL 4	SSL	4/8/1985	2143578.40	677172.76	70.29	66.29	2	33	99.29	102.58	17.58	85.00			
PSDL 5	TLS	5/2/1985	2144032.62	676360.21	79.86	74.86	2	32	107.86	111.14	22.27	88.87			
PSDL 7	SSL	4/10/1985	2144600.41	676088.73	58.8	54.8	2	47	101.80	106.13	20.00	86.13			
PSDL 8	SSL	4/11/1985	2145055.23	676095.64	65	61	2	50	111.00	114.56	28.26	86.30			
PSDL 9 A	SSL	-	2145535.66	676346.37	50.8	45.8	2	72	117.18	120.64	38.40	82.24			
PSDL 9 ASR	SSL	3/23/1995	2145574.72	676308.18	54.35	44.35	4	72	116.35	119.76	36.93	82.83	25.13	3	25.13
PSDL 9 TR	TLS	3/13/1995	2145564.97	676311.05	70.24	65.24	4	51	116.24	119.79	19.87	99.92	22.65	4	22.65
PSDL 9	TLS	4/15/1985	2145558.40	676312.69	71.99	66.99	2	49	116.99	119.83	19.80	100.03			
PSDL 11	-	4/17/1985	2145650.14	677061.64	-			67	152.20	155.15	56.23	98.92			
PSDL 12	TLS	4/18/1985	2144461.65	675878.3	78.65	73.65	2	28	102.65	106.08	16.73	89.35			
PSDL 13	PSL	4/22/1985	2144417.20	675396.63	41.36	36.36	2	93	129.36	143.53	63.00	80.53			
PSDL 14 A	SSL	4/22/1985	2144934.61	675408.44	49.46	44.46	2	95	139.46	142.78	56.86	85.92			
PSDL 14	TLS	4/22/1985	2144939.80	675395.46	73.47	68.47	2	70	139.47	142.60	51.40	91.20			
PSDL 16	TLS	4/24/1985	2145938.63	674429.87	63.63	58.63	2	97	156.63	158.98	56.42	102.56			
PSDL 17 A	SSL	4/25/1985	2146218.63	675030.37	49.54	44.54	2	110	154.54	157.64	60.05	97.59	8.65	6	8.65
PSDL 17	TLS	4/25/1985	2146236.75	675042.84	65.54	61.54	2	93	154.54	158.16	54.76	103.40			
PSDL 20	TLS	5/1/1985	2145478.76	674535.01	77.62	73.62	2	96	169.62	172.92	81.45	91.47			
PSDL 21 A	SSL	-	2145366.26	675186.96	48.67	43.67	2	78	121.67	124.50	38.97	85.53			
PSDL 21	TLS	5/2/1985	2145371.30	675165.35	65.72	61.72	2	60	121.72	125.39	35.59	89.80	4.58	24	4.58
PW 4	UBC-A/B	-	2145511.20	676495.37	-		4		124.13	127.39	44.40	82.99	54.19	4	54.19
SL 1	TLS	8/22/1986	2144949.10	675848.81	76.97	71.97	2	45	116.97	120.29	28.29	92.00	3.26	24	3.26
SL 2	TLS	8/21/1986	2145175.72	676042.77	74	69	2	51	120.00	123.50	24.14	99.36	4.95	24	4.95
SL 3	TLS	8/20/1986	2145426.97	676245.56	72.65	67.65	2	50	117.65	121.14	20.44	100.70	5.39	24	5.39
SL 4	TLS	10/1/1986	2144921.35	676060.75	70.4	65.4	2	48	103.40	106.75	10.72	96.03			
SL 5	PSL	10/2/1986	2144933.15	676056.7	45.14	40.14	2	63	103.14	107.11	24.00	83.11			
SL 6	TLS	10/2/1986	2145310.19	676546.94	73.55	68.55	2	51	119.55	122.82	17.08	105.74			
SL 7	SSL	10/2/1986	2145321.47	676555.85	53.8	48.8	2	71	119.80	123.66	44.07	79.59			
SL 8	TLS	10/3/1986	2145800.45	676544.43	64.86	59.86	2	80	139.86	143.23	49.21	94.02	5.57	5 days	5.57
SL 9	SSL	10/3/1986	2145804.20	676558.63	51.39	46.39	2	94	140.39	143.96	61.37	82.59	5.90	0	29.50
SL 11	SSL	7/30/1987	2145280.78	676330.97	53.11	48.11	2	64	116.73	119.87	36.07	83.80			
SL 12	TLS	7/31/1987	2145291.07	676338.32	72.44	67.44	2	45	116.63	119.90	15.28	104.62			
SL 13	PSL	1/26/1988	2145388.86	675159.4	37.47	32.47	4	90	122.47	125.98	44.52	81.46	31.99	0	159.95
SL 14 PR	PSL	6/23/1994	2145361.80	675262.54	34.16	26.46	4	98	124.46	127.98	46.69	81.29	35.80	0	179.02
SL 15	PSL	2/22/1988	2146205.55	675021.52	31.35	26.35	4	128	154.35	158.31	76.51	81.80			
SL 16	PSL	2/25/1988	2145913.72	675835.36	35.77	30.77	4	95	125.77	129.61	47.39	82.22			
SL 19 SR	SSL	12/5/1995	2145676.52	677037.01	30.15	25.15	4	127	152.15	155.65	73.02	82.63	37.53	4	37.53
SL 19	SSL	2/18/1988	2145685.11	677062.42	72.84	67.84	4	85	152.84	156.34	73.61	82.73			
SL 20 SR	SSL	7/21/1994	2144846.88	677891.3	55.31	50.31	4	99	149.31	152.96	70.75	82.21	20.83	0	104.15
SL 21 PR	PSL	7/7/1994	2144852.82	677890.42	45.93	40.93	4	108	148.93	152.63	70.36	82.27	27.00	0	134.98
SL 22	PSL	1/22/1988	2144028.94	677259.28	49.19	44.19	4	87	132.55	135.22	54.30	80.92	23.98	4	23.98
SL 23	PSL	2/11/1988	2144283.21	676457.69	41.03	36.03	4	92	128.03	131.33	50.45	80.88	29.29	0	146.44
SL 24	PSL	2/8/1988	2144461.41	676415.8	43.87	38.87	2	92	127.06	130.87	49.97	80.90	6.85	0	34.25
UBC 1	UBC-B	8/8/1986	2144932.47	676068.63	11.58	1.58	2	102	103.58	106.44	22.58	83.86	13.41	0	67.06
UBC 2 AIR	UBC-A	7/28/1997	2145549.57	676348.48	15.45	10.45	4	107	117.45	121.20	37.80	83.40	47.64	2	47.64
UBC 2	UBC-A	8/12/1986	2145552.31	676348.97	20.07	10.07	2	108	118.07	121.41	38.01	83.40			

Table 1. Well Construction Summary Table and Purge Volumes

Well ID	Screened Unit	Installation Date	X Coordinate	Y Coordinate	Top of Screen Elevation	Bottom of Screen Elevation	Well Diameter (inches)	Total Depth (feet)	Ground Surface Elevation	TOC Elevation	Depth to Water (040103)	Groundwater Elevation (040103)	One Well Volume (gallons)	Recovery Time (hours)	Maximum Purge Requirements (gallons)
UBC 3	PSL	8/6/1986	2145809.04	676570.38	33.67	23.67	2	118	141.67	144.96	62.40	82.56	9.60	0	48.00
UBC 4	UBC-A	8/3/1986	2145326.58	676539.63	26.84	16.84	2	103	119.84	123.11	40.79	82.32	10.67	0	53.37
UBC 5	UBC-B	10/1/1986	2144583.91	676092.26	9.53	-0.47	2	104	103.53	107.49	23.79	83.70	13.72	0	68.60
UBC 6	UBC-B	9/30/1986	2145192.14	676058.63	4.78	-5.22	2	125	119.78	123.64	39.77	83.87	14.52	?	72.61
UBC 8	UBC-B	11/13/1986	2144965.50	675852.82	7.32	-2.68	2	120	117.32	120.79	36.98	83.81	14.10	?	70.49
UBC 9	UBC-B	8/3/1987	2145269.21	676321.21	14.74	4.74	2	113	116.83	119.93	36.16	83.77	12.88	0	64.41
UBC 10	UBC-A	1/31/1991	2145526.45	675019.82	23.59	13.59	4	111	124.59	127.72	46.53	81.19	44.14	0	220.71
UBC 11	UBC-A	5/20/1991	2145159.85	675510.49	19.19	14.19	4	108	122.19	125.60	44.51	81.09	43.69	0	218.43
UBC 12	UBC-A	5/24/1991	2144986.26	675749.63	30.25	25.25	4	95	120.25	123.67	42.52	81.15	36.50	0	182.51
UBC 13	UBC-A	5/13/1991	2145097.12	675972.37	21.45	16.45	4	104	119.45	122.87	41.69	81.18	42.27	0	211.34
UBC 14	UBC-A	5/13/1991	2145309.20	676153.15	34.15	24.15	4	95	119.15	122.73	41.31	81.42	37.40	0	186.99
UBC 15 AR	UBC-A	5/10/1996	2144888.88	676480.75	35.41	30.41	4	97	127.41	130.58	49.21	81.37	33.28	2	33.28
UBC 15	UBC-A	5/27/1991	2144896.18	676482.74	37.81	32.81	4	95	127.81	131.11	49.72	81.39			
UBC 16	UBC-A	3/11/1992	2144589.44	676418.78	30.75	25.75	4	101	126.75	130.07	49.20	80.87	35.99	0	179.97
UBC 17 B	UBC-B	3/11/1991	2143920.84	676664.83	9.55	4.55	4	126	130.55	134.24	50.44	83.80	51.75	0	258.75
UBC 17	UBC-A	3/8/1995	2144020.04	676587.69	25.67	21.67	4	108	129.67	132.29	51.66	80.63	38.50	0	192.50
UBC 18 B	UBC-B	12/8/1991	2143971.86	676987.12	14.19	9.19	4	124	132.19	135.58	52.06	83.52	48.54	0	242.69
UBC 18	UBC-A	3/2/1995	2143941.36	676841.49	32.07	27.07	4	105	132.07	133.97	54.63	79.34			
UBC 19	UBC-A	12/9/1992	2145755.85	676107.77	15.3	5.3	4	120	125.30	131.49	48.49	83.00			
UBC 21	UBC-A	12/11/1992	2146478.22	675814.99	10.6	0.6	4	143	142.60	146.14	62.95	83.19			
UBC 22 AR	UBC-A	11/30/1995	2145170.83	676632.88	19.54	14.54	4	113	127.54	130.82	48.74	82.08	44.10	2	44.10
UBC 22	UBC-A	12/23/1992	2145165.04	676643.12	19	14	4	114	128.00	132.02	49.95	82.07			
UBC 23	UBC-A	11/17/1992	2145421.56	676779.25	16.25	11.25	4	130	138.00	141.25	57.39	83.86	47.41	0	237.07
UBC 24	UBC-A	9/31/1992	2145737.24	677290.04	29.7	24.7	4	139	163.70	167.20	84.48	82.72	37.89	0	189.44
UBC 25	UBC-A	11/10/1992	2147318.91	677569.43	4.9	-0.1	4	174.5	174.40	178.24	94.06	84.18	55.03	0	275.17
UBC 26	UBC-A	10/5/1992	2145787.30	677583.7	30.17	25.17	4	133	157.17	160.67	76.63	84.04	38.44	0	192.21
UBC 27	UBC-A	10/23/1992	2148015.08	676802.14	1.9	-3.1	4	177	173.90	177.30	93.16	84.14	56.97	0	284.84
UBC 28 AR	UBC-A	2/14/1995	2148088.34	676168.88	9.44	4.44	4	167	171.44	175.03	90.98	84.05	51.99	0	259.93
UBC 28	UBC-A	10/28/1992	2148080.20	676166.01	9	4	4	167	171.00	174.50	90.30	84.20			
UBC 29 AR	UBC-A	12/11/1995	2145665.03	676998.62	13.1	8.1	4	143	151.10	154.60	70.59	84.01	49.57	0	247.85
UBC 29	UBC-A	11/11/1992	2145668.85	677004.07	11.8	6.8	4	144	150.80	154.13	70.09	84.04			
UBC 30	UBC-A	7/27/1994	2144081.41	677431.1	29.72	24.72	4	109	133.72	137.52	56.65	80.87	36.67	3	36.67
UBC 31	UBC-A	6/27/1995	2146567.96	676657.39	13.6	8.6	4	155	163.60	167.10	83.05	84.05	49.27	0	246.34
UBC 34	UBC-A	4/27/2001	2146057.30	676620.18	13.17	8.17	4	132	140.17	143.69	59.81	83.88	49.44	0	247.19
UBC 35	UBC-A	4/24/2001	2146345.66	676607.99	11.11	6.11	4	140	146.11	149.54	65.63	83.91	50.80	0	254.02
UBC 48	UBC-A	8/8/1996	2146717.98	676828.6	7.37	2.37	4	163	165.37	168.86	84.78	84.08	53.36	0	266.78
UBC 49	UBC-A	8/14/1996	2146857.21	676968.34	4.43	-0.57	4	166	165.43	168.54	84.35	84.19	55.35	0	276.74
UBC 51	UBC-A	7/2/1995	2144009.13	677126.78	30.8	25.8	4	107	132.80	135.59	54.77	80.82	35.93	24	35.93
UBC 52	UBC-A	7/1/1995	2144148.01	677721.65	24.59	19.59	4	118	137.79	140.95	57.40	83.55	41.77	3	41.77
UBC 53	UBC-A	4/20/2001	2145355.84	675278.4	16.97	11.97	4	113	124.97	128.25	47.10	81.15	45.17	0	225.87
WT 1	WT	9/19/1986	-	-	119.98	114.98	2	25	138.98	142.32	DRY	DRY	0.00		
WT 8	WT	12/13/1986	2146866.84	676703.9	135.45	130.45	2	23	153.45	156.71	16.53	140.18	1.59	0	7.93
WT 10	WT	-	2144238.05	675780.12	86.21	81.21	2	23.5	104.71	107.96	19.51	88.45			
WT 11	WT	-	2143778.54	675850.11	82.89	77.89	2	20	97.89	101.21	19.60	81.61			
WT 12	WT	-	2143775.60	675906.65	83.93	78.93	2	18	96.93	100.27	18.53	81.74			
WT 15	WT	-	2144333.36	676190.45	94..26	89.26	2	18	107.26	110.57	17.70	92.87			
WT 16	WT	-	2144589.86	676100.78	94.03	89.03	2	13.5	102.53	105.90	10.85	95.05			
WT 20	WT	3/17/1989	2145652.44	676403.47	122.39	112.39	4	14.5	126.89	130.62	15.88	114.74	1.53	3	1.53
WT 23	WT	6/9/1989	2145462.53	676452.02	115.29	105.29	4	13	118.29	121.79	9.46	112.33	4.60	3	4.60
WT 24	WT	6/9/1989	2145566.76	676297.19	112.97	102.97	4	13	115.97	119.47	7.38	112.09	5.96	3	5.96
WT 26	WT	6/9/1989	2146447.77	676231.08	132.93	122.93	4	15	137.93	140.07	8.86	131.21	5.41	0	27.03
WT 27	WT	3/20/1990	2145628.22	676215.65	112.06	107.06	4	12	119.06	122.06	8.37	113.69	4.33	0	21.65
WT 30	WT	6/5/1990	2144876.52	676046.13	97.45	92.45	4	10.5	102.95	106.05	6.57	99.48	4.59	0	22.95
WT 32	WT	6/6/1990	2146107.08	675828.25	119.69	114.69	4	23	137.69	140.81	21.43	119.38	3.06	3	3.06

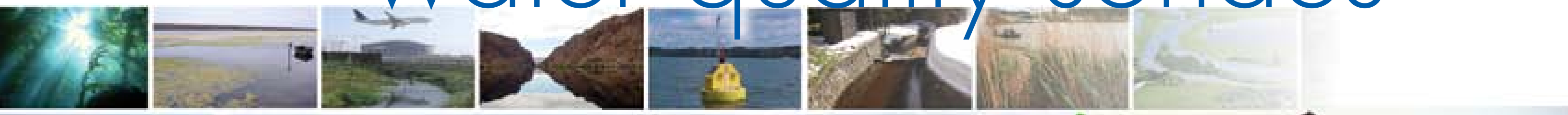
APPENDIX B

MONITORING EQUIPMENT SPECIFICATIONS

Water Quality Sonde
(In-Well)

6-series multiparameter

water quality sondes



long-term monitoring

profiling & spot sampling

sensor guide

Why YSI?

For 60 years YSI, an employee-owned company, has pioneered the development of water quality sensors for use in natural waters.

Our technology saves you time: We know that meeting the global need for improved environmental monitoring requires fewer technical personnel and a lower cost of ownership. YSI provides turn-key monitoring solutions, easier to use and install equipment, and intuitive interfaces.

Our reliability improves efficiency: Successful monitoring efforts depend on accurate and defensible data. We deliver reliable instruments and continuously develop safeguards and system checks to ensure you obtain the highest quality data as quickly as possible.

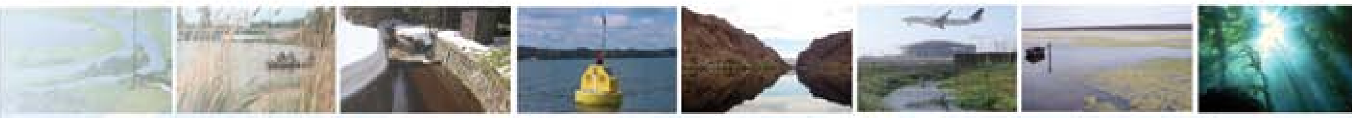
Our employees understand your challenges: Our technical support staff has extensive field experience which helps them provide hands-on support for your monitoring challenges.

Our customers can reach us: We have 17 global offices and 300 employees on 5 continents.

Our experience is proven: We have the largest installed base of multiparameter sondes with over 20,000 instruments in use worldwide.

Top photo: Mike Lizotte (left), YSI's US applications specialist, takes oxygen measurements to spot check sensor performance on a submerged monitoring platform in Biscayne Bay, Florida.

Bottom: Rigor Ma (right), YSI China applications specialist, trains a customer on the operation of a continuous monitoring station in Xiamen, China.



Choosing YSI
helps you reduce operating costs without sacrificing data accuracy.

Environmental monitoring takes significant investments in time and money. This investment is jeopardized when something goes wrong. Our instruments are reliable and make your data collection as problem-free as possible.

Reduce labor costs through longer maintenance intervals and fewer system failures.

Do it right the first time **with our easy-to-use software and superior technical support.**

Obtain quality data **through features such as zero calibrations on our oxygen sensors and post-processing features in our software.**

multiparameter sondes
for long-term monitoring

YSI's upgraded 6-Series family includes versatile, multiparameter sondes designed for real-time environmental monitoring and extended deployment.

V2 Sondes

All Version 2 (V2) sondes accept our V2 optical sensors and have a rugged design for long-term monitoring. These sensors feature multiple anti-fouling components and long battery life to provide you with value for your budget.

Seven V2 sondes are offered with sensor payloads ranging from 5-9 sensors and multiple memory and power options to accommodate many different applications. In addition to the sensor options, YSI software calculates up to five additional parameters.

Biofouling protection

Integrated wipers, copper-alloy anti-fouling parts, and a nanopolymer solution significantly deter the growth of biological organisms – thus extending your deployments and reducing your operating costs.

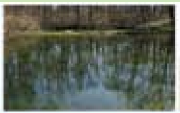
Applications (suggested uses but not limited to)


Source water monitoring


Short-term studies or spot sampling with complete sensor suite


Dredging studies


Integration into buoys or vertical profiling system


Long-term unattended monitoring


Underway sampling with flow cell for horizontal mapping

6600 V2

6600 V2 sonde features the largest sensor payload capability and longest battery life. Choose between 2 and 4 optical ports. The 6600 V2 and **6600EDS V2** are also available with a pH wiping system.

6600 V2-4 with four ports for any combination of these optical sensors: ROX dissolved oxygen, blue-green algae, turbidity, chlorophyll, or rhodamine

6920 V2

6920 V2 sonde is an economical, 15-parameter logging system; battery powered for long-term, in situ monitoring and profiling. Choose between 1 and 2 optical ports.

600OMS V2

600OMS V2 sonde is our smallest V2 sonde, perfect for applications such as turbidity or oxygen monitoring. Accepts 1 optical sensor as well as conductivity, temperature, and depth.

6820 V2

6820 V2 sonde is a cost-effective sampling system with up to 15-parameter reporting capability, ideal for profiling and spot-checking. Choose between 1 and 2 optical ports.

multiparameter sondes

for monitoring, sampling & logging

600 Sondes

YSI 600 sondes are designed for specific applications where a fewer number of parameters is required and size and ease-of-use are of primary concern. All five 600 sondes offer a small and economical package for water quality sampling purposes.

Compact 600 sondes have diameters less than 2". The sensors are of the same high quality offered on YSI 6000 sondes.

Applications (suggested uses but not limited to)

Source water monitoring

Spot sampling

Short-term, unattended studies

Surface and groundwater monitoring

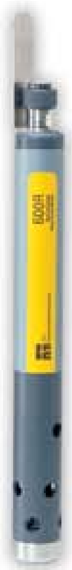
Water level monitoring

600 Sondes

600LS is our simplest sonde, designed for spot sampling level measurements and tide gauge measurements.

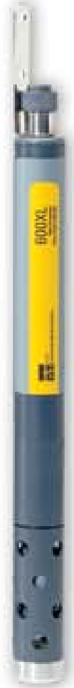
600R includes conductivity and temperature sensors and options to add pH and Rapid Pulse™ dissolved oxygen. Ideal for large monitoring programs and educational applications.

The 600QS system includes a 600R, 650 display logger, field cable, and additional sensor options such as ORP and vented level.



600XL and 600XLM sondes are more versatile, ideal for water level monitoring as well as ground water and surface water monitoring. Both sondes include DO, temperature, and conductivity sensors and options to add pH or pH/ORP, depth, and vented level measurements. The XLM offers batteries for unattended, *in situ* monitoring.

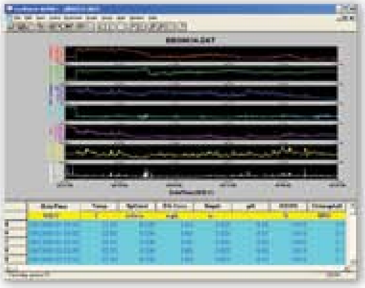
The new **V2** version of both sondes has an optical sensor port.



Data Analysis Software

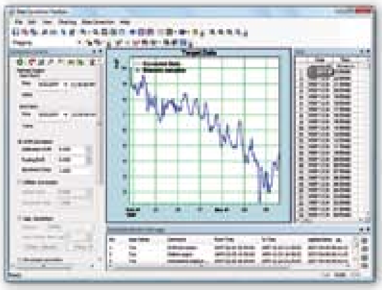
EcoWatch® for Windows®

Standard with all YSI sondes, EcoWatch software makes communication with water quality sensors simple. Includes sensor calibration and sonde configuration tools as well as basic graphing.



AQUARIUS Time-Series™

Optional for YSI sondes, AQUARIUS Time-Series software takes data processing to the next level. Includes advanced graphing tools, error detection and correction, and modeling capabilities.



drinking water protection

Agriculture and
well water

Reservoir
monitoring

Water towers
and urban areas

Drinking Water Sondes

Gather baseline knowledge and detect events with YSI drinking water sondes. These specialized sondes provide process and quality control throughout a distribution network, helping you deliver safe drinking water.

600DW-B

600DW-B sonde measures temperature, conductivity, pH, ORP, and free chlorine. Portable and powered by batteries or AC.

6920DW

6920DW sonde measures parameters above plus turbidity. Portable and powered by batteries or AC.

sonde interfaces

650MDS

All YSI 6-Series sondes work with the versatile **650MDS** (Multiparameter Display System).

- Easily log real-time data, calibrate, and set up sondes for deployment
- Designed for reliable field use featuring a waterproof IP-67, impact-resistant case
- Upload data to a PC
- Optional barometer and GPS interface

6500 Environmental Process Monitor

6500 Environmental Process Monitor continuously monitors DO, conductivity, temperature, and pH with uninterrupted data. The compact, cost-effective monitor will connect to any 6-Series multiparameter instrument.

By replacing multiple instruments, it reduces labor for installation and operation. Includes 8 scaleable 4-20 mA current loop channels and 4 SPDT relays. Allows calibration in the field or lab.

YSI 6-series
quick select guide

Features/Parameters	V2 Sondes					600 Sondes				Drinking Water		System
	6600	6600EDS	6920	6820	600OMS	600R	600XL	600XLM	600LS	6920DW	600DW-B	600QS
Field-replaceable probes	●	●	●	●	●		●	●		●	●	
RS-232 & SDI-12 standard	●	●	●	●	●	●	●	●	●	●	●	●
Fits 2″ wells					●	●	●	●	●		●	●
Internal memory	●	●	●	●	●	●	●	●	●	●	●	●
Internal power (batteries)	●	●	●		■			●	■	●	●	
Flow cell	■	▲	■	■		■	■	■		■	■	■
Ammonium/ammonia*	□		■	■			▲	▲				
Blue green algae	■	■	■	■	■		□	□				
Chloride*	□		■	■			▲	▲				
Chlorophyll	■	■	■	■	■		□	□				
Conductivity	●	●	●	●	●	●	●	●	■	●	●	●
Depth	■	■	■	■	■		■	■				■
Dissolved oxygen	□	■	□	□		■	■	■				■
Dissolved oxygen, optical	■	■	■	■	■		□	□				
Free chlorine										■	■	
Nitrate*	□		■	■			▲	▲				
Open channel flow**	■	■	■	■	■		■	■	●			
ORP	■	■	■	■			■	■		■	■	■
PAR (Photosynthetically Active Radiation)	▲	▲										
pH	■	■	■	■		■	■	■		■	■	■
Resistivity**	●	●	●	●	●	●	●	●	■	●	●	●
Rhodamine	■	■	■	■	■		□	□				
Salinity	●	●	●	●	●	●	●	●	■	●	●	●
Specific conductance**	●	●	●	●	●	●	●	●	■	●	●	●
Temperature	●	●	●	●	●	●	●	●	●	●	●	●
Total dissolved solids**	●	●	●	●	●	●	●	●	■	●	●	●
Turbidity	■	■	■	■	■		□	□		■		
Vented level	■	■	■	■	■		■	■	●			

* Freshwater only. ** Calculated parameters.

● Standard ■ Customer Selectable ▲ Special Order
□ Available only on 6600 V2-2 □ Available only on 6920 V2-1 or 6820 V2-1
□ Available only on 600XL V2 or 600XLM V2

high accuracy sensors

Sensors

Quality data is the product of quality sensors and we have built our reputation on providing the highest performance, most reliable water quality sensors available. Our engineers give as much attention to sensor performance in the laboratory as they do to performance under the harshest environmental conditions for extended periods. Additionally, all YSI sensors are field replaceable, helping you with maintenance and unexpected situations.

Optical

Our optical sensors, with integrated extended-deployment wipers, offer excellent performance. The copper-alloy anti-fouling versions offer the longest deployment times in the industry—saving you time and money.

Additionally, user-adjustable data filtering capabilities allow optimized response time or detection limits.

ROX® Optical Dissolved Oxygen The most reliable, accurate, and maintenance-free DO sensor available for worry-free oxygen measurement.

Blue-green Algae Fluorescence sensors monitor blue-green algae biomass in freshwater or marine environments in real-time.

Turbidity Superior linearity, 1-, 2-, or 3-point calibration options and excellent agreement with the industry standard benchtop instrument (Hach 2100AN).

Chlorophyll Accurately monitor total algal biomass without interference from turbidity, ambient light, or dissolved organics.

Rhodamine Conduct dye-tracing studies (flow, transport, mixing) with this sensitive fluorescence sensor.

Electrochemical

Rapid Pulse™ Dissolved Oxygen The most advanced polarographic technology available, Rapid Pulse DO is virtually insensitive to flow rate and exhibits large range (0-50mg/L). EPA approved method.

pH/ORP Excellent performance in cold and low ionic waters. Field-replaceable and includes integrated reference electrode. Fast Response sensor and Extended-deployment versions with wipers available.

Ion-selective electrodes

Measure **ammonia, nitrate,** and **chloride**. Designed for short-term monitoring and spot sampling.

Physical

Conductivity Superior linearity and easy one-point calibration.

Temperature Extremely accurate, field-replaceable temperature sensor.

Integrated

Depth & Vented Level Excellent accuracy through calibration to extremely high precision through temperature compensation over the entire operating range.

PAR Integrate the industry-standard LI-COR® PAR (Photosynthetically Active Radiation) sensor for biological studies. Wiped PAR also available.

Typical performance specifications

	Range	**Resolution**	**Accuracy**
Rapid Pulse dissolved oxygen % air saturation	0 to 500%	0.1%	0 to 200%: ±2% of reading or 2% air saturation, whichever is greater; 200 to 500%: ±6% of reading
Rapid Pulse dissolved oxygen mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±2% of reading or 0.2 mg/L, whichever is greater; 20 to 50 mg/L: ±6% of reading
ROX optical dissolved oxygen# % air saturation	0 to 500%	0.1%	0 to 200%: ±1% of reading or 1% air saturation, whichever is greater; 200 to 500%: ±15% of reading; relative to calibration gases
ROX optical dissolved oxygen# mg/L	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L: ±1% of reading or 0.1 mg/L, whichever is greater; 20 to 50 mg/L: ±15% of reading; relative to calibration gases
Conductivity+	0 to 100 mS/cm	0.001 to 0.1 mS/cm (range-dependent)	±0.5% of reading + 0.001 mS/cm
Temperature	-5 to 50°C	0.01°C	±0.15°C
pH	0 to 14 units	0.01 unit	±0.2 unit
Shallow depth	0 to 9.1 m (0 to 30 ft)	0.001 m (0.001 ft)	±0.018 m (±0.06 ft)
Medium depth	0 to 61 m (0 to 200 ft)	0.001 m (0.001 ft)	±0.12 m (±0.4 ft)
Deep depth	0 to 200 m (0 to 656 ft)	0.001 m (0.001 ft)	±0.3 m (±1 ft)
Vented level	0 to 9.1 m (0 to 30 ft)	0.001 m (0.001 ft)	±0.003 m (±0.01 ft)
Open-channel flow	Calculated measurement, requires vented level		
Free chlorine	0 to 3 mg/L	0.01 mg/L	±15% of reading or 0.05 mg/L, whichever is greater
ORP	-999 to +999 mV	0.1 mV	±20 mV in Redox standard solutions
Salinity	0 to 70 ppt	0.01 ppt	±1% of reading or 0.1 ppt, whichever is greater
Nitrate/nitrogen*	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Ammonium/ammonia/ nitrogen*	0 to 200 mg/L-N	0.001 to 1 mg/L-N (range dependent)	±10% of reading or 2 mg/L, whichever is greater
Chloride*	0 to 1000 mg/L	0.001 to 1 mg/L (range dependent)	±15% of reading or 5 mg/L, whichever is greater
Turbidity#	0 to 1,000 NTU	0.1 NTU	±2% of reading or 0.3 NTU, whichever is greater in YSI AMCO-AEPA Polymer Standards
Rhodamine WT#	0-200 µg/L	0.1 µg/L	±5% of reading or ±1 µg/L, whichever is greater
Chlorophyll# ++	**Range** 0 to 400 µg/L chl *a* 0 to 100 RFU	**Resolution** 0.1 µg/L chl *a* 0.1% FS; 0.1 RFU	**Linearity** R^2 > 0.9999 for serial dilution of Rhodamine WT solution from 0 to 500 µg/L
Blue-green algae# phycocyanin	**Range** 0-280,000 cells/mL	**Detection limit** 220 cells/mL§	**Linearity** R^2 = 0.9999 for serial dilution of Rhodamine WT from 0 to 400 µg/L
Blue-green algae# phycoerythrin	0-200,000 cells/mL	450 cells/mL§§	R^2 = 0.9999 for serial dilution of Rhodamine WT from 0 to 8 µg/L
PAR	**Range** 400-700 nm waveband **Linearity** Max. deviation of 1%	**Calibration** ±5% **Sensitivity** Typically 3µA per 1000 µmol s-1 m-2 in water	**Stability** <±2% change over 1 year

Depth rating for optical probes is 61 m (200 ft); depth rating for anti-fouling optical probes with copper-alloy probe housing is 200 m (656 ft). * Freshwater only. Maximum depth rating of 15.2 m (50 ft). + Report outputs of specific conductance (conductivity correct to 25° C), resistivity, and total dissolved solids are also provided. These values are automatically calculated from conductivity according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed 1989). ** To maintain accuracy specification, flow must be at least 500 mL/min and pH should not change by more than ±0.3 units if mean pH is between 8.5 and 9.3. ++ Specification determined using monocultures of *Isochrysis sp.* and fluorometric extraction of chlorophyll *a*. Actual detection limits will vary depending on natural algae assemblage. § Estimated from cultures of *Microcystis aeruginosa*. §§ Estimated from cultures of *Synechococcus sp.*

YSI Environmental
Pure Data for a Healthy Planet.®

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ISO **14001**
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CE

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Third-Party Verification You Can Trust

ETV

YSI is the only company in its field to apply for and receive verification from the US EPA's Environmental Technology Verification Program. Independent tests on the YSI 6600EDS sonde and six sensors demonstrated the accuracy of YSI sensor technology when compared to established standards in saltwater and freshwater. Find information on performance characteristics of YSI water quality sensors at www.epa.gov/etv.*

Alliance for Coastal Technologies

The Alliance for Coastal Technologies (ACT) has tested the YSI 6600EDS V2 and 6600 V2 sondes and 3 sensors under real-world conditions. Find evaluation reports at www.act-info.us.

MCERTS sira

YSI multiparameter sondes have achieved the UK Environment Agency MCERTS certification for continuous water monitoring. Find more information at www.mcerts.net.

*Use of the ETV name or logo does not imply approval or certification of this product nor does it make any explicit or implied warranties or guarantees as to product performance.

Environmental Calculation Report

YSI Inc. saved the following resources by using Utopia U2:XG paper, made with 30% recycled post-consumer waste:

trees	energy	greenhouse gas	water	solid waste
2	1.3 mil BTUs	617.45 lbs CO_2	659 gal	109 lbs

YSI *incorporated*
Who's Minding the Planet?®

Water Quality Sensors
Long-term Monitoring Systems
Profiling & Spot Sampling Instruments
Flow & Velocity Instruments
Integrated Systems & Services

This quote prepared for: Matthew Zenker
Quoted By: Kevin McClurg
Quote Date: 12/09/2010

Quote No. 15043

Choosing YSI

helps you reduce operating costs without sacrificing data accuracy.

Environmental monitoring takes significant investments in time and money. **We understand** the challenges of working in natural environments.

Reduce labor costs through **longer maintenance intervals and fewer system failures.**

Do it right the first time with our easy-to-use software and superior technical support.

Obtain quality data through features such as zero calibrations on our oxygen sensors and post-processing features in our software.

To: Matthew Zenker
AECOM
8540 Colonnade Center Dr.
Suite 306
Raleigh, NC 27615

Phone: (919) 239-7190
matthew.zenker@aecom.com

Quoted By:	Kevin McClurg
Quote Date:	12/09/2010
Valid Through:	04/27/2011
Quote No.	15043

Line#	Part#	Description	Price	Qty	Extend
1	603-002	600XLM-M Multi-Parameter Water Quality Logger - Medium depth (0-200ft) - 6560 Conductivity/Temperature Probe Kit - 6570 Maintenance Kit - Powered from 4 AA cells which are included	$4,740.00	1	$4,740.00
2	650-03	Model 650 Display with Low Memory, with Barometer - Power: 4 Alkaline C Cells, Waterproof to IP 67 - Memory: standard memory limited to 150 data sets - Interfaces with any standard 6 series sonde and field cable - Includes barometer	$1,770.00	1	$1,770.00
3	006093	6093 100 ft Field Cable - Urethane jacketed - Kevlar reinforced with strain relief	$620.00	1	$620.00
4	006562	6562 DO Field Replaceable 6-Series Probe Kit 0 - 50 mg/L , +/- 2% of reading or 0.2 mg/L - Includes membrane kit	$560.00	1	$560.00
5	006882	6882 Chloride Probe Kit (Fresh Water Only)	$425.00	1	$425.00
6	005083	5083 _ Flow Cell - Fits 556, 600XL and 600XLM instruments - Includes quick disconnects	$361.00	1	$361.00
7	006561	6561 pH Field Replaceable 6-Series Probe Kit 0 - 14 pH units , +/- 0.2 unit - Includes storage solution and bottle	$230.00	1	$230.00
8	006067	6067B Dry calibration cable - Leave it connected to PC - Lab or office use only	$205.00	1	$205.00
9	006038	6038 110 VAC to 12 VDC power supply - Used with the 6095B and 6067B cable	$65.00	1	$65.00
10	EstSHIP	Shipping Cost - Estimated shipping price, actual freight charge will be applied to invoice - Ground Shipping and Insurance	$25.00	1	$25.00
				Total	$9,001.00

Quote is continued on next page.

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FOB: Point of Origin

To place this order please email or fax a copy of your PO to:

Fax: 937-767-1058
Email: orders@ysi.com
Attn: Order Entry
1725 Brannum Lane
Yellow Springs, OH 45387

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All purchase orders should have a complete billing and complete shipping address on purchase order.
For order acknowledgement please provide email address to send updates on order.

YSI's Tax identification # 31 0526418
YSI's DUNS # 004246716

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YSI Incorporated
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Cincinnati OH 45264-0373

ACH (With ADDENDA Record):
US Bank NA
Cincinnati, OH 45202
Acct# 8506321; ABA# 042000013

Taxes and Tariffs are additional and not included in the pricing unless explicitly stated as a line item.
Tax exempt customers must include Tax ID on their PO.

You might be interested in these additional products and services:

6600 V2-4 Multiparameter Sonde

Versatile, multiparameter instrument for real-time environmental monitoring and extende deployment. Features the largest water quality sensor payload, including 4 optical sensors, and integrated anti-fouling wipers.

Optical Sensors

Optical fluorescence technology for in situ measurements. YSI's optical sensors provide long-term, accurate data with the convenience of field replacement.

Optical Dissolved Oxygen with the widest measurement range available
Optical Chlorophyll and Blue-Green Algae for algae monitoring
Optical Turbidity Rhodamine WT

Anti-fouling Kits

For long-term monitoring, anti-fouling kits decrease the number of trips to the field for equipment maintenance. The innovative, copper-alloy components – including sonde guard, wiper assemblies, and tape – fit easily on sondes and sensors to dramatically halt biofouling. Your deployment intervals become longer and your data remains uncompromised.

EcoNet remote monitoring

Save time and money by reducing to your trips to the field. EcoNet lets you remotely manage your monitoring stations by providing continuous power and telemetry with a web interface. The system is a simple solution for real-time data through cellular, Ethernet, and radio communications. EcoNet requires no programming code or complicated interfaces and is the perfect complement to a water quality sonde.

You might be interested in these additional products and services:

Professional Plus

Handheld instrument designed for the field or lab. Measure dissolved oxygen, pH, ORP, conductivity, Ammonium, nitrate, chloride, salinity, TDS, Temperature and barometric pressure in various combinations. Features include IP67 waterproof rating, 3-year instrument and 2-year cable warranty, 2,000 data set memory, user-replaceable cables and sensors, multiple languages, detailed Help file, and much more. Includes Data Manager desktop software and USB communications.

www.ysi.com/proplus

Pro20

Handheld instrument for the measurement of dissolved oxygen and temperature. Easily changes to a lab instrument by connecting the self-stirring BOD probe. The instrument has a 50 data set memory, user-replaceable sensors and cables, choice of polarographic or galvanic DO sensors, IP67 waterproof rating, and 3-year instrument and 2-year cable warranty.

Choose among 1, 4, 10, 20, 30, or 100-meter cables. Special order up to 100-meters in 10-meter increments.

9300/9500 Photometers

Simple on-screen instructions walk you through the desired photometer test of choice. Choose among 100-plus tests. The instruments features IP67 waterproof ratings, large backlit graphic displays, sample tube holder for various diameters, on-screen instructions, multiple languages, and hard-sided carrying case. Reagent tablets are shipped non-hazardous.

In addition, the 9500 features a waterproof USB Connection, USB power, 500 data set memory, and user-selectable options for test units, sample numbers, dilution factors, and 30 user-defined tests.

www.ysi.com/photometers

In Well Purging – USGS

USGS
science for a changing world

Robowell — Providing Accurate and Current Water-Level and Water-Quality Data in Real Time for Protecting Ground-Water Resources

Accurate and current hydrologic data are necessary to protect the Nation's water-supply infrastructure because ground water is a limited and vulnerable resource. Robowell, an automated ground-water monitoring system, provides real-time data without incurring the high labor and laboratory costs associated with manual sampling. Using proven sampling methods, the Robowell system can monitor ground-water quality and water level in one or more wells at a monitoring site. This technology, if used with periodic manual sampling and appropriate calibration, provides the information necessary to detect abrupt changes, short-term variability, and seasonal and long-term trends in water quality and water levels. When Robowell detects these changes, it can quickly alert an operator. These capabilities make Robowell a steadfast sentry that can detect and report changes in water-quality or flow direction at contaminated sites, near potential sources of contaminants, or at public water-supply well fields.

GROUND WATER– A LIMITED AND VULNERABLE RESOURCE

Productive water-supply aquifers commonly occur in areas with shallow depths to ground water, permeable soils, and substantial flow rates, which render these aquifers susceptible to contamination from many sources (Trench, 1991; Harris and Steeves, 1994; Lent and others, 1997; Desimone and Ostiguy, 1999; Barlow, 2000). For instance, chemical spills and potential contamination commonly associated with various land-use practices (fig.1) can quickly degrade the water quality of a water-supply well. The design and operation of the supply well may also induce salt-water

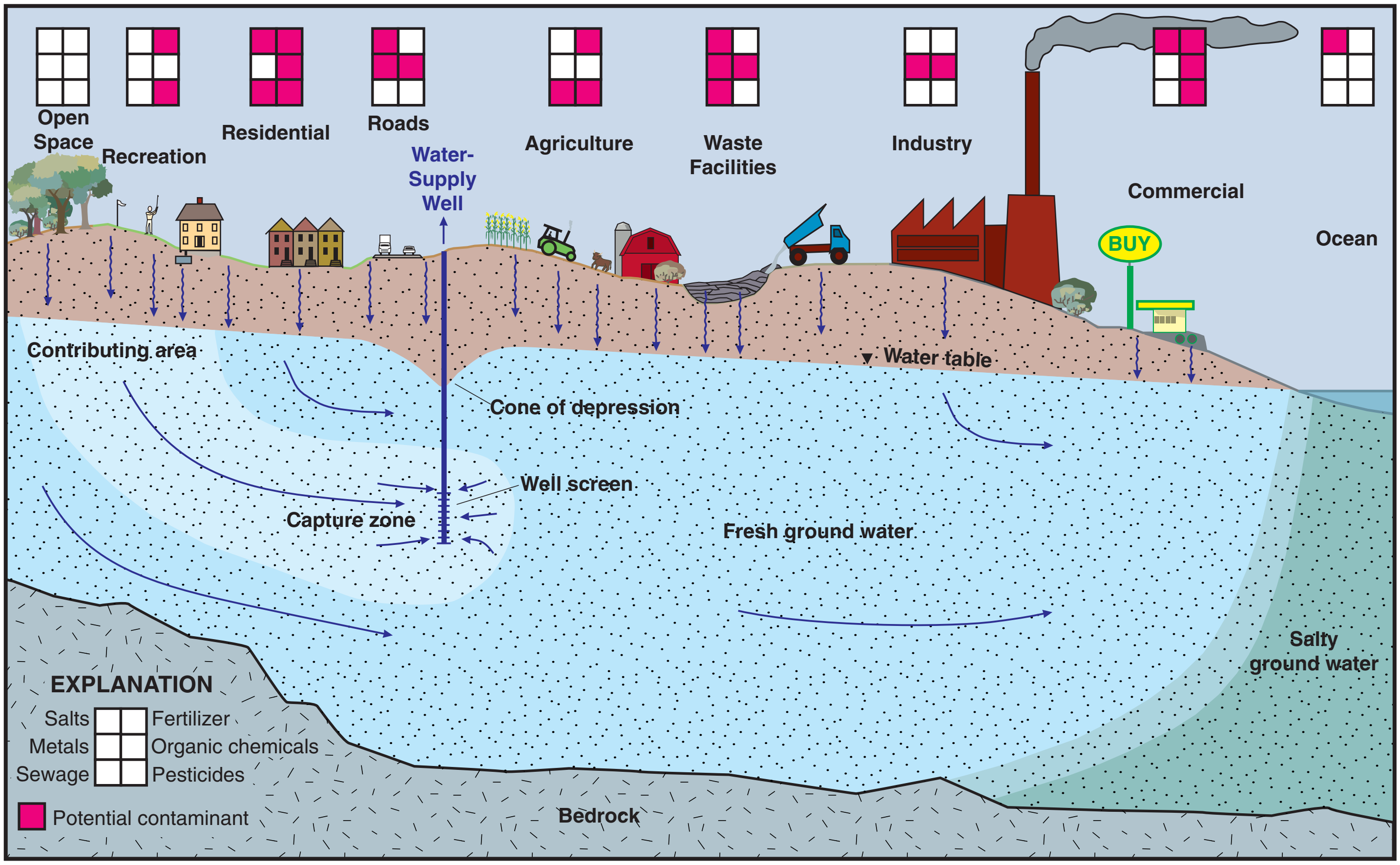

Figure 1. Potential contaminants commonly associated with various land-use practices that may affect ground-water quality in aquifers used for water supply.

U.S. Geological Survey
U.S. Department of the Interior

USGS Fact Sheet FS-053-02
July 2002

intrusion or surface-water infiltration, which would affect water quality. For example, Izbicki (2000) reported that a public-supply well in the Blackstone River Valley, Massachusetts draws water from the river to the well in as little as two days. The infiltrating river water adversely affects ground-water quality in this area. Recently, water suppliers, emergency planners, and the Department of Defense have recognized the potential for intentional chemical spills to sabotage drinking-water supplies (Lisa Olsen, U.S. Geological Survey, written commun., 2001).

Protecting public water supplies is crucial for protecting public health and investments in water-supply infrastructure (Trench, 1991; Harris and Steeves, 1994; Lent and others, 1997; Desimone and Ostiguy, 1999). Continuing development increases, the need to protect public water supplies. Development affects ground-water availability in two ways—it commonly increases water use and as development increases, it limits the number of pristine sites available for water-supply development. The balance between the availability of high-quality water and water demands is reaching a critical stage in many areas. For example, Harris and Steeves (1994) determined that only about 6 percent of the total area of Cape Cod was available for potential public-water-supply development after areas of ground-water contamination, potential saltwater-intrusion zones, and vulnerable land-use areas were eliminated. This fact is particularly notable because six sand and gravel aquifers underlie Cape Cod; therefore, the hydrologic setting does not limit potential locations of public water-supply-development areas, as is the case in many areas.

If the aquifer contributing water to a public-supply well is contaminated, little can be done to recover the resource. Active remediation is expensive and can take years to decades. Passive or natural remediation can take centuries before water in the area becomes fit to drink. Losing a well to contamination can be expensive because the value of the source area and the associated water-supply infrastructure is commonly lost. In addition, establishing and developing new water-supplies can be difficult and expensive.

Municipalities periodically sample water from supply wells to evaluate water quality. Contaminants may move into a water supply in the time between manual sampling events. By the time contaminants are usually detected, much of the area contributing water to a well may be contaminated. If early detection of contaminants is possible, pumping rates may be reduced, which will decrease the capture zone of the well, and a portion of the aquifer's production capacity may be retained.

Real-time water-level and water-quality monitoring data may help define the magnitude and variability of contamination from different land uses and may provide information for better management of water-supply areas. For instance, real-time monitoring near potential sources of pollution in and around the capture zone of public-supply wells may provide the information needed to detect contamination before it affects the supply area. Real-time water-quality monitoring also may be used to optimize the operation of existing well fields by minimizing the infiltration of surface water or saltwater, which may substantially impair the quality of public supply. Conversely, ground-water monitoring also may be used to identify

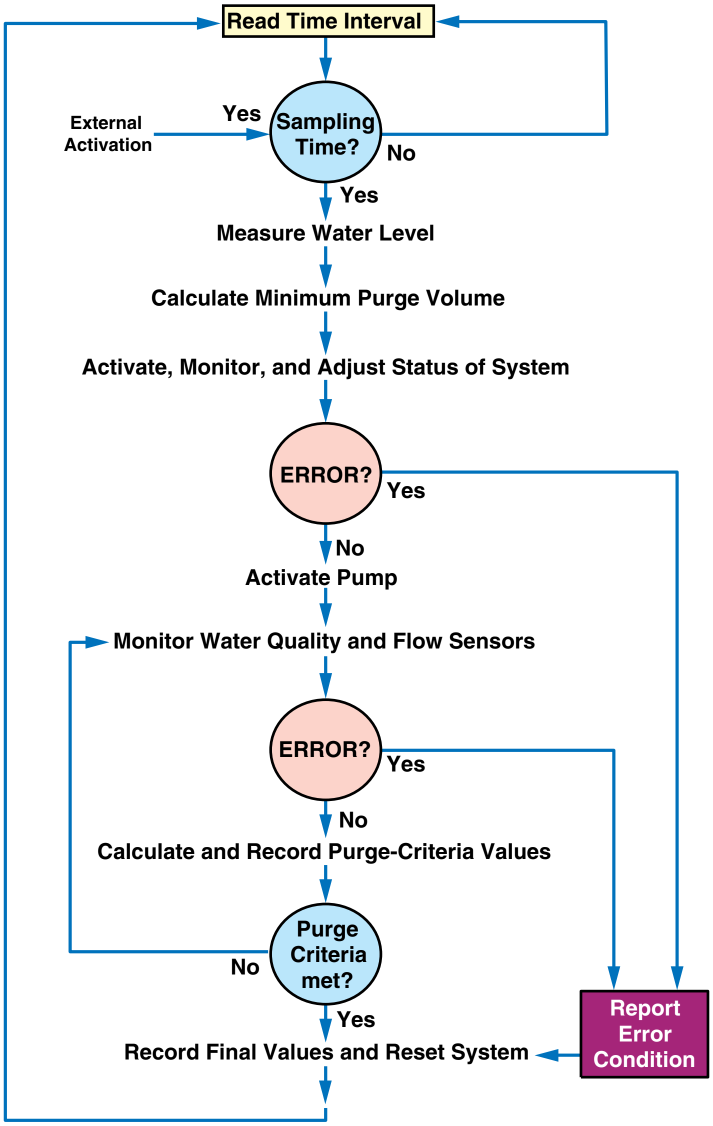

Figure 2. Robowell follows established manual sampling protocols and records water level, individual water-quality measurements, and final purge values. Robowell also records diagnostic information and any errors that may occur during the monitoring process.

subsurface discharge of ground-water contaminants to surface-water resources. Research and experience show that passive monitoring (by suspending a water-quality probe in a well) commonly does not provide representative measurements of water quality in the aquifer surrounding a monitoring well, and pumping well water is necessary to ensure representative measurements (Smith and Granato, 1998; Granato and Smith, 2001; Craig Wiegand, Water Superintendent, Provincetown Water Department, written commun., 2001).

ROBOWELL—AUTOMATED MONITORING WITH MANUAL SAMPLING PROTOCOLS

To help monitor valuable ground-water resources, the U.S. Geological Survey developed, tested, and patented Robowell. This system measures and records values of selected water-quality properties and constituents on a frequent basis, using protocols approved for manual sampling methods (Granato and Smith, 1997a,b: 2000; 2001). Robowell, however, does not incur the high labor and laboratory costs associated with frequent manual sampling. Since December 1994, six prototype monitoring units have been developed and tested. These units have measured water levels and water quality year round under different hydrogeologic conditions, well designs, and geochemical environments.

Robowell uses a computer to control a pump and a series of electronic instruments, which monitor the quality of ground water pumped through the system from a monitoring well or multilevel sampler. In the full implementation, a Robowell system will (1) activate itself as programmed, (2) perform a series of self-tests, (3) measure the water level in the well, (4) calculate the purge volume, (5) measure and record values of water-quality properties and constituents during the purge cycle, (6) determine and record the final values of the properties and constituents, and (7) return to an inactive mode (fig. 2). Granato and Smith (1999a,b; 2001) describe in detail the design and implementation of Robowell with case studies and potential applications.

The system's computer program uses information from system feedback, water-quality measurements, and an internal clock to control the monitoring process automatically. If the system functions properly, it monitors and records instantaneous measurements of water-quality properties and constituents. After each measurement, Robowell calculates purge-criteria values (for example, the range of the last five measurements). Robowell records final water-quality values and terminates the measurement process when the purge criteria are met. If the system detects equipment errors during a sampling interval, the system records error codes and measured values for the sampling interval. An operator can initiate, suspend, or modify monitoring operations in response to errors in system feedback. The operator can monitor and control the system on site or by remote control through a communications link. Robowell provides three valuable tools for ground-water monitoring:

- real-time water-level monitoring
- real-time water-quality monitoring
- real-time access to data

REAL-TIME WATER-LEVEL MONITORING

The first step toward assessing the potential vulnerability of a ground-water supply is to develop an understanding of the hydrology of the contributing area. To achieve

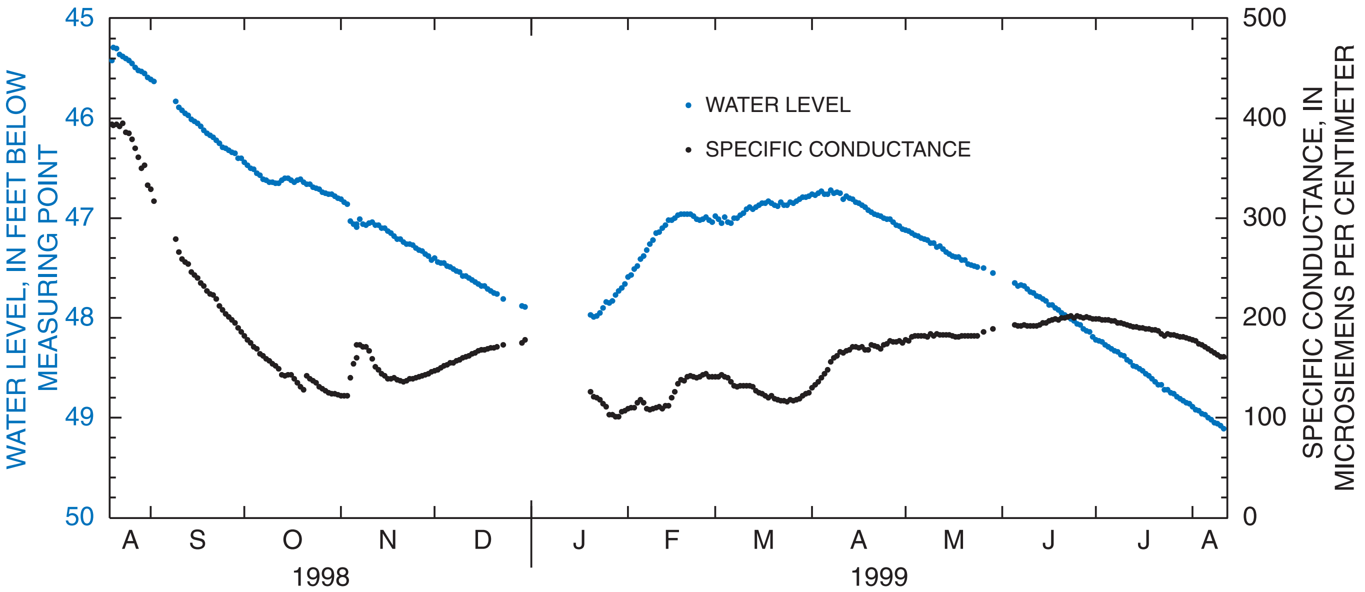

Figure 3. From August 1998 through August 1999, Robowell monitored water level and specific conductance at USGS well 422627071195901 near Walden Pond, Concord, Massachusetts. Decreasing water levels and specific conductance during August and September 1998 suggested a change in the direction of ground-water flow.

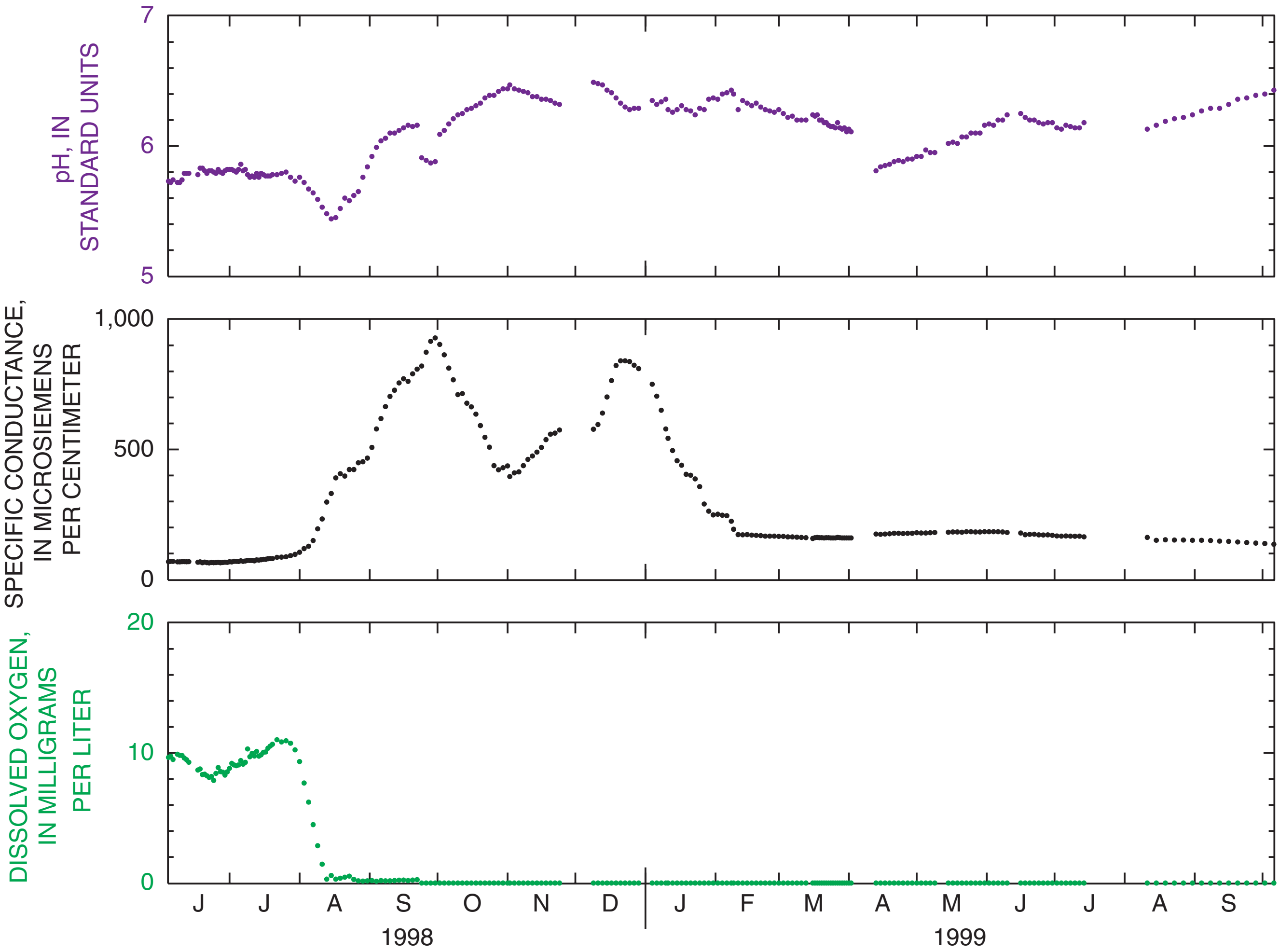

Figure 4. From June 1998 through September 1999, a Robowell prototype at USGS well 414047070321304 on Cape Cod, Massachusetts, measured changes in pH, specific conductance, and dissolved oxygen.

this, monitoring wells are drilled and tested to establish the geometry, types of sediment, and hydraulic properties of an aquifer. Water levels from these wells help determine the magnitude and direction of ground-water flow. Historically, a relatively few (in space and time) periodic water-level measurements from wells were used to characterize directions of ground-water flow, potential contaminant movement, and the degree of interaction between ground and surface water. Recent research, however, suggests that continuous water-level data may be necessary to learn how ground-water flow responds to changing river stage (or ocean tides), short-term and seasonal aquifer-recharge rates, barometric pressure, well pumping or injection rates, and other stresses on the ground-water system that affect estimates of ground-water flow and potential contaminant movement (Myers and others, 1999; Taylor and Alley, 2001). For example, Myers and others (1999) deployed a network of real-time, ground-water-level monitoring wells and detected large changes in the direction (greater than 40 degrees) and magnitude (about 50 percent of the median gradient) of flow during an 8-month study of a surficial aquifer in Kansas. Large changes in the direction and magnitude of ground-water flows have also been detected between periods of relatively high- and low-water table conditions on Cape Cod, Massachusetts (McCobb and others, 1999).

Robowell units have successfully provided real-time water-level data to monitor conditions at different study sites (Granato and Smith, 2001). At Walden Pond, in Concord, Massachusetts, the real-time water levels and associated water-quality measurements supplied by a Robowell were instrumental in detecting a change in the direction of ground-water flow. Robowell was implemented as part of a study to determine the source of nutrients to the pond. The unit was emplaced to monitor short-term and seasonal variability in ground-water quality downgradient of the State Park's septic leach field near the pond. Substantial decreases in water levels and specific conductance (a measure of total dissolved solids) during August and September 1998 (fig. 3) indicated a change in the direction of ground-water flow. The decrease in specific conductance was surprising, given the heavy use of the bathhouse facilities and the subsequent high-effluent loading rates from the septic system during the summer. Increased manual ground-water-level monitoring and installation and sampling of new wells in the area confirmed that the direction of ground-water flow had changed, and that the Robowell prototype was now on the edge, rather than in the center, of the septic-system-effluent plume. The data from Robowell and from the increased manual sampling indicated that the effluent plume was traveling toward the pond. This finding prompted seepage studies at the edge of the pond to detect the arrival of this plume.

REAL-TIME WATER-QUALITY MONITORING

Robowell can detect changes in ground-water quality because it produces a record of water-quality measurements that are taken at a user-specified frequency. Because additional measurements cost almost nothing, Robowell units can measure on an hourly, daily, or weekly interval, as needed, to characterize changes in water quality. The system can be programmed to automatically increase the frequency of measurements if it detects changes in water quality. The real-time water-quality monitoring records produced by Robowell can provide the context for interpreting results from laboratory analysis of periodic manual samples. For example, records of real-time measurements can be used with analyses of discrete samples obtained manually to identify the abrupt arrival of a contaminant plume, subtle trends caused by a diffuse source of contaminants, or an error made in the analysis of a sample.

The Robowell technology has many potential applications for monitoring possible sources of ground-water contamination, and for guarding the source areas of public supply wells (Granato and Smith, 2001). In Massachusetts, Robowell units have reliably monitored the effects of road salt, sewage effluent, septic effluent, and saltwater intrusion on ground-water quality. Units have also monitored the effects of natural biological restoration of a contaminated aquifer and geochemical effects of an experimental remediation technique. For example, the Robowell data presented in figure 4 show changes in water quality measured in a well on Cape Cod, Massachusetts. The real-time data collected by this Robowell prototype provided the information necessary to characterize ground-water quality at the site. It also provided a context for interpreting the results of laboratory analyses of samples collected in the adjacent well cluster (Granato and Smith, 1999b). Robowell may also help monitor other sources of contaminants such as nonpoint-source pollution, infiltration from stormwater-retention structures, potential leakage at municipal landfill sites, chemical spills or chemical-disposal sites, and waste sites for military munitions (Granato and Smith, 2001).

REAL-TIME ACCESS TO DATA

Access to real-time ground-water data may be necessary to protect vulnerable ground-water supplies and to optimize operation of public water-supply wells. Robowell units can use telephone lines, cellular phones, radio connections, or satellite links to transmit data in real-time. If phone connections are used, Robowell units can provide timely information by voice-modem contact, direct data-modem connection, or by links to the internet. For example, quarterly manual samples collected from USGS well 414047070321304 on Cape Cod, Massachusetts at the end of July and October 1998, and in January 1999 would not detect changes in water quality (apparent as the two peaks in specific conductance in the real-time record on figure 4) in a timely manner. In this case, if one assumes a one-month delay between manual sample collection and receipt of a water-quality analysis from a laboratory, the person relying on this quarterly manual sampling program may not be aware of a change in water quality until December 1998. The person relying on the real-time Robowell data, however, could have detected and responded to a change in water quality in early August 1998. In fact, the Robowell monitoring ground water quality at this site (fig. 4) used a voice modem to contact the project chief in early August when specific conductance measurements initially exceeded 100 and then exceeded 200 microsiemens per centimeter (Granato and Smith, 1999b; 2001). These voice-modem alerts (preprogrammed messages in English) on an answering machine and subsequent telephone access to the real-time data allowed the project chief to optimize manual-sampling efforts and minimize laboratory-analysis expenses. This sampling program was improved because the project chief could dispatch sampling teams to the remote site when the plume arrived and ground-water quality changed substantially.

Another example of the utility of real-time access to data is provided by a Robowell used to monitor the freshwater/saltwater interface in a public water-supply well in Provincetown, Massachusetts. For over a year, the unit has provided real-time water levels and water-quality data on the internet. These data provide a direct indication of hydraulic head in the aquifer, which theoretically controls the position of the freshwater/saltwater interface. Graphs of water quality in the screened zones of the monitoring wells record changes in salinity caused by movement of the freshwater/saltwater interface. A number of operational parameters including equipment-shelter air temperature and humidity, battery voltage, bladder-pump gas pressure and flow rates, and diagnostic error codes are available to the system operators on a web page to facilitate maintenance for this remote unit. The real-time data from Provincetown, sound files demonstrating the telephone voice-modem connection, and detailed information on the Robowell technology are available on-line at URL http://ma.water.usgs.gov/automon/.

SUMMARY

Protecting public health and the Nation's water-supply infrastructure requires accurate and current hydrologic data. As ground-water supplies become increasingly vulnerable to contaminants from many land uses, and as continuing development in many areas limits pristine sites for water-supply development, the need for real-time ground-water data increases. Robowell, an automated water-monitoring system, can help meet this need. Using established ground-water sampling protocols, this technology can provide real-time information about ground-water levels and water quality needed to protect ground-water supplies.

— by Gregory E. Granato
and Kirk P. Smith

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Robowell: An automated process for monitoring ground water quality using established sampling protocols.

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Robowell: An Automated Process for Monitoring Ground Water Quality Using Established Sampling Protocols

By Gregory E. Granato and Kirk P. Smith

Abstract

Robowell is an automated process for monitoring selected ground water quality properties and constituents, by pumping a well or multilevel sampler. Robowell was developed and tested to provide a cost effective monitoring system that meets protocols expected for manual sampling. The process uses commercially available electronics, instrumentation, and hardware, so it can be configured to monitor ground water quality using the equipment, purge protocol, and monitoring well design that is most appropriate for the monitoring site and the contaminants of interest. A Robowell prototype was installed on a sewage-treatment plant infiltration bed that overlies a well-studied unconfined sand and gravel aquifer at the Massachusetts Military Reservation, Cape Cod, Massachusetts during a time when two distinct plumes of constituents were released. The prototype was operated from May 10 to November 13, 1996, and quality-assurance/quality-control measurements demonstrated that the data obtained by the automated method was equivalent to data obtained by manual sampling methods using the same sampling protocols. Water level, specific conductance, pH, water temperature, dissolved oxygen and dissolved ammonium were monitored by the prototype as the wells were purged according to U.S. Geological Survey ground water sampling protocols. Remote access to the data record, via phone modem communications, indicated the arrival of each plume over a few days and the subsequent geochemical reactions over the following weeks. Real-time availability of the monitoring record provided the information needed to initiate manual sampling efforts in response to changes in measured ground water quality that proved the method and characterized the screened portion of the plume in detail through time. The methods and the case study described are presented to document the process for future use.

Introduction

Manual sampling is a necessary component of ground water quality monitoring efforts, but it has technical and financial limitations. Most of the costs involved in operating a ground water monitoring network are for the labor and materials required for manual water-sample collection (Zhou 1996). Minimizing the cost of ground water monitoring programs by using statistical strategies to reduce sampling frequency may result in data that are inadequate to (1) determine representative mean (or median) values of water quality properties and constituents; (2) detect long-term trends, periodic fluctuations, and abrupt changes in water quality; and (3) identify the accuracy of the resulting estimates of the trends (Johnson et al. 1996; Zhou 1996). Process automation is an alternative to manual methods and automated methods have been used to monitor storm water, waste water, and ground water remediation installations. However, searches of the literature, ground water monitoring equipment supply catalogs, and patent records did not reveal any automated monitoring devices or processes that meet currently accepted ground water quality sampling protocols. Therefore, the USGS developed the process and the prototype described in this paper under a technology development program. The purposes of this paper are to describe the automated process for monitoring ground water quality properties and constituents using established sampling protocols, and demonstrate the utility of this

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process using a case study. Although the USGS automated ground water monitoring process can be adapted to follow most manual sampling protocols using commercially available equipment in a variety of sampling wells, this paper documents one case study using USGS manual sampling protocols and a particular set of equipment to introduce this automated ground water quality monitoring process.

The automated ground water monitoring process described here was conceived to determine maximum and minimum contaminant concentrations at a remote study site where many small, rapid, and discrete inputs of contaminated water would infiltrate to ground water from a surface water discharge pipe. The process was tested by manual and laboratory check measurements using a prototype installed at a USGS research site on Cape Cod, Massachusetts.

Automated systems have demonstrated great utility and cost savings by increasing the quantity and quality of data collected while decreasing labor and material costs (Jolley and Rivera 1989; Webster 1990; Chiron et al. 1995; Igarashi et al. 1995; Whitfield 1995; Church et al. 1996). Automated systems can increase data density because repeated measurements do not necessarily add costs. The increased data density enables identification of seasonal cycles, transient events, and noise in the data record (Whitfield 1995). Well-designed automated systems increase data reliability by incorporating feedback or alarm systems that can alert human operators to problems and/or select an alternative course of action to solve or bypass problems detected by system logic. Data from an automated system are stored electronically to facilitate their access and interpretation. For example, automated process-flow monitoring of production wells at dispersed or remote sites in the oil and gas industry has produced cost savings by reducing site visits for manual sampling, by increasing system efficiency using feedback and alarm systems, and by generating electronic production records (Amocams Systems Engineering 1989; Fink 1995).

Historically, passive monitoring devices have been used for automated ground water quality monitoring. These passive monitoring devices use a data logger to record measurements from a water-quality probe (or probes) suspended in a well to collect ambient data at a preset frequency. However, almost all scientific and regulatory assessments of ground water quality are based in-part upon the analysis of water samples withdrawn from a well. Thus, there are many questions about the comparability of the passive monitoring record obtained from an automatic-monitoring probe and the results from analysis of water samples obtained from a well.

The complex physical and chemical processes that affect the ground water quality monitored are unique to each monitoring well and vary with time. Studies of these processes raise questions about the validity of the water quality data obtained by passive monitoring probes. Experimental data indicates that the inorganic chemistry of water standing in a well for as little as 3 weeks can change measurably (Gillham et al. 1985). Temperatures, pH, oxidation reduction potentials, and total dissolved-solids concentrations of stagnant borehole water can differ from the water in the surrounding aquifer (Herzog et al. 1991). Rust and scale on well construction materials, bacterial activity in the well, and relatively rapid interactions with the atmosphere such as volatilization of volatile-organic compounds or effervescence of dissolved gases, will affect the quality of water that remains in the well for an extended period (Herzog et al. 1991). The quality of water measured in a well is dependent upon the physical and chemical heterogeneity in the interval of the aquifer screened by a well, flow and transport in the well, and possible skin effects at the well-aquifer interface (Reilly and LeBlanc 1998). Experimental data and modeling studies have demonstrated that ambient borehole flow can redistribute water and solutes within the well and the surrounding aquifer (Church and Granato 1996; Reilly et al. 1989). Information from periodic manual sampling events during a comparative test of active and passive automated monitoring methods indicates that passive measurements are substantially biased in relation to measurements made using standard manual sampling protocols, even in short-screen water-table monitoring wells (Smith and Granato 1998).

Since the ground water and aquifer materials surrounding each monitoring well have unique physical and chemical characteristics that can change with time, there will always be some debate about the proper sampling frequency, methods, and protocols appropriate for a given site. Consistant use of sampling equipment and purging protocols appropriate to a site are necessary to obtain consistent measurements that are representative of aquifer-water quality (Herzog et al. 1991; Koterba et al. 1995; Stone 1997). To obtain consistent and representative measurements, automated monitoring techniques should follow the same protocols selected for manual sample collection.

Robowell: The Process

Robowell is an automated process that was developed and tested by the USGS to provide a method for monitoring ground water quality that meets the protocols expected for manual sampling, and yet does not incur high labor and laboratory costs. The process embodies a series of programmed instructions that activate the equipment on a preset schedule to monitor and adjust the status of the system, as it purges the well and records measured values. If the system is functioning properly, water-quality properties and constituents are monitored and recorded until purge criteria are met. An example of one implementation of the Robowell process is shown in Figure 1. Typically, a system using the process would (1) activate itself as programmed, (2) perform a series of self tests, (3) measure the water level, (4) calculate the purge volume, (5) measure and record values of water quality properties and constituents during the purge cycle, (6) determine and record the final values of the properties and constituents, and (7) return to an inactive mode. If errors are detected, the system records error codes with measured values for the sampling interval before returning to the inactive

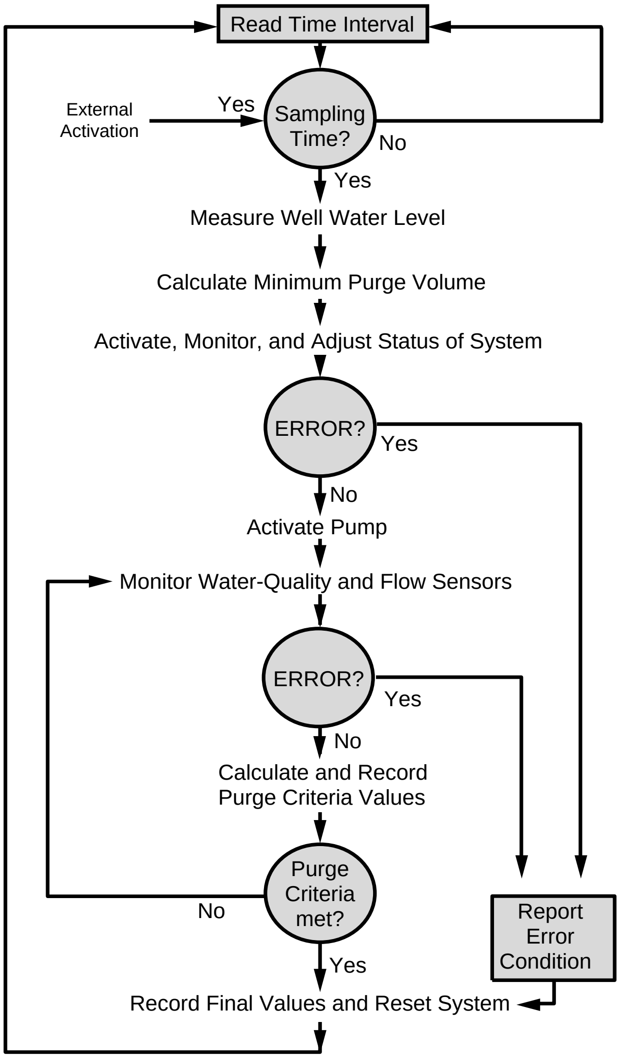

Figure 1. Generalized example of a process flow-chart for the automated ground water monitoring system.

mode. The system is controlled by a program that uses information from system feedback, water-quality measurements, and the internal clock to automatically control the process. Normal operations can be suspended or modified in response to errors in system feedback, remote control through a communications link, or direct control by technical staff maintaining the system.

The Robowell process is better than existing automated ground water monitoring systems because it is designed to meet rigorous ground water sampling protocols. These protocols require monitoring and recording of properties and constituents in water pumped from a well or multilevel sampler until purge criteria have been met (Herzog et al. 1991; Koterba et al. 1995). Measured values of each water-quality property and constituent are recorded during the purge cycle to document that final recorded values may be considered representative of water in the aquifer. Therefore, measurements made by the Robowell process are directly comparable to measurements made during manual sampling events using the same protocols.

The Robowell process can identify changes in ground water quality on a real-time basis without the cost of sample collection, processing, and laboratory analysis. Properties such as water temperature, specific conductance, and pH are indicators of ground water quality (Hem 1992), and therefore, changes in these properties indicate changes in ground water quality. A record of relatively frequent measurements of water-quality properties and/or constituents from a ground water monitoring site may provide the context for the interpretation of periodic discrete samples collected for laboratory analysis. This record may be used with analysis of the discrete samples to identify an abrupt arrival of a contaminant plume, trends caused by a diffuse source of contaminants, or an analytical error in a discrete sample. Once the hydrologic and geochemical processes and time scales at a site are reasonably well assessed, the need for discrete samples for laboratory analysis can be substantially reduced without loss of critical information. Detection of substantial changes in measured values by remote query will prompt a visit to the field installation for manual measurements. Independent manual field measurements and recalibration of the monitoring probes with a separate measuring device resets the system and further verifies recorded values. If changes in water quality are substantiated by calibration and independent manual field measurements, a sample may be collected for further documentation by laboratory analysis. The automated process can supply information needed to decide when the collection of a water sample for laboratory analysis would best meet the objectives and the quality assurance/quality control (QA/QC) design of the monitoring effort.

The automated process is designed so that it can be tailored for different applications. Purge criteria appropriate for different types of chemical constituents, sampling installations, and hydrogeologic regimes (Robin and Gillham 1987; Herzog et al. 1991; Koterba et al. 1995) can be used, and changes in purge criteria can be accommodated as new ground water sampling information becomes available. The process is designed so that sampling equipment and instrumentation can be selected on the basis of the nature of the contaminants to be detected, the hydrogeology of each site, and site logistics such as available power and communications (Granato and Smith 1998). Also, the process--if operated from a local base station--can be used to monitor one or several closely spaced wells or multilevel sampling ports.

Purge volume is a concern because of the potential purge-water disposal costs (Stone 1997). The methods chosen to dispose of purge water depend upon the purge criteria selected, the mission of the monitoring installation, the nature of the contaminants to be detected, the hydrogeology of each site, site logistics, and local regulations. Because the automated ground water monitoring process makes measurements, calculations, and decisions almost instantaneously, it will purge less water than a human operator following the same protocols. Also, this process has been designed with feedback loops to stop the purge and flag the data when the purge criteria have not been established within a

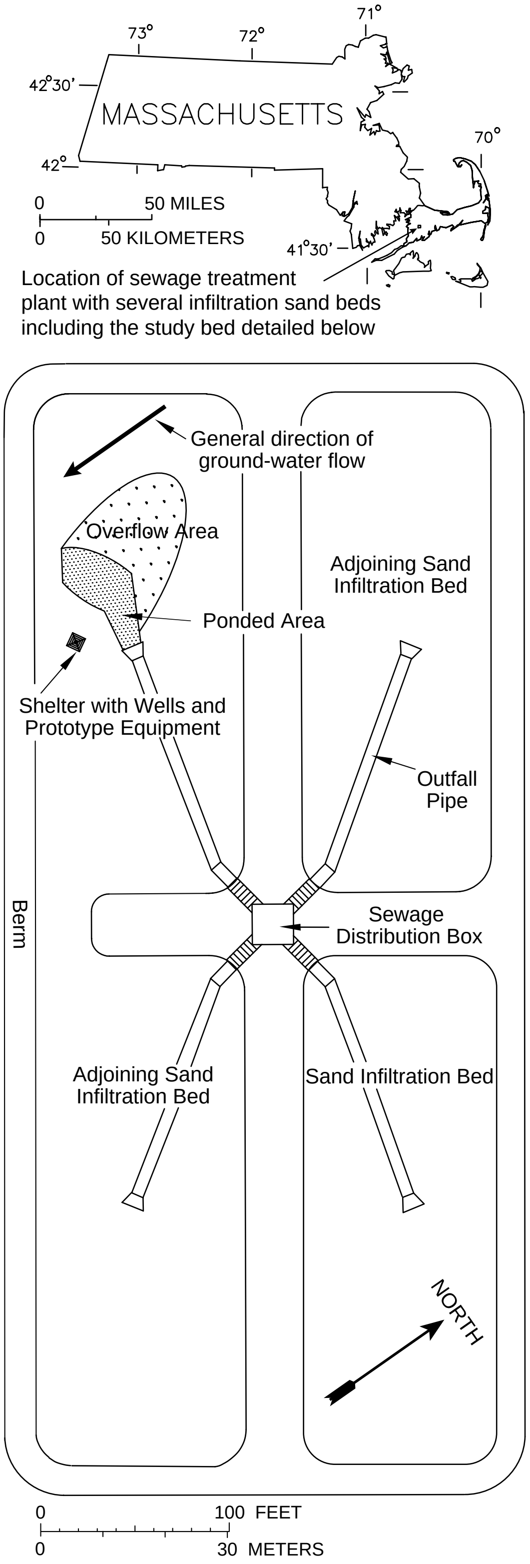

Figure 2. Map showing the study area and features of the study site, including the prototype equipment shelter, the impoundment, the overflow area, and features of the sand infiltration beds at the Massachusetts Military Reservation, Cape Cod, Massachusetts.

defined time period and/or within a defined purge volume. Primarily, the mission of the monitoring installation and nature of the contaminants to be detected establish the fate of the purge water. If the automated monitoring process is used as a sentry well to detect the arrival of a plume of contaminants, or if the contaminants being studied are not hazardous, then these relatively clean waters can be discharged to the land surface, or to a small leach field downgradient of the monitoring well. If the contaminants are hazardous, the purge water can be barreled for disposal. Also, a sentry well can be programmed to actuate a valve to divert purge water from local disposal to a collection barrel once contaminants are detected and to call a human operator once the barrel is near full capacity. If permissible, the purge volume can be reinjected back into the aquifer in a second well just downgradient of the monitoring well's capture zone using existing technology (Cardoso-Neto and Williams 1996). When local disposal of purge water is an option, the hydrogeology of each site is an important consideration. Also, the thickness of the unsaturated zone and the direction of ground water flow must be considered to prevent recycling of the purge water into subsequent measurement cycles. Purge water should be disposed in accordance with applicable regulations.

Case Study

A Robowell prototype was installed to test the technology at the U.S. Geological Survey Toxic Substances Hydrology Program Research Site (LeBlanc et al. 1991) in a sand infiltration bed of a sewage-treatment plant on the Massachusetts Military Reservation, Cape Cod, Massachusetts (Figure 2). The wells for the prototype were drilled at a study site on a sand infiltration bed used for the disposal of effluent from a sewage-treatment plant in the process of being decommissioned. Two events causing geochemical changes would occur during the study period as a result of the decommissioning of the sewage plant: (1) a large pulse (about 8.7 million liters) of partially treated sewage effluent would be applied to the infiltration bed; and (2) the solids remaining in the treatment tanks would be limed and pressed, producing another large pulse (about 5.3 million liters) that would be applied to the infiltration bed, producing two distinctive plumes of sewage effluent in ground water.

The prototype system was tested at this research site for several reasons. The expected changes in ground water quality caused by the two pulses of the effluent and subsequent cessation of effluent application would provide specific events to be monitored over a wide range of geochemical conditions. The unconsolidated deposits of sand and gravel in the area form a permeable, unconfined (water table) aquifer that is favorable for a short-term ground water quality investigation, because the hydrologic and chemical characteristics of this aquifer are well studied and well defined (LeBlanc et al. 1991).

Description of Site and Equipment

Two test wells and an equipment shelter housing the electronics, instrumentation, equipment, and hardware

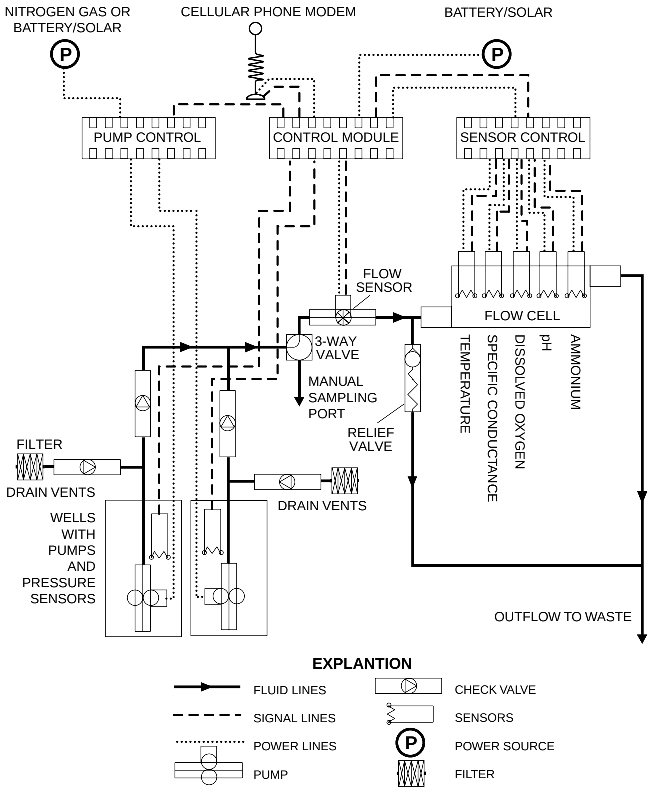

Figure 3. Schematic diagram of the prototype system showing the flow train and equipment used at the test site.

for the prototype were emplaced in a sand infiltration bed about 6 m downgradient of an impoundment constructed to form a line source of ponded infiltrating-water for the study (Figure 2). A semi-elliptical overflow area in the bed behind the impoundment was flooded when flow rates from the discharge pipe exceeded the infiltration capacity of soils in the impoundment. Two 5-cm diameter polyvinyl-chloride wells were emplaced, one screened from about 1.5 m above to 1.5 m below the water table (about 7.3 m below land surface) and another screened from about 1.5 m to 3 m below the water table (USGS wells SDW 479-0028 and SDW 479-0033, respectively).

The system schematic (Figure 3) indicates the flow train and equipment used in this prototype. The system utilized a Campbell Scientific Incorporated (CSI) CR10 data logger as the control module for the process and a CSI SM192 solid-state storage device to store data. Because electric and phone services were not readily available, batteries recharged by solar panels were used to power the controllers and other instruments, nitrogen gas was used to power the QED bladder pumps through a pneumatic logic controller, and a CSI DC112 telephone modem was used for communications. The water level in the water-table well was monitored with a Keller pressure transducer (operating range of 0-0.176 kg per square cm). A hand-operated Plastomatic three-way valve was placed near the beginning of the flow train to divert water for manual collection of samples. A 1.27 cm Data Industrial flow sensor was used to monitor the flow rate of ground water pumped through the system during purge and recording cycles. A Hydrolab Multiprobe, with a flow cell, was used as a control module for the water temperature, pH, specific conductance, dissolved oxygen, and dissolved ammonium probes under data logger control. Other instruments not shown in Figure 3 were used to monitor nitrogen pressure, shelter air temperature, battery voltage, and other system parameters.

Purge Criteria

Several purge criteria were used while developing the prototype. The first purge criterion simply required evacuation of at least three borehole volumes of water (theoretically, to remove stagnant borehole water and to sample water representative of the aquifer in the screened zone). The system monitored and recorded water level, water temperature, pH, specific conductance, and dissolved oxygen to check the assumption that geochemical stability had been achieved after three borehole volumes had been pumped. The second purge criterion required physicochemical stability (theoretically, to indicate that the sample water was representative of the aquifer in the screened zone). Water temperature, pH, specific conductance, and dissolved oxygen were measured and recorded until the variance of the last 5 readings for each property and constituent was within a predetermined range (0.2 degrees C for temperature, 0.1 units for pH, 3 percent for specific conductance, and 0.3 mg/L for dissolved oxygen) around the average of the last 5 recorded values. The third purge criterion followed the ground water sampling protocol developed for the USGS National Water-Quality Assessment Program which was also based upon the assumption that geochemical stability would indicate representative sampling from the aquifer in the screened zone (Koterba et al. 1995). Before the pump was activated, the system measured the water level and calculated the volume of water standing in the well using the inside diameter of the well. The flowmeter monitored the pumping rate during purging and sampling. Water temperature, pH, specific conductance, dissolved oxygen, and ammonium were measured and recorded every 3 minutes during the purge. The well was considered purged when the values of 5 successive measurements of these properties and constituents fell within the previously specified ranges for physicochemical stability around the median of the last 5 recorded values (Figure 4). As specified by the protocol (Koterba et al. 1995), the final measurement of pH and the median of the last five measurements of each of the other properties and constituents were recorded as the final value.

Measurement and Recording Frequency

Measurements of water-quality properties were made at different time intervals on the basis of expected changes in ground water quality. Typically, a daily time interval was used except during times of abrupt water-quality changes, when measurements were taken every 12 hours. Recorded data were either downloaded from the control and recording device in the field with a laptop computer or retrieved remotely by use of the cellular

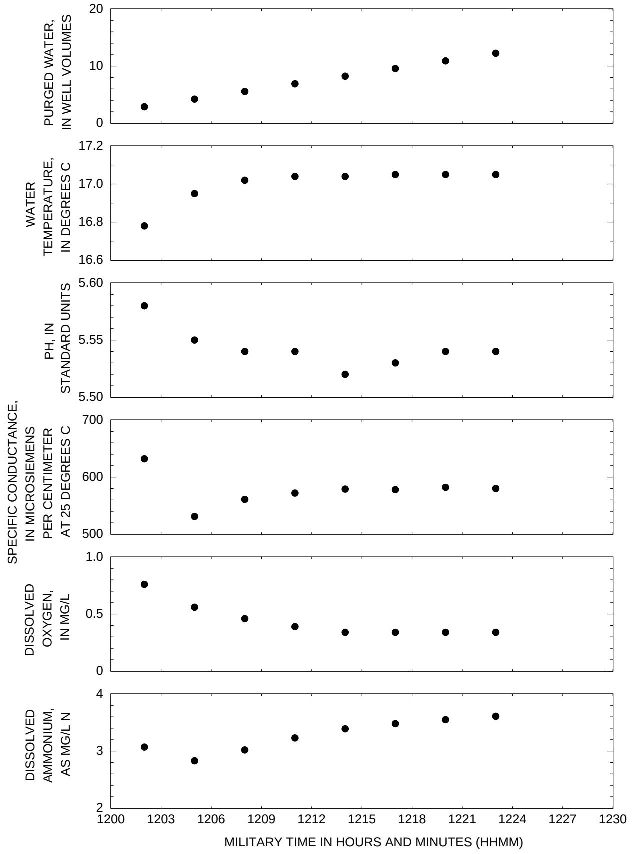

Figure 4. Real-time purge data collected on October 6, 1996 by the automated ground water monitoring process at well SDW 479-0028, Cape Cod, Massachusetts.

telephone modem. The prototype operated successfully from May 10 to November 13, 1996, and sufficient data were collected to demonstrate that the data obtained by the automated method were equivalent to dataa obtained by manual sampling methods using the same protocols (Figure 5).

Quality Assurance/Quality-Control Program

The quality-assurance/quality-control program was based on periodic comparative measurements using instrument calibration readings and measurements by independent field probes, as well as manual sampling to make field measurements and collect duplicate and equipment-blank samples for analysis at the USGS National Water Quality Laboratory (NWQL). Calibration and comparative measurements, taken while the system was manually controlled after determining post-purge stability, were used to assess system performance about every 2 weeks. Comparative water-quality measurements were made in an overflowing aspirated bottle connected to the three-way valve in the main flow line. Comparative water temperature measurements were recorded using a hand-held alcohol thermometer certified by the National Institute of Science and Technology (NIST). Comparative specific conductance and pH measurements were made using laboratory-calibrated field meters (Orion 290A and Orion 124), and in water samples sent to the NWQL. Dissolved-oxygen measurements greater than 0.9 mg/L were determined by Winkler titrations, and measurements of dissolved oxygen less than 0.9 mg/L were determined by a CHEMetrics kit (K-7501). During the study period, the pH remained less than 9, therefore almost all ammonia in solution would be present as ammonium ions (Hem 1992). Measurements of dissolved ammonia/ammonium as nitrogen determined by a CHEMetrics kit (K-1510) and by the NWQL do not differentiate between species. Samples for analysis of dissolved ammonia as nitrogen, and other nitrogen species also were collected and sent to the NWQL about every 2 weeks as duplicates to verify field measurements and to quantify nitrogen speciation. Equipment blanks--samples of deionized water processed through all pumps and wetted parts of the system--were analyzed at the NWQL for concentrations of major ions and nutrients. These blanks were collected prior to installation of the monitoring system to ensure that the sampling system would not measurably change properties and constituents of ground water. Recalibration of water-quality system probes and routine maintenance was performed at frequencies suggested by the probe manufacturers. Also, data were regularly retrieved through remote communications and examined for changes or trends in water-quality measurements. Changes or trends in water-quality measurements prompted a field visit to substantiate the changes with independent manual measurements and/or to recalibrate and maintain the water-quality probes.

Comparison of Automated and Manual Measurements

Automated water-quality measurements and manual field and laboratory measurements measured in the water-table well (SDW 479-0028) correlated closely for all properties and constituents (Figure 5). Automated measurements of pH were slightly but consistently lower than laboratory and field check measurements. The small bias in automated pH measurements were caused by pressurization of the membrane in the pH probe by the elevated water pressure in the flow cell. Close correlation between automated and manual measurements was facilitated by the remote communication capability through the modem. System measurements could be examined at any time from the office via the modem, and any unexpected changes in water quality prompted a site visit for manual calibration and testing. For example, a field visit confirmed that the ammonium probe had failed when the automated system indicated substantial increases in ammonium concentrations in mid-July. The probe was replaced and the period during which the probe was malfunctioning was shown as one of "no record" (Figure 5).

The automated monitoring system successfully documented the rapid and short-term changes in hydrologic and geochemical conditions resulting from the discharge of the sewage-plant effluent. The large discharge events and normal to high monthly precipitation totals were not notable in measured water levels because of the high hydraulic conductivities of the aquifer (Reilly and LeBlanc (1998), report values of horizontal

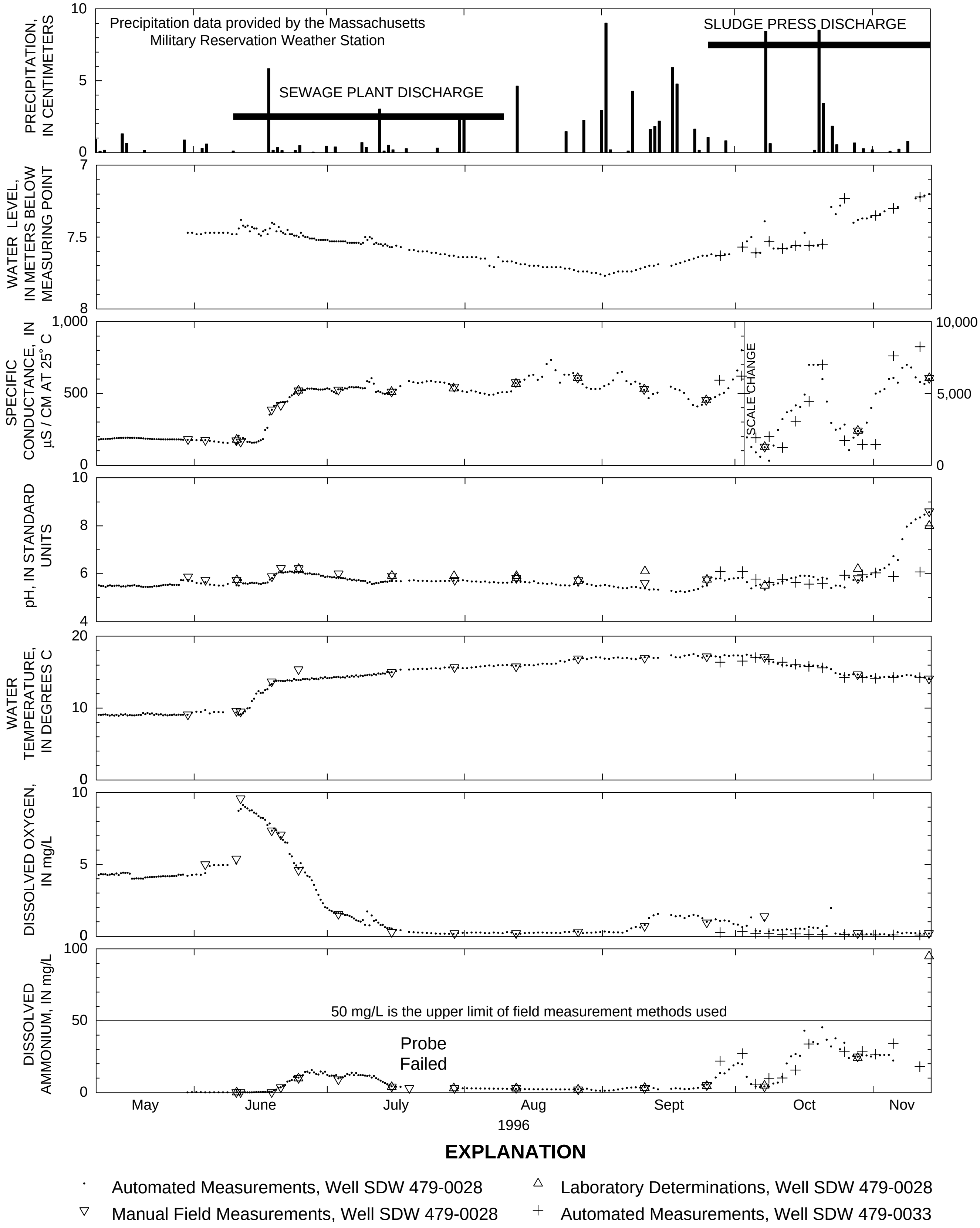

Figure 5. Automated and manual measurements of ground water quality from wells SDW 479-0028 and SDW 479-0033, Cape Cod, Massachusetts.

hydraulic conductivity that range from 24 to 295 meters per day in the same aquifer near the study site). However, the effect of sewage discharge on ground water quality properties and constituents measured by the automated system aand confirmed by manual check measurements and laboratory analysis of samples from the water table well (SDW 479-0028) was relatively rapid (about 5-6 days for specific conductance, about 8-10 days for pH and ammonium, about 3 days for water temperature, and about 1 day for dissolved oxygen). Automated measurements of water-quality properties and constituents in the adjacent well (SDW479-0033), which screened the next 1.5 m interval below the water table well, showed similar variations (Figure 5) and demonstrated the ability of the system to monitor more than one well or multilevel sampling port in the same vicinity.

Summary

The Robowell process can identify changes in ground water quality on a real-time basis by providing data comparable to manual measurements on a frequent basis without the cost of sample collection, processing and analysis. Robowell is an automated process for monitoring and recording values of selected ground water-quality properties and constituents by pumping a well or multilevel sampler using preselected purge criteria that would meet protocols expected for manual sampling. The Robowell process can be used to sample different monitoring wells and to follow different purge protocols. The methods and the case study described are presented to document the process for future use. Automated systems have demonstrated great utility and cost savings by increasing the quantity and quality of data collected while reducing sampling costs.

The Robowell prototype was installed on a sewage-effluent infiltration bed in a well studied unconfined sand and gravel aquifer on the Massachusetts Military Reservation, Cape Cod, Massachusetts. The prototype utilized purge criteria recommended in ground water sampling protocols developed for the USGS National Water-Quality Assessment Program. Water temperature, pH, specific conductance, dissolved oxygen, and ammonium were recorded every 3 minutes during the purge. The well was considered purged when the values of five successive measurements of the preselected properties and constituents fell within specified ranges for physicochemical stability around the median value. The prototype operated successfully from May 10 to November 13, 1996, during which two large pulses of treated sewage effluent were discharged to the aquifer. Quality-assurance/quality-control data obtained during operation of the prototype demonstrated that the data obtained by the automated method was equivalent to data obtained by manual sampling methods using the same protocols. Once such a system is put in practice, substantial changes or trends in measured water-quality properties and constituents could be used to prompt manual measurements to verify these changes or trends in water quality.

The U.S. Geological Survey has submitted a patent application for the automated ground water monitoring system and method. For more information about this and other available technologies please contact the U.S. Geological Survey Technology Enterprise Office.

Acknowledgments

We would like to thank Denis LeBlanc and Timothy McCobb of the U.S. Geological Survey Toxic Substances Hydrology Program for logistic support and detailed hydrogeologic information about the test site. Thanks are also due to Francis Creighton and Robert Burton of the Massachusetts Military Reservation for information about the decommissioning of the sewage-treatment plant and their cooperation during the study. We would also like to thank reviewers within the U.S. Geological Survey, and reviewers for the journal for constructive comments and suggestions.

Editor's Note: The use of brand names in peer-reviewed papers is for identification purposes only and does not constitute endorsement by the authors, the U.S. Geological Survey, or the National Ground Water Association.

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The automated ground water monitoring project web page is available on the internet at:

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In Well Purging – Burge

ENVIRONMENTAL RESTORATION PROGRAM

BURGE TRICHLOROETHENE MONITORING SYSTEM EVALUATION REPORT
SITE 14 GROUNDWATER EXTRACTION AND TREATMENT SYSTEM
OPERABLE UNIT NO. 2
EDWARDS AIR FORCE BASE
CALIFORNIA

JULY 2006

Prepared for

95th AIR BASE WING
ENVIRONMENTAL RESTORATION BRANCH (95 ABW/CEVR)
EDWARDS AIR FORCE BASE, CA 93524-8060

and the

DEPARTMENT OF THE ARMY
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REPORT DOCUMENTATION PAGE

PREFACE

This document is the Evaluation Report for the Burge Trichloroethene Monitoring System at the Site 14 Groundwater Extraction and Treatment System, South Base, Operable Unit No. 2, Edwards Air Force Base, California. The evaluation report presents the field test results of the Burge Trichloroethene Monitoring System at the Site 14 Groundwater Extraction and Treatment System. This document has been prepared for the United States Air Force 95th Air Base Wing, Environmental Restoration Branch (95 ABW/CEVR) according to the requirements of Contract No. DACA05-01-D-0006, Task Order No. 0053, between the United States Army Corps of Engineers (USACE), Sacramento District, and Earth Tech, Inc. (Earth Tech).

The USACE project manager is Susan Yarbrough. The 95 ABW/CEVR project manager is Paul Schiff The Earth Tech program manager is Ray Sugiura and the project manager is Karl Eggers.

Approved:

Ray Sugiura, Program Manager
RG California No. 3579

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LIST OF ABBREVIATIONS AND ACRONYMS

<	less than
μg/L	micrograms per liter
95 ABW/CEVR	95th Air Base Wing, Environmental Restoration Branch
AC	alternating current
AFB	Air Force Base
AFCEE/ERD	Air Force Center for Environmental Excellence, Environmental Restoration Division
AFFTC/EMR	Air Force Flight Test Center, Environmental Restoration Division
AGMS	automated groundwater monitoring system
DC	direct current
ERP	Environmental Restoration Program
GAC	granular activated carbon
GETS	groundwater extraction and treatment system
LTM	long-term monitoring
NA	not applicable
NC	not calculated
NS	not sampled
O&M	operation and maintenance
OU2	Operable Unit No. 2
PC	personal computer
QAPP	Quality Assurance Project Plan
RPD	relative percent difference
STL	Severn Trent Laboratories
TCE	trichloroethene
U.S.	United States
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

This evaluation report presents the results of field tests conducted on the Burge Trichloroethene (TCE) Monitoring System at the Site 14 Groundwater Extraction and Treatment System (GETS), located at the South Base Fire Fighting Training Facility, Operable Unit No. 2, Edwards Air Force Base, California. The monitoring system was used to measure the concentration of TCE in the influent and effluent of the Site 14 GETS. Testing was performed over an approximately seven month period, from April 2004 through October 2004.

The project objectives were to: 1) evaluate the mechanical durability and operation and maintenance (O&M) requirements of the monitoring system; 2) determine the accuracy of the monitoring system; and 3) assess the usefulness of the monitoring system for routine O&M at an operating groundwater treatment system. Based on testing of the system, the following conclusions were reached:

- The system was capable of being operated remotely. However, failure of remote communications occasionally prevented the system from being operated on a weekly basis. In addition, costs were incurred to restore/maintain the remote communication system
- No repairs to the sensor were required. However, ancillary components required repair or replacement. Maintenance of the sensor was limited to refilling the reagent and standard solutions, and was performed during repair of ancillary components
- Accuracy of the monitoring system, as determined by analyzing mid-calibration samples, was within the acceptable limits 55 percent of the time. Compared to laboratory results for the treatment system influent and effluent, the monitoring system was within the acceptable limits 78 percent of the time and 0 percent of the time, respectively.

In summary, the Burge TCE Monitoring System appears capable of accurately measuring the concentration of TCE in the treatment system influent. However, insufficient detections above the laboratory and monitoring system reporting limits for the treatment system effluent prevented a full assessment of the utility of the system for measuring low contaminant concentrations. To ensure confidence in the monitoring system results, trained personnel must review all calibration results to ensure they are within acceptable limits as well as review the monitoring results to verify that they are reasonable. If any results were outside predefined limits, an additional monitoring event would need to be performed.

1.0 INTRODUCTION

This evaluation report presents the results of field tests conducted on the Burge Trichloroethene (TCE) Monitoring System at the Site 14 Groundwater Extraction and Treatment System (GETS), located at the South Base Fire Fighting Training Facility, Operable Unit No. 2 (OU2), Edwards Air Force Base (AFB), California (Figure 1-1). The monitoring system was used to measure the concentration of TCE in the influent and effluent of the Site 14 GETS. Testing was performed over an approximately seven month period, from April 2004 through October 2004.

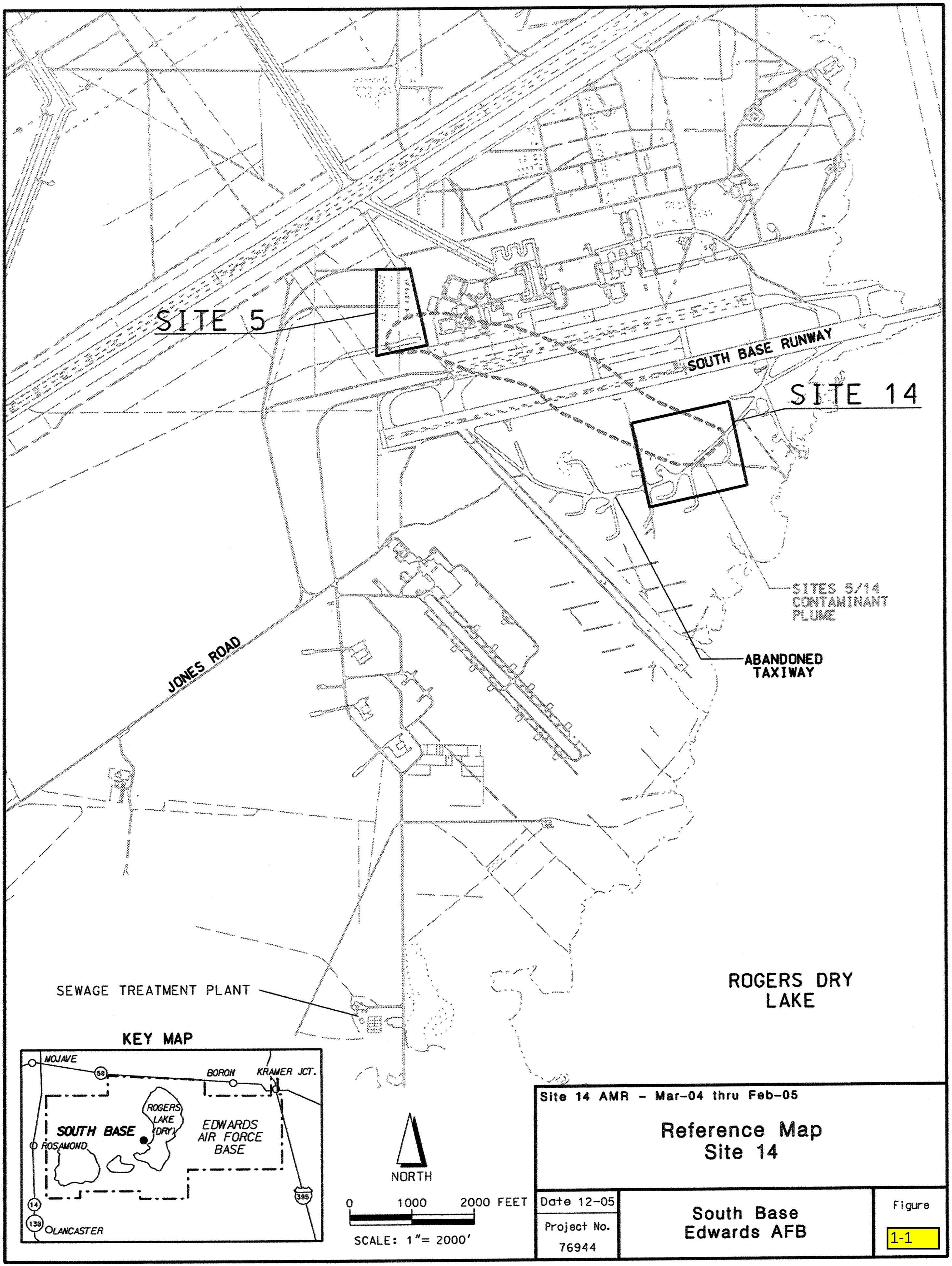
Testing of the Burge TCE Monitoring System at the Site 14 GETS was a follow up to a one-year field test performed at Site 19, located in Operable Unit No. 1, Main Base Flightline, Edwards AFB. Based on the Site 19 test (Earth Tech 2003b), it was determined that the monitoring system was not suitable for use at groundwater monitoring wells as part of the long-term monitoring (LTM) program due to operational requirements and the inherent long time periods between sampling events. However, it was recommended that the system be tested at a groundwater treatment system.

1.1 PROJECT OBJECTIVES AND SCOPE

The project objectives were to: 1) evaluate the mechanical durability and operation and maintenance (O&M) requirements of the monitoring system; 2) determine the accuracy of the monitoring system; and 3) assess the usefulness of the monitoring system for routine O&M at an operating groundwater treatment system.

The scope of work included

- Installing the Burge TCE Monitoring System at the Site 14 GETS
- Setting up a communications system so that the monitoring system could be operated remotely
- Operating the monitoring system on a weekly basis for a period of six months
- Preparation of this evaluation report to include a copy of the Burge Environmental submittal to the United States Environmental Protection Agency (USEPA) for certification of the monitoring system.



Site 14 AMR - Mar-04 thru Feb-05

Reference Map
Site 14

Date 12-05	South Base Edwards AFB	Figure
Project No. 76944		1-1

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1.2 PROGRAM BACKGROUND AND EVALUATION CRITERIA

The Burge TCE Monitoring System is being tested at Edwards AFB as part of the Edwards AFB Environmental Restoration Program In Situ Sensor Development Program. The purpose of this in situ sensor program is to eventually reduce the labor and analytical costs for conventional groundwater sampling. The in situ sensor program specifies that sensors be evaluated using the following criteria:

1. Mechanical Durability and O&M Requirements:
   - A. Evaluate whether the robustness and longevity of the sensor mechanism and housing meet minimum requirements for unattended operation of 3 months and operational lifetime of 2 years. Metal housing parts and fasteners should show no significant corrosion, and rubber or Teflon parts should show no significant degradation for prolonged periods. The minimum acceptable lifetime of field-replaceable housing components is 3 months.
   - B. Evaluate the O&M requirements of the sensor, the estimated period of time the sensor mechanism can operate before adjustment, calibration, replacement of parts, or replenishment of expendables. These factors will be evaluated by extended field deployment. The required maintenance schedule should be no more than quarterly.
2. Accuracy, Sensitivity, and Repeatability of Sensor Measurements:
   - A. Evaluate sensors for use as a screening tool versus more quantitative measurements. To evaluate the detection limits and sensitivity ranges of the sensors, they will be field deployed in locations that have known chemical types and concentrations (near the high- and low-detection limits of the sensor) to evaluate the accuracy of the predicted sensitivity ranges.
   - B. Compare concentrations measured by the sensor to fixed laboratory results. Evaluate the accuracy and repeatability of sensor measurements by collecting samples manually and sending to an off-site laboratory for analysis. If possible, the sensor will be calibrated against a known standard prior to measurement. The following criteria shall be evaluated:
     - a. Concentrations measured by the sensor should be within a range of 30 percent above and 15 percent below the analytical results measured by a fixed laboratory on samples collected concurrently.
     - b. Variation in laboratory results of samples collected from the same location at different times will be tracked for comparison with the variation in sensor measurements over time collected in the same location.
     - c. Sensor measurements should not vary by more than 20 percent from reading to reading and by no more than 20 percent per month (unless influenced by an active remediation system). Greater variation shall be verified by recalibrating the sensor or analyzing samples to determine if there has been any natural changes in the in situ contaminant concentrations. Self-calibrating sensors should measure a known concentration of the target compound to within ± 15 percent of the known compound.

3. Usefulness of Sensor for O&M and/or LTM Tasks:
    A. Evaluate whether the sensor could reduce O&M and/or LTM costs. The cost of capital expenditure and O&M for sensors and supporting equipment, when averaged over a maximum 5-year period, must be less than sampling and analysis costs.
    B. Data quality of sensor measurements must be sufficient to meet or exceed regulatory requirements for monitoring level data where sensor measurements are used in lieu of conventional sampling and analysis.

2.0 SYSTEM DESCRIPTION

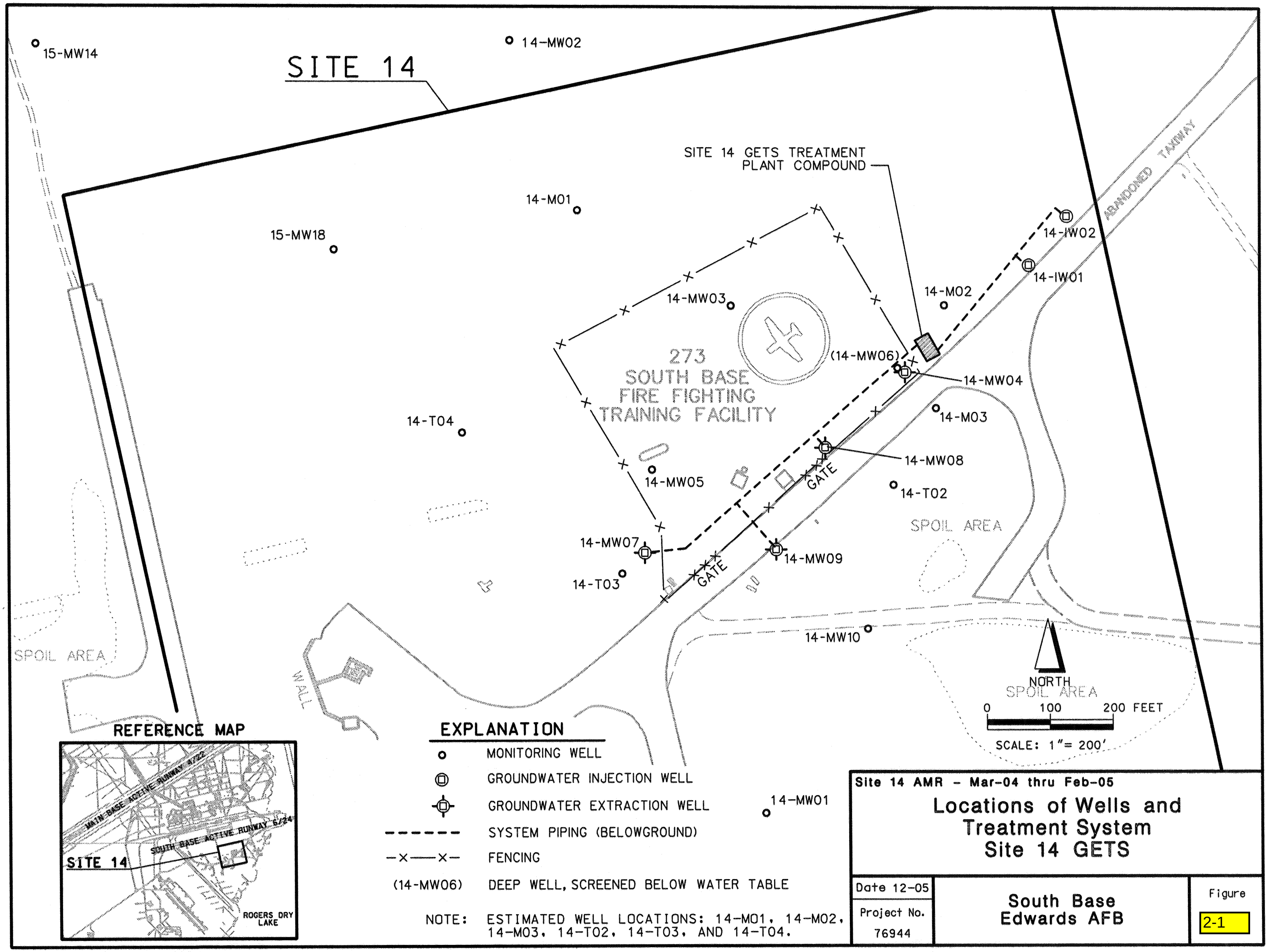
2.1 SITE 14 GETS DESCRIPTION

The Site 14 GETS consists of four groundwater extraction wells, a groundwater treatment system, and two injection wells. Figure 2-1 shows locations of the extraction and injection wells and the treatment system. The treatment system uses granular activated carbon (GAC) to adsorb TCE, as well as other organic contaminants that may be present in the extracted groundwater.

Figure 2-2 shows a simplified process flow diagram of the Site 14 GETS. The *Site 14 O&M Manual* (Earth Tech 2000) contains a detailed description of the system. Bottom-loading submersible pneumatic pumps P-100 through P-400 continually extract groundwater from Extraction Wells 14-MW04, 14-MW08, 14-MW09, and 14-MW07, respectively. Air compressor AC-6000 supplies compressed air to the submersible pneumatic pumps. A header pipe collects extracted groundwater and discharges it to equalization tank T-1000. The equalization tank fills until the ultrasonic level transmitter LT-1000 indicates that the tank has filled to the high-level set point. When this occurs, transfer pump P-2000 pumps groundwater from the equalization tank through influent filter F-3000, through two pressure vessels (C-4000 and C-4001) each containing a minimum of 1,000 pounds of GAC, through effluent filter F-5000, and, finally through a header pipe into Injection Wells 14-IW01 and 14-IW02 where the treated water is reinjected into the aquifer. Power to the transfer pump ceases when the water level in the equalization tank drains to the low-level set point. When power to the transfer pump ceases, injection of treated groundwater also ceases.

2.2 BURGE TCE MONITORING SYSTEM DESCRIPTION

This section presents a brief description of the Burge TCE Monitoring System. A more detailed description of the monitoring system is contained in the *Instruction Manual, HJ-100 Automated Ground-Water Monitoring System with TCE Sensor and Burge Sampler* (Burge Environmental Undated). Figure 2-3 shows the primary components of the monitoring system as installed at the Site 14 GETS. Photographs of the monitoring system as installed at Site 14 are contained in Appendix A-1.



EXPLANATION

○	MONITORING WELL
◙	GROUNDWATER INJECTION WELL
⊕	GROUNDWATER EXTRACTION WELL
- - - - - -	SYSTEM PIPING (BELOWGROUND)
—×——×—	FENCING
(14-MW06)	DEEP WELL, SCREENED BELOW WATER TABLE

NOTE: ESTIMATED WELL LOCATIONS: 14-M01, 14-M02, 14-M03, 14-T02, 14-T03, AND 14-T04.

Site 14 AMR – Mar-04 thru Feb-05

Locations of Wells and Treatment System Site 14 GETS

Date 12-05

Project No. 76944

South Base Edwards AFB

Figure 2-1

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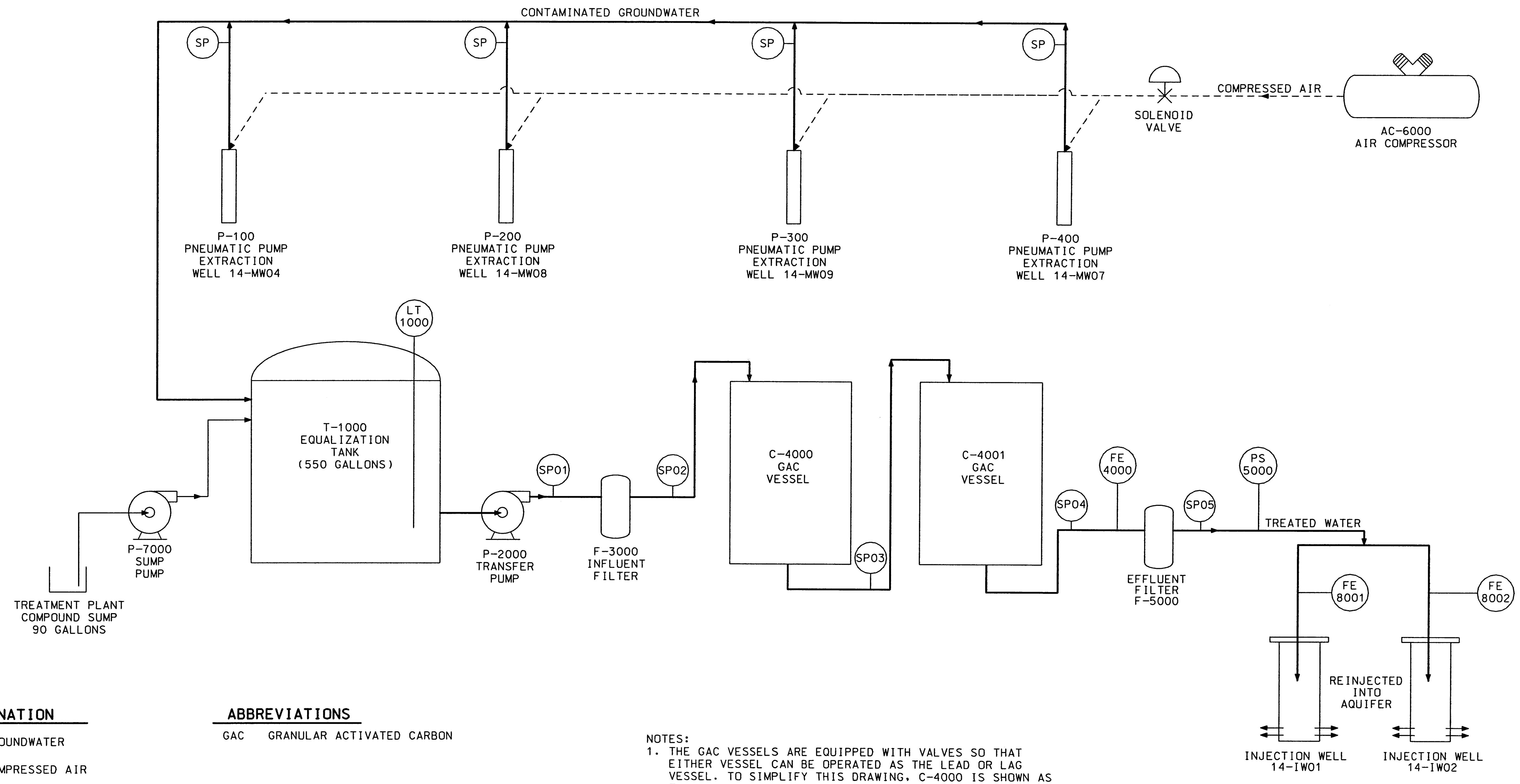


EXPLANATION

- → GROUNDWATER
- - - -► COMPRESSED AIR
- FE 4000 FLOW METER AND ID NUMBER
- LT 1000 LEVEL TRANSMITTER AND ID NUMBER
- SP01 SAMPLE PORT AND ID NUMBER
- PS 5000 PRESSURE SWITCH AND ID NUMBER

ABBREVIATIONS

GAC	GRANULAR ACTIVATED CARBON

NOTES:

1. THE GAC VESSELS ARE EQUIPPED WITH VALVES SO THAT EITHER VESSEL CAN BE OPERATED AS THE LEAD OR LAG VESSEL. TO SIMPLIFY THIS DRAWING, C-4000 IS SHOWN AS THE LEAD VESSEL AND C-4001 AS THE LAG VESSEL.
2. SEE THE PIPING & INSTRUMENTATION DIAGRAM CONTAINED ON SHEET 1 IN THE *SITE 14 OPERATION AND MAINTENANCE MANUAL* (EARTH TECH 2000) FOR ADDITIONAL DETAILS.

Site 14 AMR – Mar-04 thru Feb-05

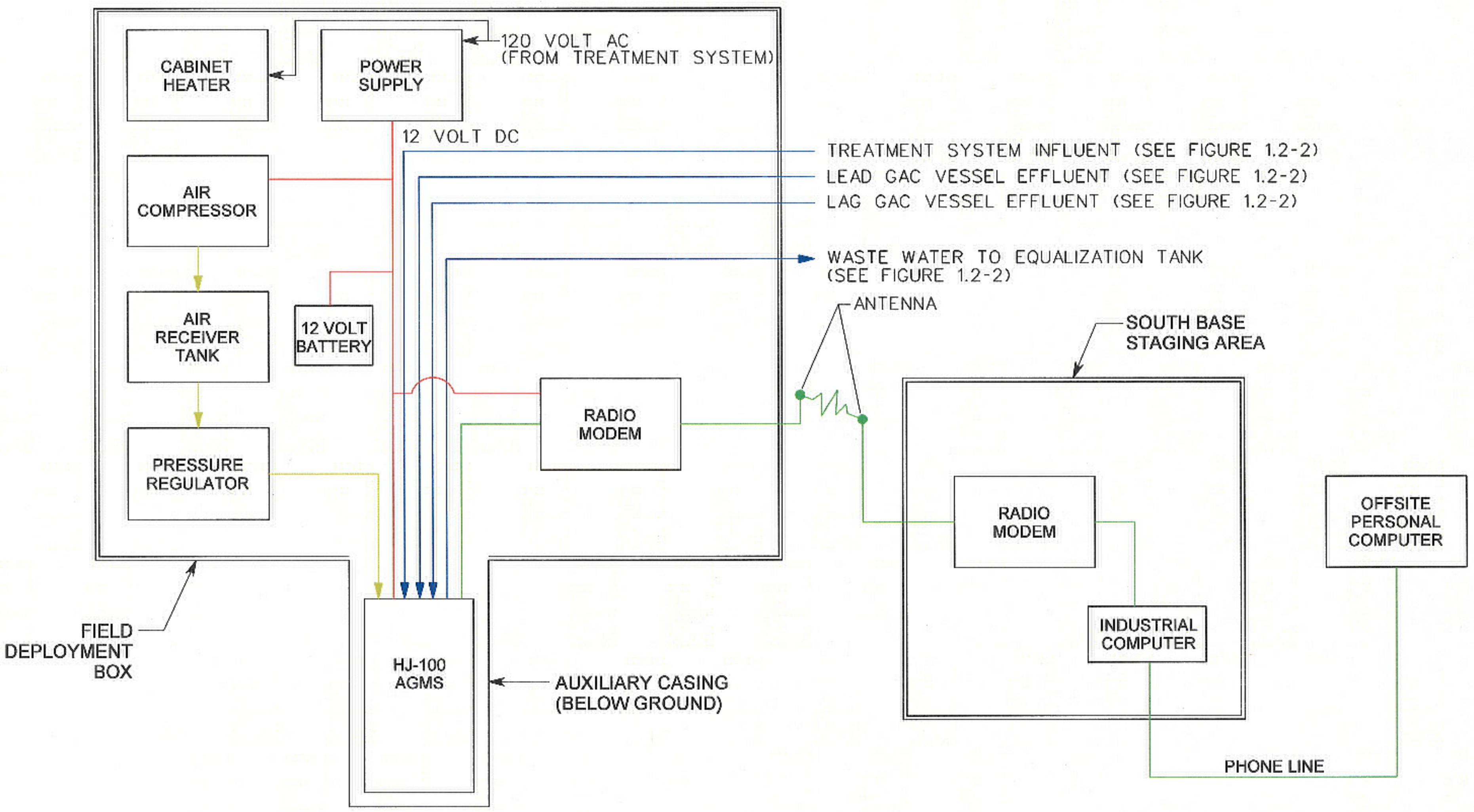
Process Flow Diagram
Site 14 Groundwater Extraction
and Treatment System

Date 12-05
Project No.
76944

South Base
Edwards AFB

Figure
2-2

EDWARDS\ 76944\B4909FGA.A01



LEGEND

— COMMUNICATION (2 WAY)

— 12 VOLT DC

— COMPRESSED AIR

— WATER

ABBREVIATIONS

AC	ALTERNATING CURRENT
AGMS	AUTOMATED GROUNDWATER MONITORING SYSTEM
DC	DIRECT CURRENT
GAC	GRANULAR ACTIVATED CARBON

Site 14 AMR Mar-05 thru Feb-06

Burge Trichloroethene
Monitoring System Components

Date 3-07

Project No. 86071

South Base
Edwards AFB

Figure 2-3

The central component of the monitoring system is the HJ-100 Automated Groundwater Monitoring System (AGMS), manufactured by Burge Environmental, Inc. of Tempe, Arizona. The AGMS is located in a belowground casing to protect exposed components and for temperature control, which is critical for accurate operation.

A field deployment box is positioned over the protective casing with a hole cut in the floor of the box to allow access to the AGMS. Contained in the field deployment box are a 12 volt deep cell battery, an air compressor, an air receiver tank, a pressure regulator, a radio modem, two solenoid valves, and a small carbon filter. Power to the system is provided by a 120 volt alternating current (AC) to 12 volt direct current (DC) power supply located in the control panel of the Site 14 GETS.

Data acquisition and control of the monitoring system is provided by a personal computer (PC) located inside the office trailer at Earth Tech's South Base staging area. The PC communicates with the AGMS via a pair of radio modems, one at the office trailer and one in the field deployment box. The PC is connected to a phone line via a phone modem allowing "remote" operation of the system from an offsite (i.e., remote) PC using the software program PC Anywhere.

3.0 FIELD PROCEDURES

3.1 BURGE TCE MONITORING SYSTEM OPERATION

At the beginning of each monitoring event, the AGMS is flushed for a set time period with blank water. The blank water is generated by passing treated water from the Site 14 effluent sampling port (sample port SP05 [see Figure 2-2]) through the small carbon filter located in the field deployment box. After flushing the system, the AGMS opens one of the two solenoid valves in the field deployment box, allowing the sample chamber to be filled to a preset level with the water to be sampled. A stirring rod then agitates the sample, causing TCE to partition into the headspace above the water sample. The gaseous TCE enters a microporous tube, referred to as the optrode, suspended in the headspace. Following a set time period, a Fujiwara reagent (3 percent tetrabutyl ammonium hydroxide in pyridine) is injected into the optrode while at the same time a pulsed-green light is passed through the optrode. The reagent reacts with the gaseous TCE, changing color from clear to red. A detector measures the attenuation (i.e., color change) of the light passing through the optrode until the reaction is complete (i.e., no further attenuation is measured). The rate of attenuation is directly proportional to the concentration of TCE in the sample.

After each analysis is completed, the liquid in the sample chamber is drained to a waste sump at the bottom of the AGMS. Compressed air then ejects the water from the sump to the Site 14 GETS for subsequent treatment. Lastly, the AGMS is flushed with blank water and purged with compressed air before the next sample is introduced.

The AGMS uses a three-point calibration curve (0 micrograms per liter [μg/L] [blank], 30 μg/L [mid], and 60 μg/L [high] TCE) to calculate the concentration of TCE in an unknown sample. The blank (water) is generated by passing treated water from the Site 14 GETS effluent sampling port through a small carbon filter. The mid- and high-calibration standards are generated in the AGMS by injecting a known volume of a TCE standard into blank water as the sample chamber is filled.

During field testing at the Site 14 GETS, the monitoring system was operated solely by Burge Environmental personnel. In most cases the system was operated remotely (i.e., from Burge Environmental's Tempe Arizona office). Burge personnel would access the PC at the South Base staging area to preprogram the date and time that the AGMS was to operate. At a later date, Burge personnel would again access the PC at the South Base staging area to review the data from the last monitoring event and program the next event. “Real time” remote monitoring was not performed because the monitoring system was typically programmed to operate at night to minimize any effect that high day time temperatures would have on monitoring results. Also, each analysis of a water sample requires approximately ½-hour to 1-hour to complete. On several occasions, when Burge personnel were on site to perform maintenance, the system was operated locally (i.e., directly from the PC at the South Base staging area).

On occasion, a calibration check sample, which is identical to the mid-calibration standard (made by the same method to the same concentration as the mid-calibration standard), was analyzed after a group of water samples had been analyzed to assess system performance. This sample is referred to as a “final mid-calibration sample”.

3.2 SITE 14 GETS OPERATION

The Site 14 GETS was operated by Earth Tech personnel with no changes made to the normal O&M procedures. In general, the system was monitored once per week. As part of the routine O&M of the Site 14 GETS, samples of the treatment system influent and effluent were collected monthly by Earth Tech personnel in accordance with procedures presented in the *Site 14 Treatability Study Work Plan* (Earth Tech 1998). These water samples were analyzed by Severn Trent Laboratories (STL), Los Angeles in accordance with the *Quality Assurance Project Plan (QAPP), Addendum for Monitoring Level Data* (Earth Tech 2003a). To the extent possible, the date that these water samples were to be collected were communicated to Burge personnel so that they could program the Burge TCE Monitoring System to operate on the same date.

4.0 RESULTS AND DISCUSSION

4.1 MONITORING SYSTEM OPERATION AND MAINTENANCE

Table 4-1 presents a summary of Burge TCE Monitoring System operations. The testing program at the Site 14 GETS envisioned operating the Burge TCE Monitoring System at least once per week. However, the monitoring system was operational on only 20 of the 30 weeks available between 27 March 2004 and 22 October 2004, or 67 percent of the time. The system was not operational for 10 weeks (33 percent of the time) due to failure of the remote communication system on three occasions, overheating of the air compressor, and a programming error.

Repairs were performed by Burge Environmental personnel as needed. The repairs included rerouting the power cable, replacing the Teflon waste discharge line, replacing the Teflon sample lines, and installing a fan to cool the air compressor. The power line, waste line, and sample lines were damaged by rodents chewing on them.

Maintenance of the system was limited to refilling the calibration standard and reagent bottles. The bottles were refilled on two occasions by Burge Environmental personnel during site visits to repair the system. The field testing was terminated in October 2004 when the reagent was exhausted.

4.2 MONITORING SYSTEM CALIBRATION

The AGMS was calibrated 10 times during the field testing program. Calibration consisted of analyzing a blank water sample (0 μg/L TCE), a mid-calibration standard (30 μg/L TCE), and high-calibration standard (60 μg/L TCE) to develop a three-point calibration curve. Figure 4-1 shows the ten calibration curves generated. Table 4-2 presents the instrument response at each calibration point and the difference between consecutive calibrations.

As shown on Figure 4-1, the mid- and high calibration points for the first four calibration curves were grouped in a fairly narrow range, while those for the later six curves varied significantly. The sixth calibration curve, generated on 21 August 2004, was significantly higher than the earlier curves. This change was attributed to air being accidentally passed through the optrode's porous wall while

TABLE 4-1. SUMMARY OF BURGE TCE MONITORING SYSTEM OPERATIONS

(Page 1 of 2)

Weekly Time Period[(a)]	System Operated	Comment[(b)]
27-Mar to 2-Apr-04	Yes	From 29-Mar through 2-Apr, the monitoring system was installed, the automated groundwater monitoring system (AGMS) was calibrated, and the system was operated locally (i.e., from the South Base staging area.
3-Apr to 9-Apr-04	Yes	The system was operated remotely.
10-Apr to 16-Apr-04	No	On 12-Apr, remote communication failed; the system could not be operated.
17-Apr to 23-Apr-04	No	System not operational due to communication failure.
24-Apr to 30-Apr-04	No	System not operational due to communication failure.
1-May to 7-May-04	No	On 4-May and 5-May, diagnosed that the phone line used for remote communication was faulty, temporarily switched to the second phone line at the South Base staging area while the faulty phone line was repaired by Base personnel, and modified the AGMS from a pressurized bottle to a syringe injection calibration system. The AGMS was believed to be malfunctioning (it was detecting elevated concentrations of TCE in the effluent) so it was removed and transported to Burge Environmental's office in Tempe, Arizona for testing and repair. It was determined that the monitoring system was functioning properly.
8-May to 14-May-04	Yes	On 13-May and 14-May, the AGMS was reinstalled, calibrated, and operated locally**.** Burge Environmental personnel collected influent and effluent water samples for laboratory analysis.
15-May to 21-May-04	Yes	The system was operated remotely.
22-May to 28-May-04	Yes	The system was operated remotely.
29-May to 4-Jun-04	No	On 1-Jun, remote communication failed; the system could not be operated.
5-Jun to 11-Jun-04	Yes	On 5-June, Earth Tech personnel identified the cause of the remote communication failure as a power outage that shut off the computer at the South Base staging area; the computer was rebooted and the AGMS was operated remotely. On 6-Jun, the AGMS was not functional due to the sample chamber not being purged. Earth Tech personnel determined that the air compressor had overheated and shutoff, thus there was no compressed air to purge the sample container. The thermal switch was reset and the air compressor restarted. The problem recurred before the next monitoring event was completed.
12-Jun to 18-Jun-04	No	System not operational due to air compressor failure.
19-Jun to 25-Jun-04	No	System not operational due to air compressor failure.
26-Jun to 2-Jul-04	Yes	From 29-Jun through 1-Jul, the following work was conducted: 1) installed a fan to cool the air compressor; 2) replaced the Teflon waste discharge line, which had been chewed in half by rodents; 3) repaired with electrical tape and rerouted the power line, which had been chewed on by rodents; 4) refilled the calibration standard and reagent bottles; 5) calibrated the AGMS; and 6) locally operated the system. On 1-Jul, Burge Environmental personnel collected an influent water sample for laboratory analysis.

TABLE 4-1. SUMMARY OF BURGE TCE MONITORING SYSTEM OPERATIONS
(Page 2 of 2)

Weekly Time Period[a]	System Operated	Comment[b]
3-Jul to 9-Jul-04	Yes	The system was operated remotely.
10-Jul to 16-Jul-04	Yes	The system was operated remotely.
17-Jul to 23-Jul-04	Yes	The system was operated remotely.
24-Jul to 30-Jul-04	Yes	The system was operated remotely.
31-Jul to 6-Aug-04	Yes	The system was calibrated and operated remotely
7-Aug to 13-Aug-04	Yes	The system was calibrated and operated remotely
14-Aug to 20-Aug-04	No	On 14-Aug, remote communication failed due to a power outage turning off the computer. On 16-Aug, rebooted the computer, refilled the calibration standard and reagent bottles, replaced the Teflon samples lines, which had been chewed on by rodents, and locally operated the system.
21-Aug to 27-Aug-04	Yes	The system was calibrated and operated remotely.
28-Aug to 3-Sep-04	Yes	The system was operated remotely.
4-Sep to 10-Sep-04	Yes	The system was operated remotely.
11-Sep to 17-Sep-04	Yes	The system was operated remotely.
18-Sep to 24-Sep-04	Yes	The system was operated remotely.
25-Sep to 1-Oct-04	Yes	The system was calibrated and operated remotely.
2-Oct to 8-Oct-04	Yes	The system was operated remotely.
9-Oct to 15-Oct-04	No	The system was calibrated remotely. A programming error caused the AGMS to malfunction, resulting in invalid results.
16-Oct to 22-Oct-04	Yes	On 20-Oct, the system was calibrated remotely. The AGMS ran out of reagent and testing was terminated.

Notes:

[a] Time period starts on Saturday and ends on Friday.

[b] All activities were performed by Burge Environmental personnel unless otherwise noted.

AGMS	automated groundwater monitoring system
TCE	trichloroethene

FIGURE 4-1. BURGE TCE MONITORING SYSTEM CALIBRATION CURVES

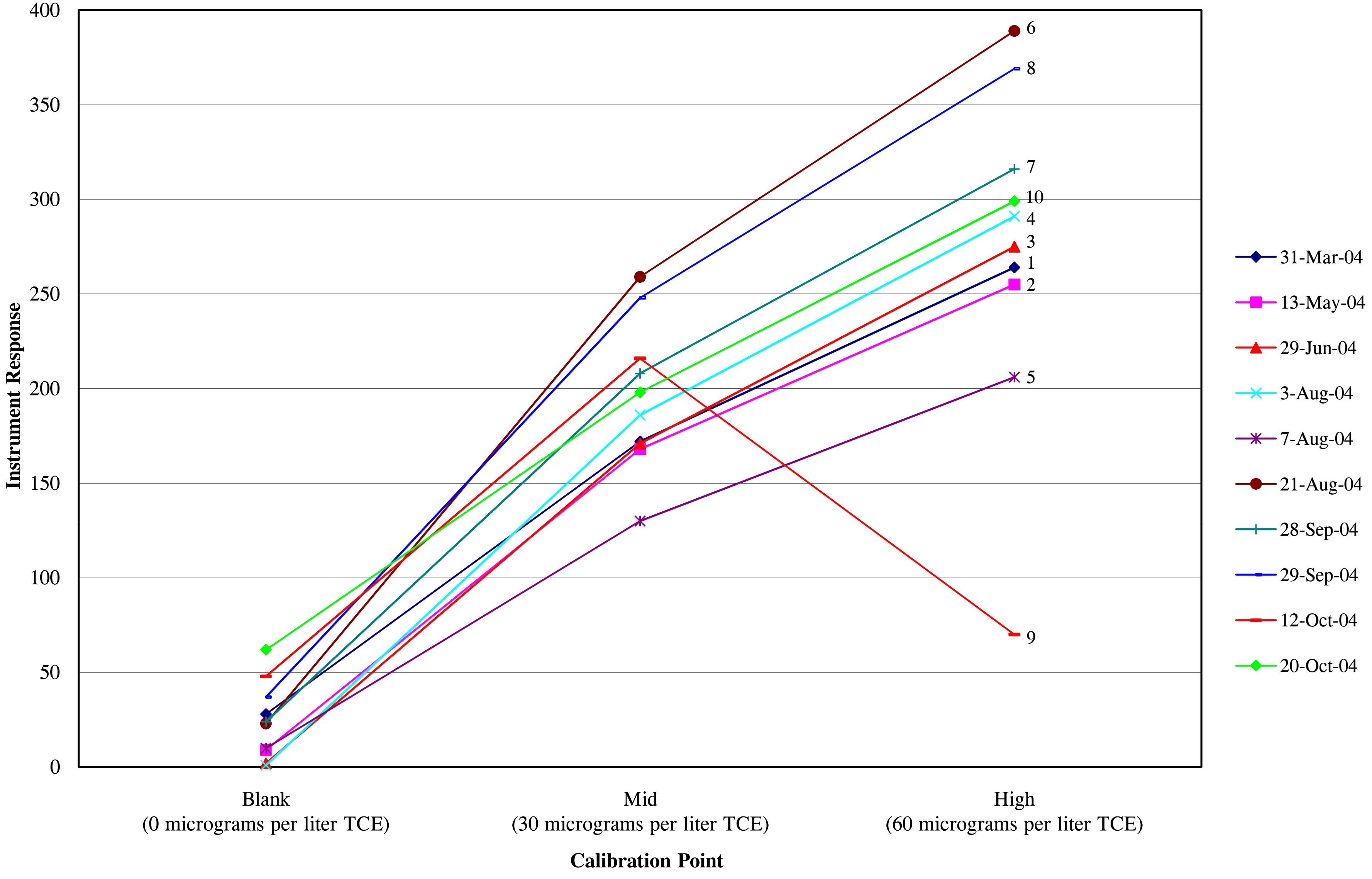


TABLE 4-2. SUMMARY OF BURGE TCE MONITORING SYSTEM CALIBRATION

(Page 1 of 2)

	Calibration Point						
	Blank (0 μg/L TCE)		Mid (30 μg/L TCE)		High (60 μg/L TCE)		
Calibration Date	Instrument Response	Change from last Calibration*	Instrument Response	Change from last Calibration*	Instrument Response	Change from last Calibration*	Comment
31-Mar-04	28	NA	172	NA	264	NA	Initial calibration after AGMS was installed. Used for samples analyzed from 31-Mar-04 thru 6-Apr-04.
13-May-04	9	-19 (-68%)	168	-4 (-2%)	255	-9 (-3%)	Calibrated after AGMS was repaired and reinstalled. Used for samples analyzed from 14-May-04 thru 29-Jun-04.
29-Jun-04	2	-7 (-78%)	171	3 (2%)	275	20 (8%)	Calibrated after standard and reagent bottles were refilled. Used for samples analyzed from 30-Jun-04 thru 31-Jul-04.
3-Aug-04	1	-1 (-50%)	186	15 (9%)	291	16 (6%)	Calibrated remotely. Used for samples analyzed from 3-Aug-04 thru 6-Aug-04.
7-Aug-04	10	9 (900%)	130	-56 (-30%)	206	-85 (-29%)	Calibrated remotely. Calibration curve appeared to be low as compared to earlier curves. Used for samples analyzed from 7-Aug-04 thru 21-Aug-04.
21-Aug-04	23	13 (130%)	259	129 (99%)	389	183 (89%)	Calibrated after standard and reagent bottles were refilled. Calibration curve was substantially different from earlier curves due to a change in the optrode sensitivity that was caused while refilling the bottles. Used for samples analyzed from 21-Aug-04 thru 26-Sep-04.
28-Sep-04	24	1 (4%)	208	-51 (-20%)	316	-73 (-19%)	Calibrated remotely. Calibration curve appeared to be low as compared to that generated on 21-Aug-04. Used only for samples analyzed on 28-Sep-04.
29-Sep-04	37	13 (54%)	248	40 (19%)	369	53 (17%)	Calibrated remotely. Calibration curve was similar to curve generated on 21-Aug-04. Used for samples analyzed from 29-Sep-04 thru 11-Oct-04.

TABLE 4-2. SUMMARY OF BURGE TCE MONITORING SYSTEM CALIBRATION
(Page 2 of 2)

	Calibration Point						
	Blank (0 μg/L TCE)		Mid (30 μg/L TCE)		High (60 μg/L TCE)		
Calibration Date	Instrument Response	Change from last Calibration*	Instrument Response	Change from last Calibration*	Instrument Response	Change from last Calibration*	Comment
12-Oct-04	48	NC	216	NC	70	NC	Calibrated remotely. High-calibration point was abnormally low, most likely due to depletion of the reagent prior to completing calibration. Not used to generate any sample results.
20-Oct-04	62	25(b) (68%)(b)	198	-50(b) (-20%)(b)	299	-70(b) (-19%)(b)	Calibrated remotely. Calibration curve was similar to curves generated on 21-Aug-04 and 29-Sep-04. Used only for samples analyzed on 20-Oct-04.

Notes:

(a) Percent change = [(current response – preceding response)/preceding response] x 100

(b) Difference based on calibration of 29- Sep-04 and 20-Oct-04.

μg/L	micrograms per liter
NA	not applicable; no preceding calibration to compare to
NC	not calculated; high calibration point was unusable
TCE	trichloroethene

refilling the calibration standard and reagent bottles on 16 August 2004. The air enlarged the pores in the wall of the optrode, increasing its permeability. The ninth calibration curve, generated on 12 October 2004, was deemed invalid; the optrode response for the high-calibration standard was abnormally low, most likely due to depletion of the reagent prior to completion of the analysis.

4.3 MONITORING SYSTEM ACCURACY

As defined in the *Edwards AFB Basewide QAPP* (Earth Tech 2003c), accuracy is the degree of agreement of a measurement, or average of measurements, with an accepted reference or "true" value. To access the accuracy of the Burge TCE Monitoring System, the final mid-calibration sample results are compared to the known concentration of the mid-calibration standard (i.e., 30 μg/L TCE). The accuracy is calculated using the following equation:

$$\text{Accuracy} = \frac{\text{final mid - calibration sample result}}{\text{mid - calibration standard concentration}} \text{ x } 100$$

Table 4-3 presents the final mid-calibration sample results and the calculated accuracies. The final mid-calibration sample results ranged from a low of 2.4 μg/L to a high of 35.8 μg/L. The calculated accuracy of the AGMS ranged from a low of 8 percent to a high of 119 percent. For comparison, the accuracy, as specified in the in situ sensor program evaluation criteria (see Section 1.2, evaluation criteria # 2.B.c) should be within ±15 percent. Based on this, acceptable final mid-calibration sample results should be between 25.5 μg/L and 34.5 μg/L.

Figure 4-2 shows the distribution of the final mid-calibration sample results and compares them to the lower and upper acceptable limits. The final mid-calibration sample results were outside the acceptable limits for 14 out of 31 samples, or 45 percent. Additionally, final mid-calibration results were outside the acceptable limits for each instrument calibration period.

4.4 MONITORING SYSTEM PRECISION

As defined in the *Edwards AFB Basewide QAPP* (Earth Tech 2003c), precision is a measure of mutual agreement among individual measurements of the same parameter under prescribed, similar conditions.

TABLE 4-3. FINAL MID-CALIBRATION SAMPLE RESULTS AND AGMS ACCURACY

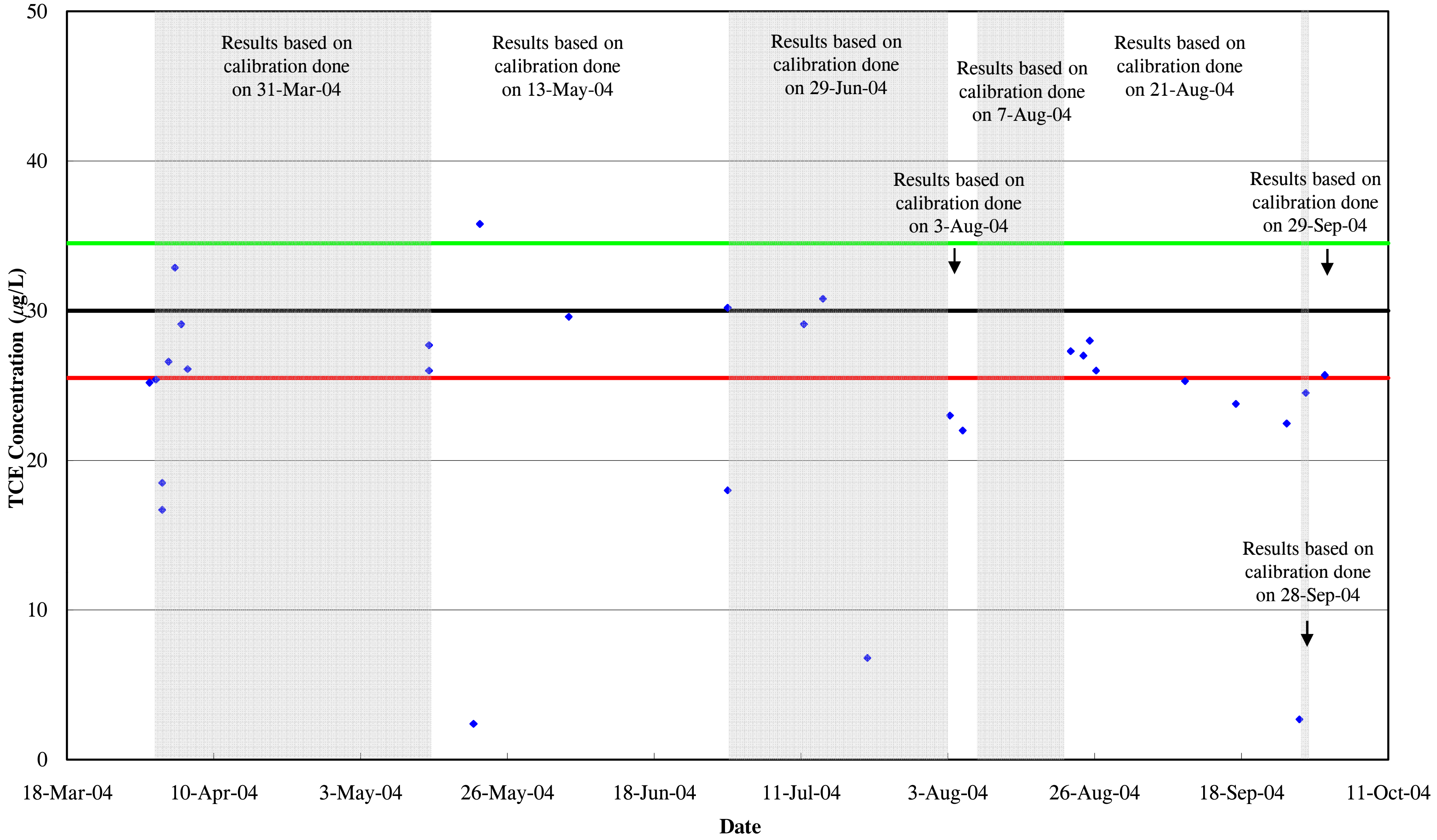
Monitoring Date	Final Mid-Calibration Sample Results (μg/L TCE)	AGMS Accuracy (percent)	Within Acceptable Accuracy*	AGMS Calibration Date
31-Mar-04	25.2	84	No	31-Mar-04
1-Apr-04	25.4	85	No	⇩
2-Apr-04	16.7	56	No	⇩
2-Apr-04	18.5	62	No	⇩
3-Apr-04	26.6	89	Yes	⇩
4-Apr-04	32.9	110	Yes	⇩
5-Apr-04	29.1	97	Yes	⇩
6-Apr-04	26.1	87	Yes	⇩
14-May-04	26.0	87	Yes	13-May-04
14-May-04	27.7	92	Yes	⇩
21-May-04	2.4	8	No	⇩
22-May-04	35.8	119	No	⇩
5-Jun-04	29.6	99	Yes	⇩
30-Jun-04	18.0	60	No	29-Jun-04
30-Jun-04	30.2	101	Yes	⇩
30-Jun-04	30.2	101	Yes	⇩
12-Jul-04	29.1	97	Yes	⇩
15-Jul-04	30.8	103	Yes	⇩
22-Jul-04	6.8	23	No	⇩
4-Aug-04	23.0	77	No	3-Aug-04
6-Aug-04	22.0	73	No	⇩
23-Aug-04	27.3	91	Yes	21-Aug-04
25-Aug-04	27.0	90	Yes	⇩
26-Aug-04	28.0	93	Yes	⇩
27-Aug-04	26.0	87	Yes	⇩
10-Sep-04	25.3	84	No	⇩
18-Sep-04	23.8	79	No	⇩
26-Sep-04	22.5	75	No	⇩
28-Sep-04	2.7	9	No	28-Sep-04
29-Sep-04	24.5	82	No	29-Sep-04
2-Oct-04	25.6	86	Yes	⇩

Notes:

* Acceptable accuracy is between 25.5 and 34.5 micrograms per liter (85 and 115 percent).

μg/L	micrograms per liter
AGMS	automated groundwater monitoring system
TCE	trichloroethene

FIGURE 4-2. FINAL MID-CALIBRATION SAMPLE RESULTS COMPARED TO ACCEPTABLE LIMITS



Notes:
μg/L micrograms per liter
TCE trichloroethene

Precision is independent of the error (accuracy) of the analyses and reflects only the degree to which measurements agree with one another, not the degree to which they agree with the "true" value for the parameter measured. Precision is calculated in terms of relative percent difference (RPD), which is calculated as follows:

$$\mathrm{RPD} = \frac{\left|X_1 - X_2\right|}{\left(X_1 + X_2\right)/2} \times 100$$

where RPD is the relative difference for a sample pair, and X_1 and X_2 represent the individual values for the analyte in the two samples in the sample pair.

For many monitoring events, the monitoring system was programmed to analyze two water samples from each sample port. These sample pairs were used to calculate the RPD, and thus the precision of the AGMS. Generally, RPD criteria are not valid for sample results that are less than five-times the laboratory reporting limit. The reputed lower reliable detection limit of AGMS is 1 μg/L. Therefore, an RPD was not calculated for samples pairs when the reported concentration in one or both samples was less 5 μg/L.

Appendix B presents the Burge TCE Monitoring System results and the calculated RPDs for sampling pairs. The calculated RPDs for influent sample pairs ranged from a low of 0 percent to a high of 25 percent, with an average of 5 percent. The calculated RPDs between effluent sample pairs ranged from a low of 3 percent to a high of 17 percent, with an average of 11 percent. For comparison, the acceptable precision goal for analysis of volatile organic compounds in water using USEPA Method 8260B, as specified in the *Edwards AFB Basewide QAPP* (Earth Tech 2003c), is an RPD below 45 percent.

4.5 COMPARISON OF MONITORING SYSTEM AND LABORATORY RESULTS

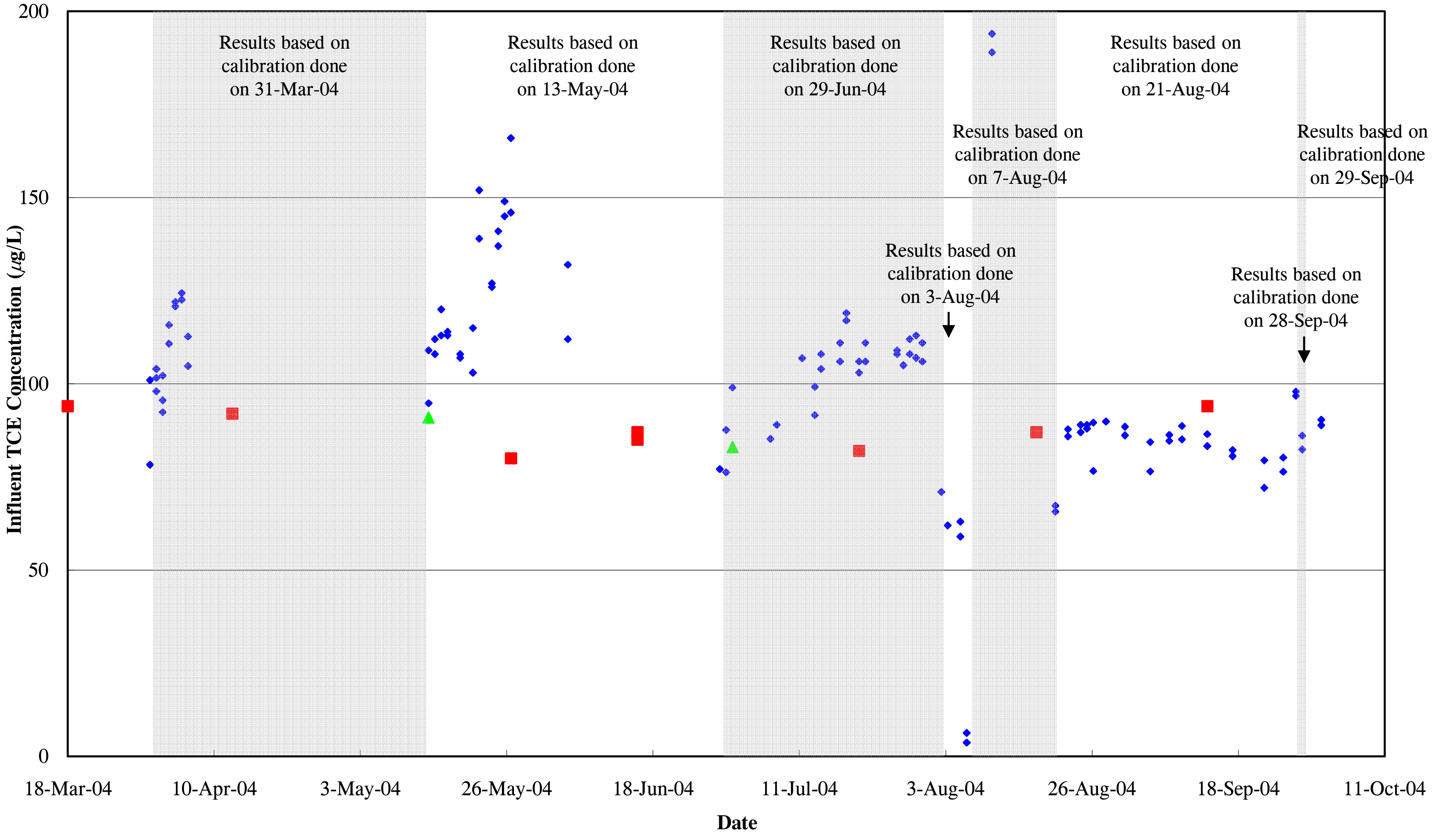
A summary of the Burge TCE Monitoring System results are presented in Appendix B. Only the results from when the system was operating properly are included. Complete monitoring results are included in the Burge Environmental reports contained in Appendix A. Complete analytical results for samples collected by Earth Tech and analyzed by STL are presented in Appendix C.

Figures 4-3 and 4-4 show the concentration of TCE in the treatment system influent and effluent, respectively. Included on the figures are the laboratory analytical results and the Burge TCE Monitoring System results.

Table 4-4 compares the Burge TCE Monitoring System results against laboratory results, along with the percent difference between the two results. Only data for those days when both the monitoring system was operated and samples for laboratory analysis were collected are presented on Table 4-4. The calculated difference between the monitoring system results and laboratory results ranged from -13 percent to 52 percent for the treatment system influent, and from -33 percent to -19 percent for the treatment system influent. For comparison, the in situ sensor program evaluation criteria (see Section 1.2, evaluation criteria # 2.B.a) specifies that the monitoring system results should be within a range of 30 percent above to 15 below the laboratory analytical results. Based on this, 7 out of 9 influent monitoring results were within the acceptable range, and 0 out of 2 effluent monitoring results were within the acceptable range.

Table 4-5 compares the range of monitoring system results for each calibration period to the range of laboratory results. For the treatment system influent, the variability of the monitoring system results ranged between 13 percent and 116 percent, compared to 18 percent for the laboratory results. For comparison, the in situ sensor program evaluation criteria (see Section 1.2, evaluation criteria # 2.B.a) specifies that the monitoring system results should not vary more than 20 percent between readings. No comparison was performed for the treatment system effluent because of insufficient detections above the laboratory and monitoring system reporting limits.

FIGURE 4-3. INFLUENT SAMPLING RESULTS

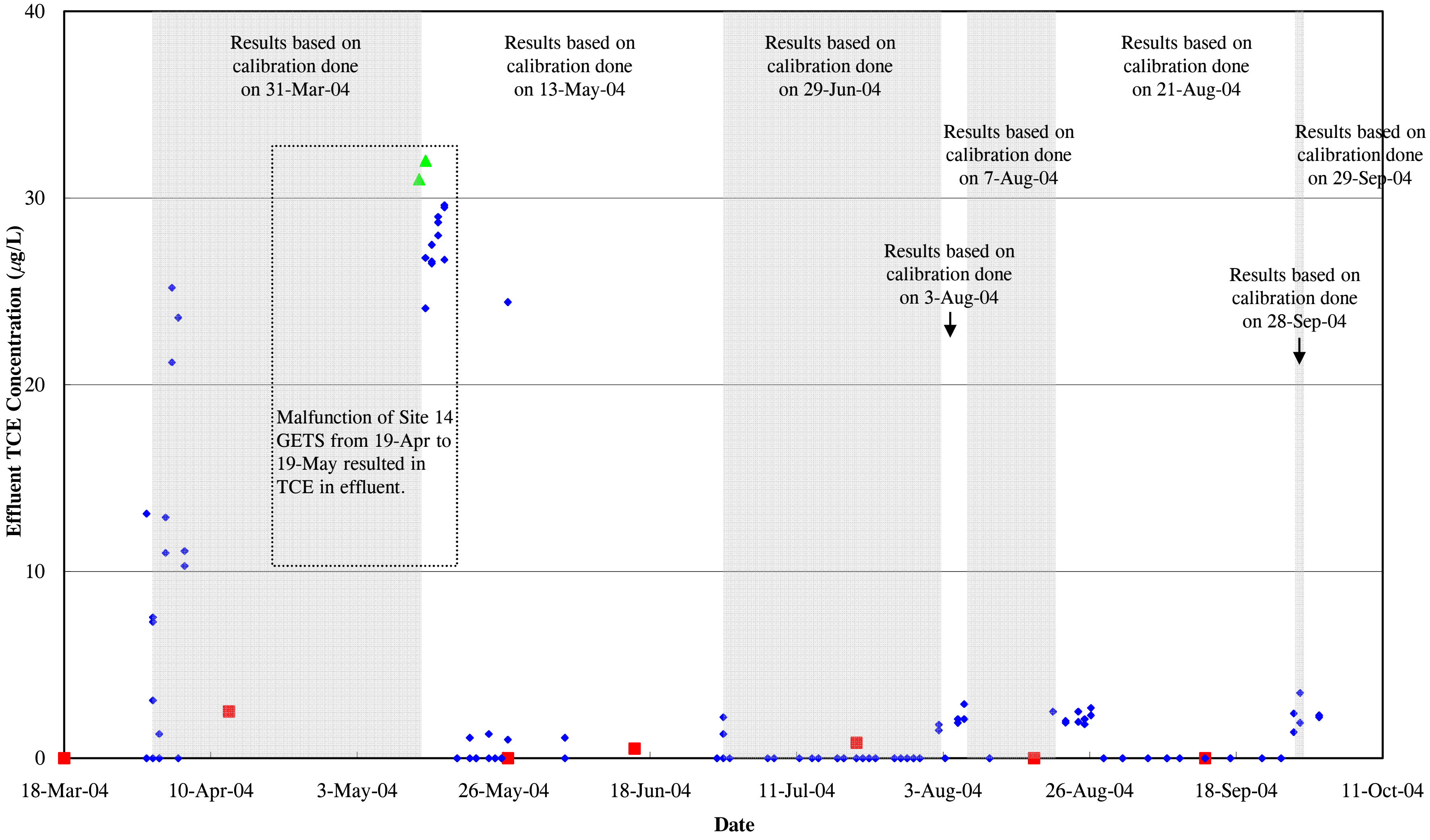


Notes:

µg/L micrograms per liter

TCE trichloroethene

FIGURE 4-4. EFFLUENT SAMPLING RESULTS



Notes:

µg/L micrograms per liter

TCE trichloroethene

Results reported as less than 1.0 µg/L are shown as 0.0 µg/L.

TABLE 4-4. COMPARISON OF AGMS RESULTS TO LABORATORY RESULTS

	Treatment System Influent			Treatment System Effluent		
Monitoring and/or Sampling Date	Monitoring System Result (μg/L TCE)	Laboratory Results (μg/L TCE)	Difference [(a)] (Percent)	Monitoring System Result (μg/L TCE)	Laboratory Results (μg/L TCE)	Difference [(a)(b)] (Percent)
14-May-04	95/109	91[(c)]	5% / 17%	24/27	32[(c)]	-33% / -19%
27-May-04	146/166	80[(d)]	45% / 52%	24.4/<1.0	<1[(d)]	NC / NC
1-Jul-04	99	83[(c)]	16%	<1.0	NS	NC
21-Jul-04	106/103	82[(d)]	23% / 20%	<1.0/<1.0	0.83 [(d)]	NC / NC
14-Sep-04	83/87	94[(d)]	-13% / 8%	<1.0/<1.0	<1[(d)]	NC / NC

Notes:

Only includes data for when samples were collected on same day that Burge TCE Monitoring System was operated.

(a) Difference = [(Monitoring System Result – Laboratory Result)/Laboratory Result] x 100

(b) Difference was not calculated if either the monitoring system or laboratory results were <1 μg/L.

(c) Sample collected by Burge Environmental. See Appendix A for laboratory result.

(d) Analyzed by Severn Trent Laboratories, Los Angeles. See Appendix C for laboratory result.

<	less than
μg/L	micrograms per liter
AGMS	automated groundwater monitoring system
NC	not calculated
NS	not sampled
TCE	trichloroethene

TABLE 4-5. VARIATION OF AGMS RESULTS AND LABORATORY RESULTS

			Treatment System Influent			Treatment System Effluent		
From		To	High (μg/L TCE)	Low (μg/L TCE)	Difference[a] (percent)	High (μg/L TCE)	Low (μg/L TCE)	Difference[a][b] (percent)
Monitoring Period[c]			**Burge TCE Monitoring System**			**Burge TCE Monitoring System**		
31-Mar-04	to	6-Apr-04	124	78	59%	25	<1.0	NC
13-May-04	to	29-Jun-04	166	77	116%	30[d]	<1.0[d]	NC
30-Jun-04	to	31-Jul-04	119	76	57%	2.2	<1.0	NC
3-Aug-04	to	6-Aug-04	71	59	20%	2.1	<1.0	NC
7-Aug-04	to	11-Aug-04	194[d]	3.7[d]	[d]	2.9[e]	<1.0[e]	NC
21-Aug-04	to	26-Sep-04	90	66	36%	2.7	<1.0	NC
29-Sep-04	to	2-Oct-04	90	82	13%	3.5	1.9	NC
Sampling Period[e]			**Laboratory Results (STL)**			**Laboratory Results (STL)**		
18-Mar-04	to	14-Sep-04	94	80	18%	2.5	<1.0	NC

Notes:

[a] Difference = [(high - low)/low] x 100

[b] Difference was not calculated if low result was <1 μg/L.

[c] Each monitoring period is for one calibration, which was done at the start of the period. Breaks in monitoring periods are when system was not operational.

[d] Calibration appears to be invalid, thus difference was not calculated.

[e] Includes laboratory results of all samples collected and analyzed by all STL, Los Angles between the specified dates.

<	less than
μg/L	micrograms per liter
AGMS	automated groundwater monitoring system
NC	not calculated
STL	Severn Trent Laboratories
TCE	trichloroethene

5.0 EVALUATION AND CONCLUSIONS

Table 5-1 presents a comparison of the Burge TCE Monitoring System performance to the in situ sensor program evaluation criteria. Based on this comparison, the following conclusions were reached:

- The system was capable of being operated remotely. However, failure of remote communications occasionally prevented the system from being operated on a weekly basis. In addition, costs were incurred to restore/maintain the remote communication system
- No repairs to the AGMS were required. However, ancillary components required repair or replacement. Maintenance of the AGMS was limited to refilling the reagent and standard solutions, and was performed during repair of ancillary components
- Accuracy of the AGMS, as determined by analyzing final mid-calibration samples, was within the acceptable limits 55 percent of the time. Compared to laboratory results for the treatment system influent and effluent, the AGMS was within the acceptable limits 78 percent of the time and 0 percent of the time, respectively
- The AGMS results fluctuated considerably more than laboratory results. For the treatment system influent, the AGMS results varied between 13 percent and 116 percent compared to 18 percent for the laboratory results and 20 percent for the acceptable variation
- The monitoring system correctly indicated the presence of TCE in the treatment system effluent during a process upset condition of the Site 14 GETS. However, modifications to the Site 14 GETS were implemented that would preclude a repeat of this situation (Earth Tech 2005).

In summary, the Burge TCE Monitoring System appears to be capable of accurately measuring the concentration of TCE in the treatment system influent. However, insufficient detections above the laboratory and monitoring system reporting limits for the treatment system effluent prevented a full assessment of the utility of the system for measuring low contaminant concentrations. To ensure confidence in the monitoring system results, trained personnel must review the calibration curve to verify it is valid, program the AGMS to analyze a final mid-calibration sample with each group of water samples, verify that the final mid-calibration sample result is within acceptable limits, and lastly review the monitoring results to verify that they are reasonable. If any results were outside predefined limits, an additional monitoring event would need to be performed.

TABLE 5-1. SUMMARY OF BURGE TCE MONITORING SYSTEM RESULTS COMPARED TO EVALUATION CRITERIA

(Page 1 of 2)

Evaluation Criteria	Performance of Burge TCE Monitoring System
1. Mechanical Durability and O&M Requirements	
A. Evaluate whether the robustness and longevity of the sensor mechanism and housing meet minimum requirements for unattended operation of 3 months and operational lifetime of 2 years. Metal housing parts and fasteners should show no significant corrosion, and rubber or Teflon parts should show no significant degradation for prolonged periods. The minimum acceptable lifetime of field-replaceable housing components is 3 months.	The AGMS (i.e., the sensor) meet the requirement for unattended operation. However, other system components (e.g., power cable and Teflon water supply lines and waste discharge line) required replacement during field testing. In addition, a fan was required to cool the air compressor.
B. Evaluate the O&M requirements of the sensor, the estimated period of time the sensor mechanism can operate before adjustment, calibration, replacement of parts, or replenishment of expendables. These factors will be evaluated by extended field deployment. The required maintenance schedule should be no more than quarterly.	Replenishment of expendables (i.e., reagent and standard) was approximately 2 months. Limiting the number of samples analyzed and the frequency of calibration could reduce the need to replenish expendables to no more than quarterly. Conversely, more frequent calibration and calibration checks would increase the frequency that expendables need replenishing.
2. Accuracy, Sensitivity, and Repeatability of Sensor Measurements	
A. Evaluate sensors for use as a screening tool versus more quantitative measurements. To evaluate the detection limits and sensitivity ranges of the sensors, they will be field deployed in locations that have known chemical types and concentrations (near the high- and low-detection limits of the sensor) to evaluate the accuracy of the predicted sensitivity ranges.	Contaminants in the treatment system influent were limited to cis-1,2-dichloroethene at concentrations less than 1 μg/L and TCE at concentrations of 80 μg/L to 96 μg/L. The influent was diluted by 50 percent so that the concentration of TCE was less than the high-calibration point of the AGMS. Contaminants in the treatment system effluent were limited to TCE at concentrations typically less than 1 μg/L.
B. Compare concentrations measured by the sensor to fixed laboratory results. Evaluate the accuracy and repeatability of sensor measurements by collecting samples manually and sending to an off-site laboratory for analysis. If possible, the sensor will be calibrated against a known standard prior to measurement. The following criteria shall be evaluated:	The AGMS was calibrated 10 times during the field test. Of nine valid calibration curves, four were grouped in a fairly narrow range and five showed significant variance.

TABLE 5-1. SUMMARY OF BURGE TCE MONITORING SYSTEM RESULTS COMPARED TO EVALUATION CRITERIA

(Page 2 of 2)

Evaluation Criteria	Performance of Burge TCE Monitoring System
a. Concentrations measured by the sensor should be within a range of 30 percent above and 15 percent below the analytical results measured by a fixed laboratory on samples collected concurrently.	For the treatment system influent, 7 out of 9 monitoring system results (78 percent) were within the specified range of the laboratory results. For the treatment system effluent, 0 out of 2 monitoring system results were within the specified range of the laboratory results.
b. Variation in laboratory results of samples collected from the same location at different times will be tracked for comparison with the variation in sensor measurements over time collected in the same location.	A total of 10 treatment system influent samples, including one duplicate sample, and 9 treatment system effluent samples were collected for laboratory analysis.
c. Sensor measurements should not vary by more than 20 percent from reading to reading and by no more than 20 percent per month (unless influenced by an active remediation system). Greater variation shall be verified by recalibrating the sensor or analyzing samples to determine if there has been any natural changes in the in situ contaminant concentrations. Self-calibrating sensors should measure a known concentration of the target compound to within ±15 percent of the known compound.	For the treatment system influent, the monitoring system results varied between 13 percent and 116 percent, compared to 20 percent for the laboratory results. Insufficient detections above the laboratory and monitoring system reporting limits for the treatment system effluent prevented assessment of the utility of the system for measuring low contaminant concentrations. Final mid-calibration results were outside the acceptable limits for each instrument calibration period
3. Usefulness of Sensor for O&M and/or LTM Tasks	
A. Evaluate whether the sensor could reduce O&M and/or LTM costs. The cost of capital expenditure and O&M for sensors and supporting equipment, when averaged over a maximum 5-year period, must be less than sampling and analysis costs.	The cost savings of using the Burge TCE monitoring system would be directly related to the frequency of sampling. Widely spaced sampling events would most likely be more expensive with the Burge TCE monitoring system than conventional methods on a per sample basis. However, if very frequent sampling were required, the monitoring system would most likely be less expensive on a per sample basis.
B. Data quality of sensor measurements must be sufficient to meet or exceed regulatory requirements for monitoring level data where sensor measurements are used in lieu of conventional sampling and analysis.	The AGMS has not been approved by the regulatory agencies for use at Edwards AFB in lieu of conventional sampling and analysis. A draft package was prepared by Burge Environmental for submittal to the USEPA for acceptance of the AGMS for analysis of TCE in water.

6.0 REFERENCES

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APPENDIX A

BURGE ENVIRONMENTAL MONITORING REPORTS

Appendix A-1	**Burge Report Dated March 29, 2004 – April 12, 2004**
Appendix A-2	**Burge Report Dated May 12 – June 1, 2004**
Appendix A-3	**Burge Report Dated June 1 – July 15, 2004**
Appendix A-4	**Burge Report Dated June 1 – August 31, 2004**
Appendix A-5	**Burge Report Dated September 1, 2004 – October 26, 2004**

APPENDIX A-1

BURGE REPORT DATED MARCH 29, 2004 – APRIL 12, 2004

APPENDIX A-2

BURGE REPORT DATED MAY 12 – JUNE 1, 2004

APPENDIX A-3

BURGE REPORT DATED JUNE 1 – JULY 15, 2004

APPENDIX A-4

BURGE REPORT DATED JUNE 1 – AUGUST 31, 2004

APPENDIX A-5

BURGE REPORT DATED SEPTEMBER 1, 2004 – OCTOBER 26, 2004

APPENDIX B

SUMMARY OF BURGE TCE MONITORING SYSTEM RESULTS

APPENDIX C

STL ANALYTICAL RESULTS

ABBREVIATIONS AND EXPLANATIONS FOR ANALYTICAL RESULTS TABLES

Table Heading:

Base: EDWRD (Edwards Air Force Base)

Site: Site ID

Point: Location (well or sample port) where the sample was collected

Sampling Date: Date and time sample was collected

Sample Depth: Depth below ground surface sample collected; only applicable for soil samples

Sample Type: FD1 field duplicate sample
N1 normal sample

Field Sample: Unique identifier number assigned to the sample in the field

Lab Sample: Unique identifier number assigned to the sample by the lab

PVC/Run: PR/1 Primary result, run 1

Status: *Validated* Data has been validated by Earth Tech

Column Headings and Data:

Units μg/L micrograms per liter

Results: Concentration and Laboratory Data Qualifier

ND contaminant not detected at or above the method detection limit.
J estimated concentration; result is below the reporting limit.

QA: Earth Tech Data Qualifiers (if any)

No data qualifiers.

RL,DF: Reporting limit and dilution factor

APPENDIX D

BURGE ENVIRONMENTAL SUBMITTAL FOR USEPA CERTIFICATION

DEMONSTRATION DESCRIPTION

In August 1999, the performance of six groundwater sampling devices was evaluated at the US Geological Survey Hydrological Instrumentation Facility at the NASA Stennis Space Center in southwestern Mississippi. Each technology was independently evaluated in order to assess its performance in the collection of volatile organic compound- (VOC) contaminated water.

The verification test design incorporated the use of a 5-inch diameter,100-foot standpipe at the USGS facility. The standpipe, serving as an "above-ground" well, was filled with tap water spiked with various concentration levels of six target volatile organic compounds. The target compounds (1,2-dichloroethane, 1,1-dichloroethene, trichloroethene, benzene, 1,1,2-trichloroethane, and tetrachloroethene) were chosen to represent the range of VOC volatility likely to be encountered in normal sampler use. Water sampling ports along the exterior of the standpipe were used to collect reference samples at the same time that groundwater sampling technologies collected samples from the interior of the pipe. A total of seven trials were carried out at the standpipe. The trials included the collection of low (~20 µg/L) and high (~200 µg/L) concentrations of the six target VOC compounds in water at sampler depths ranging from 17 to 91 feet. A blank sampling trial was also included in the test matrix.

The standpipe trials were supplemented with additional trials at groundwater monitoring wells in the vicinity of sites with VOC-contaminated groundwater at the NASA Stennis facility. The sampling devices were deployed in a number of 2-inch and 4-inch wells, along with co-located submersible electric gear pumps as reference samplers. The principal contaminant at the onsite monitoring wells was trichloroethene. The onsite monitoring provided an opportunity to observe the operation of the sampling system under typical field-use conditions.

All technology and reference samples were analyzed by two identical field-portable gas chromatograph-mass spectrometer (GC/MS) systems that were located at the test site during the verification tests. The GC/MS analytical method used was a variation of EPA Method 8260 purge-and-trap GC/MS, incorporating a headspace sampling system in lieu of a purge and trap unit. The overall performance of the groundwater sampling technologies was assessed by evaluating sampler precision and comparability with reference samples. Other logistical aspects of field deployment and potential applications of the technology were also considered in the evaluation.

Details of the demonstration, including an evaluation of the sampler's performance, may be found in the report entitled *Environmental Technology Verification Report: Burge Environmental Inc., Multiprobe 100,* EPA/600/R-00/074.

TECHNOLOGY DESCRIPTION

The Multiprobe 100 is a discrete, multi-level sampler that is designed for permanent deployment in a well. The sampler is designed for use with a complementary automated wellhead analyzer for TCE called the Optrode. Only the sampling module was evaluated in this test. Optrode performance was not evaluated in this demonstration.

The Multiprobe 100 consists of two units with tubing and wiring interconnections. A upper receiving module which is deployed at the wellhead on top of the well is 18 inches long, 3.25 inches in diameter, and weighs 3 pounds. The lower sampling module, which is inserted into the water column inside the well, is 12 inches long, 3.25 inches in diameter and also weighs 3 pounds. The system is constructed of Teflon, borosilicate glass, stainless steel and Delrin®, a solvent-resistant, acetal homopolymer resin. Electrical solenoid valves are used to select the sampling level and control gas flow to the sampler. Water level sensors in the water chambers of both modules are used to trigger valve changes during the sampling process. A small, battery-operated microprocessor controller is used to control the valves used during the sampling process.

The lower sampling module is filled with water from the selected sampling level by hydrostatic pressure. The water sample is then pushed up to the upper receiving module by pressurizing the sampling chamber headspace with nitrogen gas. Samples can be manually dispensed into analysis vials from the upper receiving module, however, the system is primarily intended for interconnection with automated analyzers, such as the Optrode, which would also be positioned at the wellhead.

The system also has the ability to purge volatile organic compounds from water *in situ* with subsequent analysis by sensors, such as the Optrode, that are positioned in the headspace or at the wellhead. Following the purge, the vapors can also be transported via tubing to the surface for collection and analysis. The *in situ* purge capability of the sampler was not tested in this investigation.

VERIFICATION OF PERFORMANCE

The following performance characteristics of the Multiprobe 100 groundwater sampling system were observed:

Precision: The precision of the sampler was determined through the collection of a series of replicate samples from two standpipe trials using low (~20 µg/L) and high (~200 µg/L) VOC concentrations at 17, 35, 53 and 91-foot depths. Each trial included 6 target VOCs at each of the sampling depths, resulting in a total of 24 cases per trial. Multiprobe 100 precision, represented by the relative standard deviation, for all compounds at all concentrations and sampling depths evaluated in this study ranged from 3 to 21% with a median value of 9.4 %. In 27 of the 48 cases, the Multiprobe 100 was less precise than the reference sample set. The F-ratio test was used to assess whether precision differences between Multiprobe 100 and reference samples were statistically significant. Test results showed that precision differences between the Multiprobe 100 and reference samples were statistically insignificant at the 95% confidence level in 46 of the 48 test cases.

Comparability with a Reference: Multiprobe 100 sampler results from the standpipe trials were compared with results obtained from reference samples that were collected at the same time. Both Multiprobe 100 and reference samples were analyzed by the same method using the same GC/MS system. Sampler comparability is expressed as percent difference relative to the reference data. Sampler differences for all target VOC compounds at all concentrations and sampler depths in this study ranged from -30 to 15%, with a median percent difference of -5%. The t-test for sample means was used to assess whether the observed differences between Multiprobe 100 and reference samplers were statistically significant. These tests revealed that in 31 of 48 trials, differences were statistically indistinguishable from 0% at the 95% confidence level. Of the remaining 17 cases that were statistically different from 0%, 16 showed a negative Multiprobe 100 sampler bias. Statistically significant negative sampler bias ranged from – 10 to – 30%.

Versatility: Sampler versatility is the consistency with which it performed with various target compounds, concentration levels, and sampling depths. In terms of precision, Multiprobe 100 performance was generally consistent at the range of concentrations and collection depths evaluated in this study. The Multiprobe 100 showed a trend toward negative bias for 11DCE and TCE and the sampler showed consistently negative bias for PCE at all concentrations and sampler depths. As a result of its physical size, the Multiprobe 100 cannot be installed in wells with diameters less than 4 inches. In light of these considerations, the Multiprobe 100 sampler in its aqueous sampling mode is judged to have limited versatility.

Logistical Requirements: The Multiprobe 100 is designed for permanent installation in 4-inch or larger wells. The installation would require either custom installation by Burge Environmental personnel or user installation following approximately two days of training. Although the system is optimized for automated operation, it can also be used in a manual mode. The system is also capable of being removed from one installation for redeployment in a second well however several hours of disassembly and re-assembly time would be required. The system also requires a source of compressed nitrogen at the wellhead.

Overall Evaluation: The results of this verification test show that the Multiprobe 100 multi-level sampler can be used to collect VOC-contaminated water samples that are generally statistically comparable to reference samples. Sampler recoveries for PCE in the aqueous sampling and transfer mode were consistently low when compared to reference samples. Further investigation of sampler performance for this compound may be required. The Multiprobe 100 is a component of an overall automated sampling and analysis system. Only the sampler module was evaluated in this test. A complete system evaluation would be warranted prior its deployment in long term automated monitoring applications.

As with any technology selection, the user must determine if this technology is appropriate for the application and the project data quality objectives. For more information on this and other verified technologies visit the ETV web site at http://www.epa.gov/etv.

Gary J. Foley, Ph.D	Samuel G. Varnado
Director	Director
National Exposure Research Laboratory	Energy and Critical Infrastructure Center
Office of Research and Development	Sandia National Laboratories

NOTICE: EPA verifications are based on evaluations of technology performance under specific, predetermined criteria and appropriate quality assurance procedures. The EPA and SNL make no expressed or implied warranties as to the performance of the technology and do not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Mention of commercial product names does not imply endorsement.

THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

ETV JOINT VERIFICATION STATEMENT

TECHNOLOGY TYPE: **GROUNDWATER SAMPLING TECHNOLOGIES**

APPLICATION: **VOC-CONTAMINATED WATER SAMPLING**

TECHNOLOGY NAME: **Multiprobe 100**

COMPANY: **Burge Environmental**

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The U.S. Environmental Protection Agency (EPA) has created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations and stakeholder groups consisting of regulators, buyers, and vendor organizations, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The Site Characterization and Monitoring Technologies Pilot, one of 12 technology areas under ETV, is administered by EPA's National Exposure Research Laboratory. Sandia National Laboratories, a Department of Energy laboratory, is one of the verification testing organizations within the ETV Site Characterization and Monitoring Pilot. Sandia collaborated with personnel from the US Geological Survey to conduct a verification study of groundwater sampling technologies. This verification statement provides a summary of the results from a verification test of the Multiprobe 100 sampler manufactured by Burge Environmental.

The accompanying notice is an integral part of this verification statement.

Continuous VOC Headspace Monitor

DRAFT MEMORANDUM

To: **Dr. Javier Santillan, HQ AFCEE/TDV**

Mr. Franz Steffes, Spangdahlem Air Base – Germany

From: **Mr. Patrick Haas, P.E. Haas & Associates**

Mr. Scott Pittenger, Earth Tech AECOM

Mr. Manish Joshi, Earth Tech AECOM

Subject: **Laboratory and Field Testing of an On-Line Sensor/Monitor System for Detection of Volatile Organic Compounds (VOCs) in Drinking Water**

Date: **22 July 2009**

Earth Tech AECOM has been tasked by HQ AFCEE/TDV to evaluate applicability of on-line or in-situ sensors for monitoring VOC contamination in groundwater and drinking water systems. As part of this effort, an on-line sensor and monitoring system (known as VOC Monitor) was identified as a potential candidate for applicability in raw (drinking) water systems. The VOC monitor is manufactured in the United Kingdom (UK), and is being used as an on-line alarm system for monitoring VOC contaminants at several drinking water treatment plants (primarily in the UK). The VOC Monitor uses four solid state sensors (Metal Oxide Sensors) to monitor changes in the concentration of total VOCs in air above a water stream. For drinking water applications, the VOC Monitor is recommended to be installed in the treatment process prior to chlorination since it is sensitive to low levels of trihalomethane (THM) concentrations. **Attachment 1** provides the details and specifications of the VOC Monitor.

Some of the features of the VOC Monitor include:

- High sensitivity to VOCs;
- Minimizes false alarms by comparing the current reading with a ‘history’ of readings;
- Non-contact measurements (non-fouling and low maintenance); and
- Has telemetry options (including wireless transmittal).

A VOC Monitor was procured by Earth Tech AECOM to validate the sensitivity of the system to low levels of VOC contaminants and THMs. The VOC Monitor was set up in a laboratory and startup testing was performed in accordance with the manufacturer's recommendations in April 2009. **Attachment 2** presents the instrument manual for the VOC Monitor. Upon verification of proper operation of the VOC Monitor and the data collection software, tests were performed to determine the sensitivity of the VOC Monitor. These tests were performed by sampling the head space in 1-liter bottles containing approx. 500 mL of pre-determined concentrations of VOC-spiked water. The following tests were performed:

- Detection Limit Evaluations
    - Contaminants included Benzene, Tetrachloroethene (PCE), Trichloroethene (TCE), and Vinyl Chloride (VC);
    - Performed at least 7 sample runs at 1 µg/L concentration for each contaminant.
- Calibration Curves
    - Contaminants included Benzene, PCE, TCE, VC;
    - Performed calibration using 1, 5, 10, 25, 50, 75 and 100 µg/L concentrations for each contaminant.
- Contaminant Mixture Evaluations
    - Contaminant mixtures include Benzene & TCE, Benzene & PCE, Benzene & PCE, TCE, VC;
    - Evaluated system response at 1, 5, 10 µg/L concentration of each contaminant.

Attachment 3 presents the results of the detection limit (sensitivity) evaluations. The results show the average response for the four sensors in the VOC monitor. These results indicate that VOC contaminant concentrations of approx. 1 µg/L can be detected by the VOC Monitor. **Attachment 4** presents the results of the calibration curve testing. These results show that the sensor response does not change appreciably when concentrations exceeded 25 µg/L. Therefore, this sensor system may not be suitable for estimating contaminant concentrations, however is well suited as an alarm system for detecting low-level VOC contamination. **Attachment 5** presents the results of the contaminant mixtures evaluations.

To evaluate the sensitivity of the VOC Monitor to low levels of THMs, the following tests were performed:

- Detection Limit Evaluations
    - Contaminants included Chloroform, Bromoform, Dibromochloromethane, Bromodichloromethane;
    - Performed 7 sample runs at 1 µg/L concentration for each contaminant.
- Calibration Curves
    - Contaminants included Chloroform, Bromoform, Dibromochloromethane, Bromodichloromethane;
    - Performed calibration using 1, 5, 10, 25, 50 µg/L concentrations for each contaminant.

Attachment 6 presents the results of the THM sensitivity evaluations. The results show the average response for the four sensors in the VOC monitor. These results indicate that THM concentrations of approx. 1 µg/L can be detected by the VOC Monitor. **Attachment 7** presents the results of the calibration curve testing. Comparing these results to the VOC testing shows that the VOC monitor typically shows a higher sensor response to VOCs than THMs (i.e., Sensor response to 5 µg/L VOCs is higher than response to 5µg/L THM).

Based on the results of the laboratory testing, field installation and testing of the VOC Monitor was recommended. The VOC Monitor was installed at the drinking water treatment plant at Spangdahlem Air Base in Germany in June 2009. The drinking water treatment plant receives groundwater from two water wells (North well and South well). Tracer testing performed by Spangdahlem Air Base indicated that surface water from a nearby creek may be connected to the groundwater extracted from the South well. Therefore, if the surface water in the creek gets contaminated with VOCs (e.g., due to fuel spills/vehicle accidents nearby), this may impact the drinking water at the base. The VOC Monitor would provide the base personnel with an early warning system in case of such an emergency. **Attachment 8** presents a process flow diagram of the VOC Monitor system. An approx. 30 liter tank was used as a flow through cell (tank water volume was approx. 20 L). The system is capable of monitoring groundwater from the North, South or both wells (combined). The following tests were conducted (when the South well was connected) to verify the operation of the VOC Monitor:

- Startup/Shutdown testing (multiple tests) – to simulate power failure
- Baseline testing (multiple tests) - Monitoring system response to room air (ambient conditions);

- VOC Testing;
  - Testing system response to potential interference in the ambient air;
  - Testing system response to 0.0001% and 0.0018% (v/v) ethanol;
  - Testing system response to 50 µg/L of cis 1,2-dichloroethene; and
  - Testing system response to 10 µg/L of TCE.

The startup/shutdown testing indicated that the system has to be re-set via its software to resume normal data collection (every 15 minutes). Based upon this evaluation, the startup and operation procedure was updated. The updated startup and operation procedure is presented in **Attachment 9**. **Attachment 10** presents the graph of the overnight baseline testing conducted at the water plant. This testing involved sampling headspace (every 15 minutes) in the flow-through cell. The South well was connected to the flow-through cell for this test. The results show that although the raw sensor values were fluctuating, the short term and the long term history was relatively stable. The data also shows that no alarms were noted. The software minimizes false alarms by comparing the current reading to the short term and long term history of readings. The system response to potential contamination (interference) in the room (ambient air) was tested by placing 5 ml of 37.5% alcohol in a beaker near the VOC monitor air intake/outlet for approximately 30 minutes. This data is presented in **Attachment 11**. The data shows that potential background interference for the VOC Monitor is minimal.

Attachment 12 shows the data for 0.0001% and 0.0018% alcohol concentrations in the flow-through cell. The data shows that no alarms were triggered for the lower concentration of alcohol, while both the low level alarm (Alarm 1 - 20% response) and the high level alarm (Alarm 2 - 50% response) were triggered by a 0.0018% concentration of alcohol.

Attachment 13 shows the VOC Monitor response to a concentration of 50 µg/L of cis 1,2-dichloroethene. The data shows that this concentration triggered an alarm event (Alarm 1 – low level). **Attachment 14** shows the VOC Monitor response to 10 µg/L of TCE. As seen from the graph, both the low level alarm (Alarm 1 - 20% response) and the high level alarm (Alarm 2 - 50% response) were triggered by this concentration of TCE.

These results were reviewed by the installation team (Dr. Santillan, Mr. Haas, Mr. Pittenger, and Mr. Joshi) and Mr. Steffes and it was determined that the VOC Monitor be placed into continuous operating mode at the water treatment plant. **Attachment 15** presents photographs of the system at the water treatment plant.

Attachment 1

multisensor systems

Real-time VOC Monitoring

Multisensor Systems Ltd provides cost-effective volatile organic compound (VOC) monitoring systems for industrial and environmental applications. Systems are designed to survive continuous field deployment in demanding site conditions providing rapid and reliable VOC detection capabilities. High sensitivity gas sensor array technology enables pollution event monitoring to part-per-billion concentration levels.

High sensitivity non-contact measurements, industry standard features & proven reliability combined to produce a robust, cost-effective solution for your VOC monitoring needs.

System Features

- Cost effective VOC monitoring
- High sensitivity sensor technology
- ppb concentration event monitoring
- Non-contact measurement
- Immunity from environmental influence
- Robust for field deployment
- Independently tested
- Proven reliability
- Industry standard telemetry options
- Minimal maintenance requirements
- Suitable for deployment in a range of industries

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multisensor systems
real-time VOC monitoring

Multisensor Systems Ltd. Fairburn Building, 72 Sackville Street, Manchester, M60 1QD.

Overview

Multisensor Systems Ltd was founded in September 2006 to provide reliable and cost-effective volatile organic compound (VOC) monitoring systems for industrial and environmental applications. Our products are based on leading edge technology that draws upon the experience gained from over 20 years of research at the University of Manchester (UK).

Working closely with major UK water utility and waste management companies, our systems have been refined to provide a robust solution for real-time VOC measurement in demanding site environments.

Designed to survive continuous field deployment with extended service intervals, providing remote automated operation.

Multisensor Systems uses state-of-the-art research facilities to provide ongoing product development ensuring that we remain at the cutting edge of technological innovation. We also maintain valuable links with laboratories across the UK and Europe to ensure wider-ranging capabilities if required.

Technology

Our monitoring systems are based on core technology comprising an array of gas sensors that exhibit broad selectivity and high sensitivity to a range of volatile organic compounds.

Whilst highly sensitive to VOCs, systems also provide immunity from environmental influences, essential for reliable field deployment.

Air samples are drawn across the sensor array for measurement of VOC content either directly, or via sampling systems optimised for a particular application. VOC monitoring using this approach is therefore non-contact in nature, ensuring effective operation in harsh conditions and minimising maintenance.

Multisensor System's products combine leading edge technology with industry standard features in a unique and robust package designed for deployment in demanding conditions. Innovation is inherent throughout, from sophisticated sensor control systems to software with embedded artificial intelligence.

Filename	Date	Time	Interval	Instrument ID	Analysis
FILE_080606_104428	08:06:06	10:44:28	0	ENSEW0002	

Independently Tested

In August 2006 our monitors were independently tested by the WRc as part of a Portfolio Project investigating monitoring systems for intake protection for the water industry and assessed as class-leader for detection of fuel oil contamination in clean water systems.

Instruments are able to detect fuel oil contamination at low part-per-billion (ppb) concentration levels in a range of raw waters and was the only technology capable of detecting all fuel samples on test.

portfolio

Products

Instruments are modular and bespoke systems may be configured from core elements. Sensors, sampling systems, telemetry options and software can be chosen to provide the optimum solution for your application.

Scope

Instruments are highly sensitive to a wide range of VOCs, sulphurous compounds and methane. While focused primarily on VOC monitoring for process characterisation and control, the technology provides scope for more general applications such as distributed odour monitoring if required.

Further Information

Please refer to our application notes for detailed information. If you do not see what you require, or wish to discuss your application, please contact us.

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multisensor systems
real-time VOC monitoring

multisensor systems
real-time VOC monitoring

VOC Monitor

Description

The VOC Monitor is an on-line VOC (volatile organic compound) alarm system for monitoring VOC pollutants in the air and in liquids. When monitoring VOCs in liquids the VOC Monitor extracts the air from above the liquid rather than the liquid itself and so is a non-contact method.

An internal pump draws air, at user defined intervals, into the robust polycarbonate enclosure and the air sample is passed over the sensor array which is operated in such a way as to provide immunity from environmental influences such as humidity.

The VOC Monitor does not provide a measure of the concentration of any individual compound. It monitors changes in the concentration of total VOCs present.

Features

- High sensitivity to VOCs (to ppb concentrations).
- User specified alarms (low and high).
- Avoids false alarms by comparing the current reading with the ‘history’of readings.
- Non-contact measurements (non-fouling and low maintenance).
- Industry standard telemetry options (including wireless).
- Proven reliability, robust and cost-effective.

Applications

Applications include plant protection (such as the detection of oil in water), pollution detection, process monitoring and odour monitoring. Specific examples are:

(i) Clean water treatment.

- Detection of oil, petrol, diesel and aviation fuel in water. An independent investigation by WRc (www.wrcplc.co.uk) in 2006 of oil in water monitoring systems found the VOC Monitor to be the class leader.

- Detection of herbicides & pesticides.

(ii) Waste Water treatment.

Plant protection, process monitoring and odour detection possible at;

- Activated sludge plants.
- Wastewater treatment plant intakes.
- Liquor returns.
- Filter beds.
- Rising mains.
- Pumping stations.

(iii) Aviation

Monitoring fuel spillages at air bases and airports.

(iv) Manufacturing industry

Monitoring discharges and processes which include VOCs.

(v) Oil industry

Discharges and leaks (on-shore and off-shore).

Installation

Additional equipment is recommended when monitoring VOCs in liquids. The equipment used to extract air samples (for example from above streams of waste or clean water) depends upon the application. The two photos below show: (i) On the left a small grey tank below the monitor through which clean water flows. The Monitor pump draws in air from a small (approximately 3cm deep) headspace at the top of the tank. (ii) On the right an additional external pump (in a white casing) drawing air up a (black) pipe from a stream of waste water several metres below.

(i) Clean water

(ii) Waste water

The installation of the VOC Monitor itself comprises the following straightforward steps:

(i) Fix the Monitor to a wall using the mounting brackets provided.
(ii) Connect the Monitor to the external telemetry (e.g. 4 to 20mA).
(iii) Connect the Monitor to the sampling system (where applicable) with the plastic tube provided.
(iv) Connect the Monitor to the power supply and switch on.

Maintenance

The reference air filter will need to be replaced approximately every six months (depending upon the application). The filter housing is mounted on the outside of the monitor for easy inspection and maintenance.

Specification

Dimensions (mm): 500(H) x 400(W) x 200(D). Power Supply: Automatic voltage selection from 110V to 230V AC (single phase). Temperature range: -40 to 80 °C (short term) -40 to 60 °C (continuous) Gasket material: EPDM Electrical insulation: Totally insulated	Halogen free (DIN/VDE 0472, Part 815): Yes Flammability Rating (UL 746 C 5): UL 94 HB Glow Wire Test (IEC 695-2-1) °C: 650 NEMA Class: NEMA 1, 4, 4X, 12, 13 Ingress Protection (EN 60529): IP 65 Impact Resistance (EN 50102): IK 08

Multisensor Systems Limited,
c/o UMIP, Core Technology Facility,
46 Grafton Street,
Manchester, M13 9NT
U.K.

www.multisensor.co.uk

Product Features

Fully configurable for optimised performance and ease of integration into existing site infrastructures.

Instrument

Instruments are housed in robust polycarbonate enclosures that provide a high degree of ingress protection. Enclosures are configurable with a universal key latch (or lockable latch for extra security) and are wall mountable. Power is supplied via an appliance inlet with automatic voltage selection and operation from 110 to 230V AC (single phase).

Telemetry systems (GSM/RS-422/RS-485/Profibus) and alarm triggers may be specified for integration with existing SCADA systems. Auxiliary RS-232 serial communication and current loop output (4-20mA) are provided as standard.

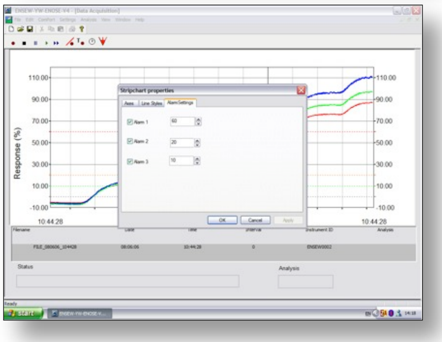
Gas systems are fully automated and enclosed with filtration units used for reference air generation and particulate protection. A six monthly service interval is required (dependent on sampling frequency).

Custom designed sensor arrays utilise robust gas sensors for reliability and maximum operating lifetime (typically two years).

Control systems provide fully automated instrument control & status monitoring and support for up to 24 gas sensors. Auto power-up restart, SMS alerts (with GSM option) and ancillary control triggers for automation are provided.

Control Software

Embedded low-level software provides instrument control via serial communication and enables cross-platform operation (PC, PDA etc, either wired or wireless via telemetry).



Optional advanced high-level software operating on the Windows™ platform provides an intuitive graphical user interface, real-time output display, data review and adds intelligence. Smart alarms that 'learn' sensor response to underlying natural variation in incoming sample reduce false alarms, but trigger when pollution events are detected.

Instruments have two operating modes. Fast acquisition mode enables high resolution data to be acquired at 2 second intervals, while normal acquisition mode is based on a 15 minute interval, synchronised on the quarter hour. On-board data storage provides capacity for typically 2 months stand-alone operation when operating in normal acquisition mode. Data can be downloaded from the instrument locally or via telemetry.

Sampling System

For wastewater applications a rugged powered fan assembly to extract VOC plumes from points of interest is available. Universal gas connections are provided to integrate with existing hardware for clean water applications or alternatively a low cost header tank can be supplied for easy plumbing at new installations.

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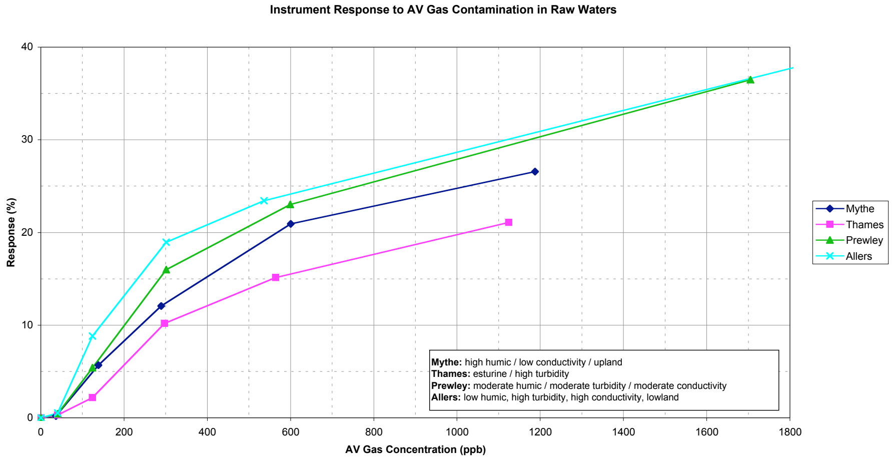
Clean Water Plant Monitoring

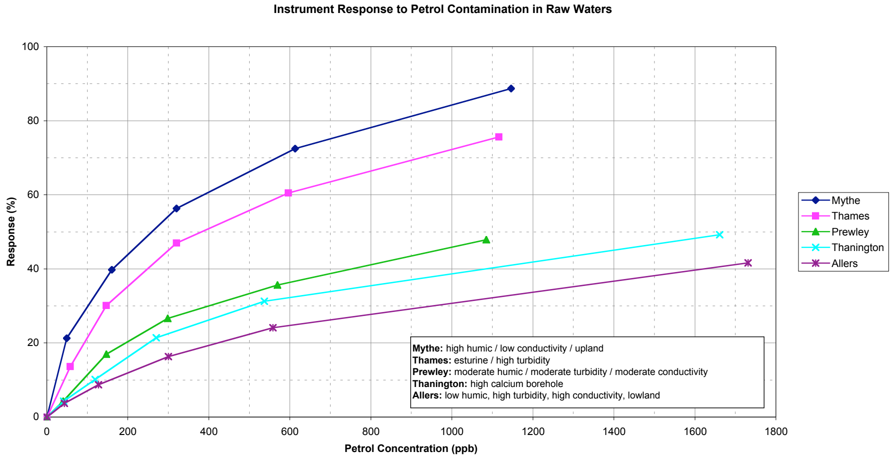
Our VOC monitors are able to provide rapid, on-line detection of ppb level pollutants in clean water systems. The high sensitivity gas sensor array technology has been shown effective for detection of raw water contamination from fuel oils (including aviation fuels), herbicides and pesticides.

Data presented here were obtained from independent testing as part of a WRc Portfolio Project investigating monitoring systems for intake protection. Trials were conducted using 200 litres of raw water of varying compositions. Fuel oil spikes were added directly to the bulk water to simulate a pollution event.

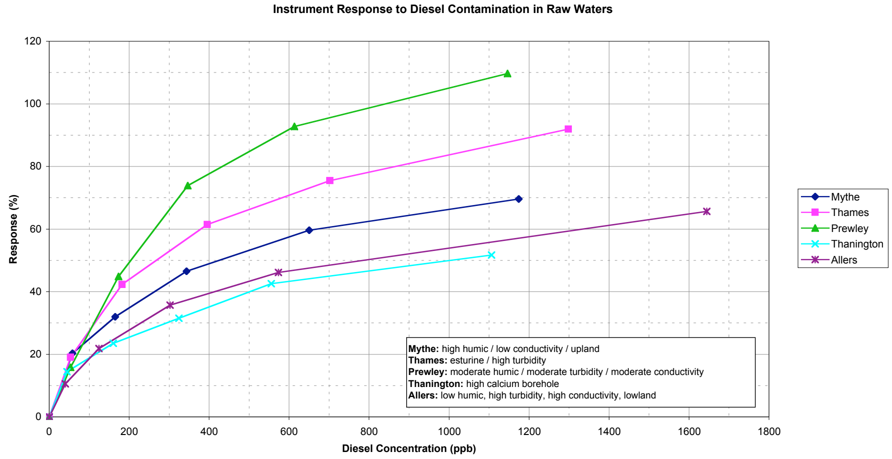
AV Gas Detection



Petrol Detection



Diesel Detection



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Data shown here were reproduced with the permission of WRc Group, South West Water, Thames Water, Severn Trent Water, Bristol Water, Mid Kent Water, Yorkshire Water & Portsmouth Water.

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Attachment 2

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Multisensor Systems Ltd
C/O UMIP
CoreT echnology Facility,46 Grafton Street Manchester
M 139 NT, Tel. 0161 6037 765 fax 0161 6067 307

Instrument Manual

Components Supplied

1. VOC Monitor
2. Power supply Socket 110 Volts (mains cable not supplied as this depends on the installation)
3. USB Cable
4. 4 wall mounting lugs
5. 1 key for VOC Monitor Box
6. 1 packet of 2 metres PTFE tubing and connector fittings
7. Cable glands (2)
8. 1 Bulkhead connector

Cabinet

Specifications

Cabinet mm: Length 500 X Width 400 X Height 200
Gasket material: EPDM
Base colour: RAL 7035
Cover colour: Smoked grey
Electrical insulation: Totally insulated
Halogen free (DIN/VDE 0472, Part 815): Yes
Flammability Rating (UL 746 C 5): UL 94 HB
Glow Wire Test (IEC 695-2-1) °C: 650
NEMA Class: NEMA 1, 4, 4X, 12, 13
Ingress Protection (EN 60529): IP 65
Impact Resistance (EN 50102): IK 08

Temperature Range

Short term: -40 … 80 °C
Continuous: -40 … 60 °C

Certificates

Fimko
Europe EN 50298: 1998
Gost R

OTHER COMPONENTS – NOT SUPPLIED

Rectangular Water Tank

Titan Wizard 10/4PCC4R Rectangular Water Tank KM4 Black (supplier B&Q Ltd)
Width (mm): 296
Depth (mm): 305
Length (mm): 442
Collection Capacity (L): 18

Titan Cistern Lid 10/4 PC4R Rectangular Water Tank Lid KM4LID Black

Cabinet Mounting

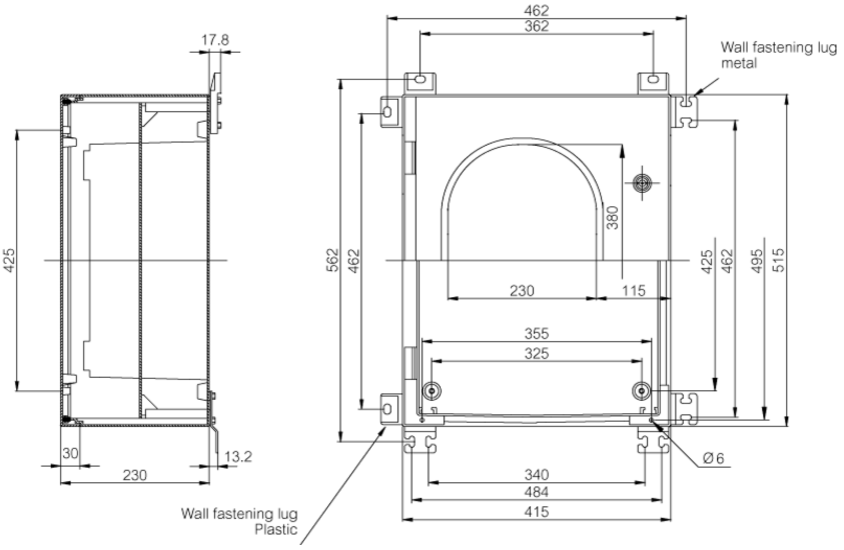


Figure 1 Cabinet dimensions and mounting

Dimensions (mm)

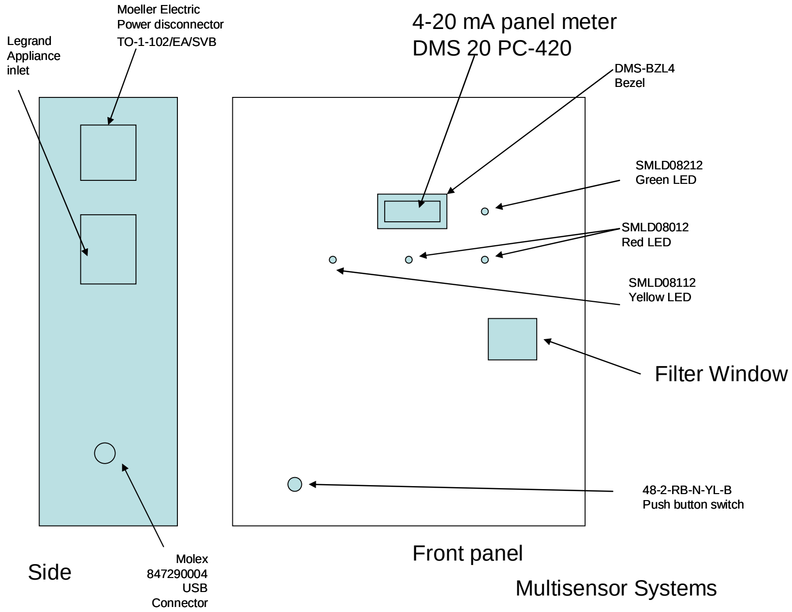


Figure 2 Front and left side panel

The system is designed to sample the headspace volatiles from a continually flowing stream of water. A simple method of doing this is to use a cistern and flow water continually in and out – avoiding splashing. The **bulkhead connector** supplied is plugged into the lid of the header tank.

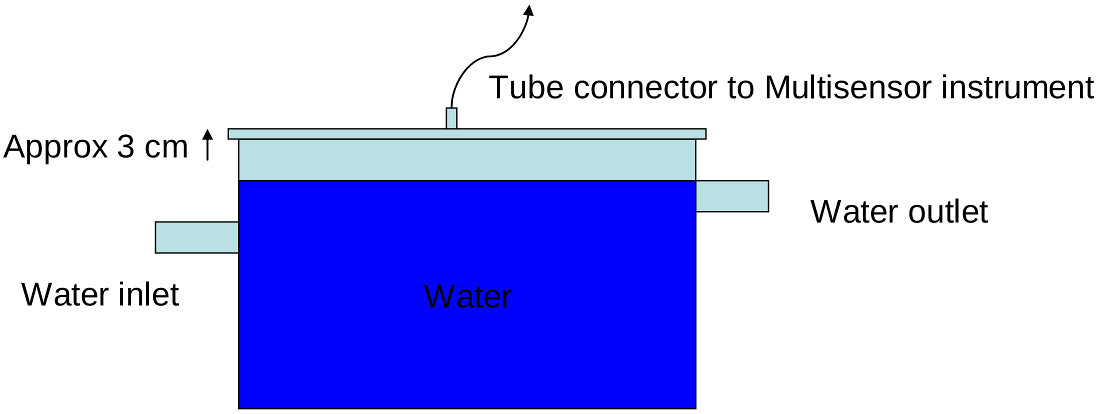


Figure 3 Flow through tank

Figure 4 Installation on site

Figure 5 Cistern tank

Some clients have made a tank in house. Figure 4 shows an installation at one company. Other clients have used a cistern from B&Q which works perfectly well – see Figure 5.

Titan Cistern Lid 10/4 PC4R Rectangular Water Tank Lid KM4LID Black,
Titan Wizard 10/4PCC4R Rectangular Water Tank KM4 Black obtained from B&Q.
Width (mm): 296
Depth (mm): 305
Length (mm): 442
Collection Capacity (L): 18

Electrical requirements 220-240 V AC or 90-120V AC, 2 Amperes

Supplied

Industrial Appliance Inlet (110V)

Industrial cable socket (110V)

4-20 mA loop Self Powered

1 digital relay NORMALLY OFF output – signals FAULT on instrument

OPTIONAL

2 digital relays – signals ALARM LEVEL 1, ALARM LEVEL 2

We have found that most clients set a threshold for an alarm directly from the 4-20 mA output, so the digital outputs are only rarely used.

The system also provides a USB connector for direct connection to an external computer for data logging, or downloading data stored in memory.

The system also has a test mode switch that allows switching to rapid sampling mode for testing the instrument against a test volatile. If the system is running in a default slow acquisition mode, then pressing the TEST button will switch the system into fast mode acquisition (2 second sampling). This allows an operator to apply a test substance to the system to make sure that everything is operational. The FAULT light comes on and the Running LED blinks rapidly, in this mode. On pressing the switch again, the system returns to normal sampling mode.

Instrument layout

Figure 6 Instrument layout

Installation Instructions

1. Screw in the 4 mounting brackets on the VOC Monitor box and fix to wall support.

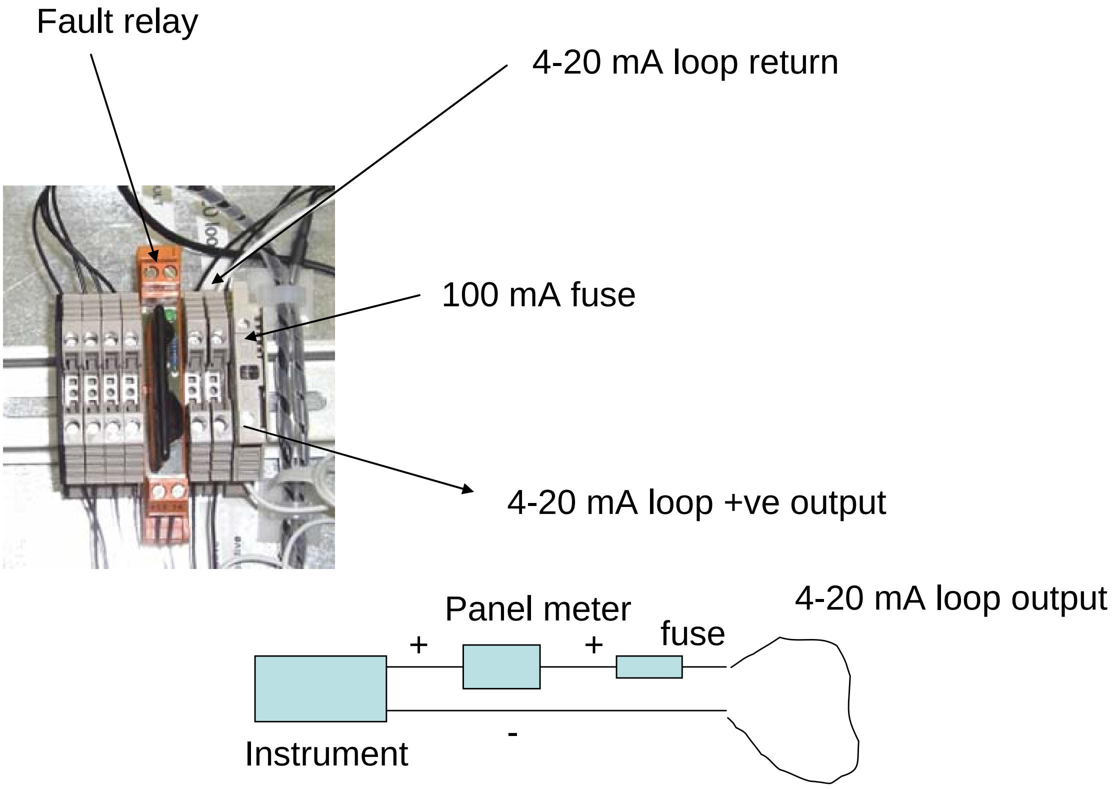
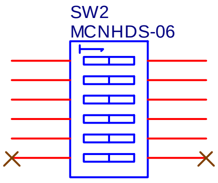


Figure 7 Location of Relays and 4-20 mA loop connectors

2. Connect the 4 to mA loop to the external telemetry system – **note this is supplied as an internally powered loop and 24 volts are supplied from the interface** – a fuse is fitted which is set to 100 mA. A white wire is fitted as a dummy external loop. Remove this, and wire in your own connections to your SCADA system. From the fuse connector – connect to the external loop +ve and then return the loop as shown. The blanked cable glands on the lower left of the instrument can be used to pass wires into and out of the instrument.

The hardware also allows an externally powered loop to be operated. However to do this, the settings on the DIP switch (SW2) on the main circuit board have to be changed and the wiring to the loop reversed (i.e. positive in to negative out, and negative in to positive out). Note that power to the instrument should be off if this setting is changed or damage may occur.



4-20mA current loop operation:-

External power supply
Switches 1,2,3 OFF
Switches 4,5,6 ON

Internal power supply
Switches 1,2,3 ON
Switches 4,5,6 OFF

Figure 8 DIP Switch Settings (Default settings is for an internally powered 4-20 mA loop)

DIP Switch for
powered 4-20 mA interface

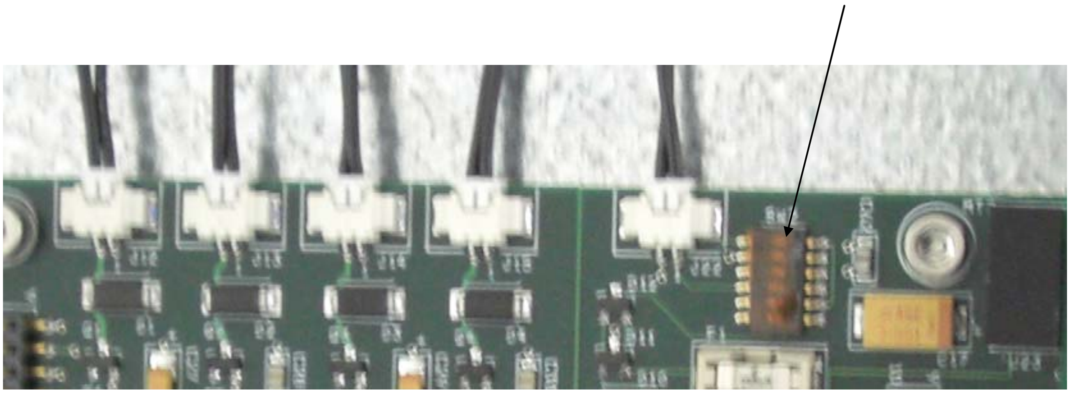


Figure 9 Position of DIP switch on main circuit board

3. A normally open relay (Fault Relay Figure 2) is supplied as standard to signal instrument faults. If this is to be used then connect relay outputs to your external digital alarm system input. The blanked cable glands can be used to pass cables into the instrument.

4. Connect sampler inlet to the inlet of the VOC monitor using the PTFE tube and connectors supplied.

6. Connect power cable to instrument and switch on.

The system automatically starts up and after a 5 minute warm-up period (running Led flashes at 5 second intervals) starts to collect data at 15 minute intervals (default setting). The indicator light will flash during data acquisition. Using the software supplied – it is possible to set sampling intervals from 15 min, 5 min, 2 min. If power goes off the instrument will automatically restart from power up at the last sampling interval used.

In normal use, it is expected that the user would be using the 4 to 20 mA current loop for telemetry and appropriate alarms would be set by the user. However the system also provides relays that trigger if the VOC levels monitored are 20% or 50% of change in sensor response (corresponding to 50 ppb and 80 ppb respectively diesel in water respectively (approximately)).

The system can be connected to an external computer for direct data acquisition using the USB cable supplied.

Data Modem

Data is logged continuously by the instrument into non-volatile memory, and about 2 months of data can be retained in memory. The instrument contains an internal GSM data modem. This can be used to upload data from the instrument remotely via dial-up. A telephone number for the SIM card supplied is given in the Appendix.

Test Mode Switch

On pressing the Test mode switch the instrument interrupts its normal mode of operation and goes into a 2 sec interval sampling mode. The fault light will come on to indicate to the operator that the instrument is in this mode. This allows an operator to test functionality of the system by presenting a test volatile to the instrument. When pressed again, the system will revert back to the previous sampling regime.

Filter

A window is provided in the front of the case to allow inspection of the internal filter used to generate a clean air baseline for the instrument. The upper part of the filter contains a molecular sieve that contains coloured granules. These granules should be blue in colour. If the granules are pink in colour, then the filter packing should be changed. The lifetime of the filter depends on the sampling frequency used for the instrument, but is normally about 6 months.

Startup of the instrument

Connect the PTFE tube to the header tank. Make sure that no water can be drawn into the instrument. The instrument operation can be observed directly using the software supplied or via the display on the front panel.

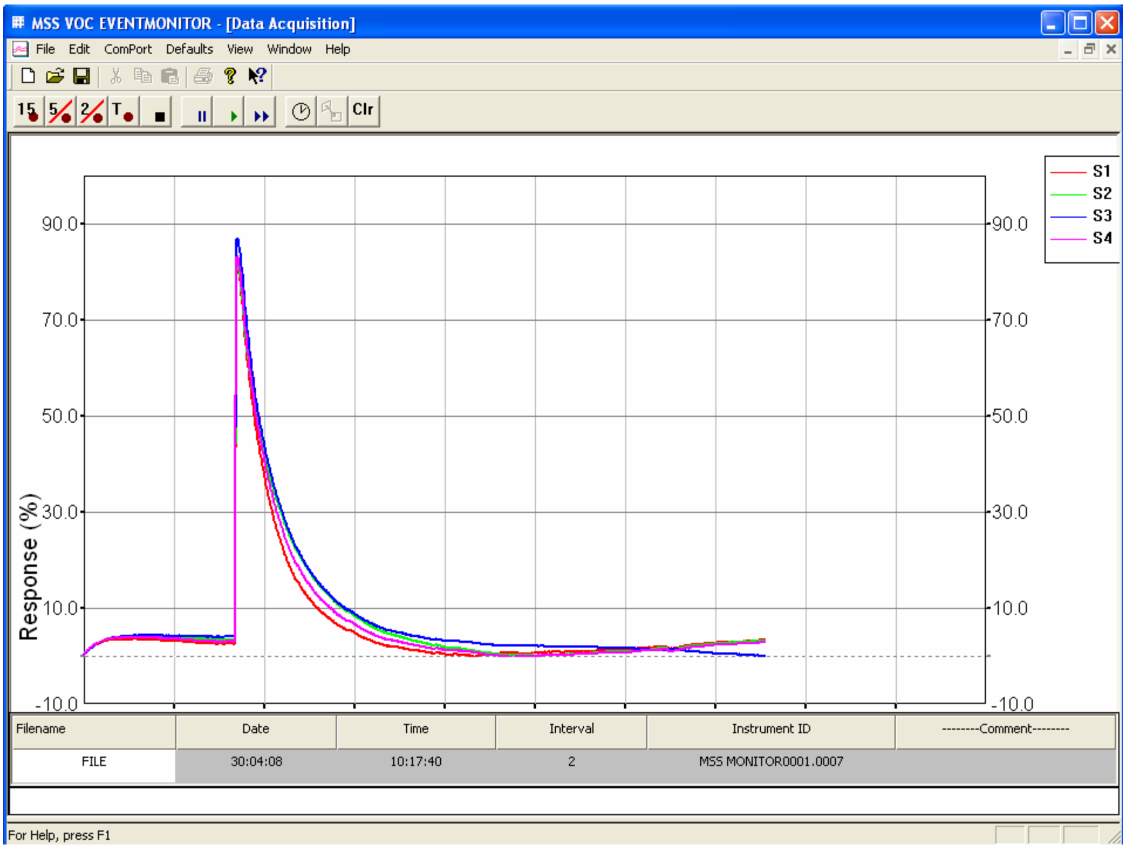
Switch on the instrument – after about 30 sec the RUNNING LED will start to blink at 5 second intervals for 5 minutes, while the instrument and sensors are warming up. After 5 minutes the instrument will start to collect data at the last sampling interval used (default 15 minute intervals).

Section 2

2 Software

A simple data acquisition software is supplied that runs on Windows 2000, Windows XP or Windows Vista. To install, you should be in administrator mode on the PC.

1. First install USB drivers. The Software is CDM xxxx. Exe
2. Run Setup.exe.   This is a provisional version of the software program to be tested before final release.
3. Some computers may need to certain windows components installed. If the Setup program complains, then cancel it, run dotnetfx.exe to install Windows Network Components, then re-run Setup.



Filename	Date	Time	Interval	Instrument ID	--------Comment--------
FILE	30:04:08	10:17:40	2	MSS MONITOR0001.0007	

Figure 10 Strip chart

OPEN Com Port

Connect the USB cable from the computer to the instrument. This mimics a serial port on your PC. Open the Comport using the Comport – Open

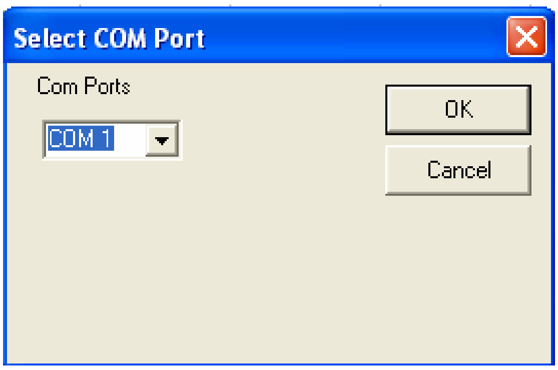
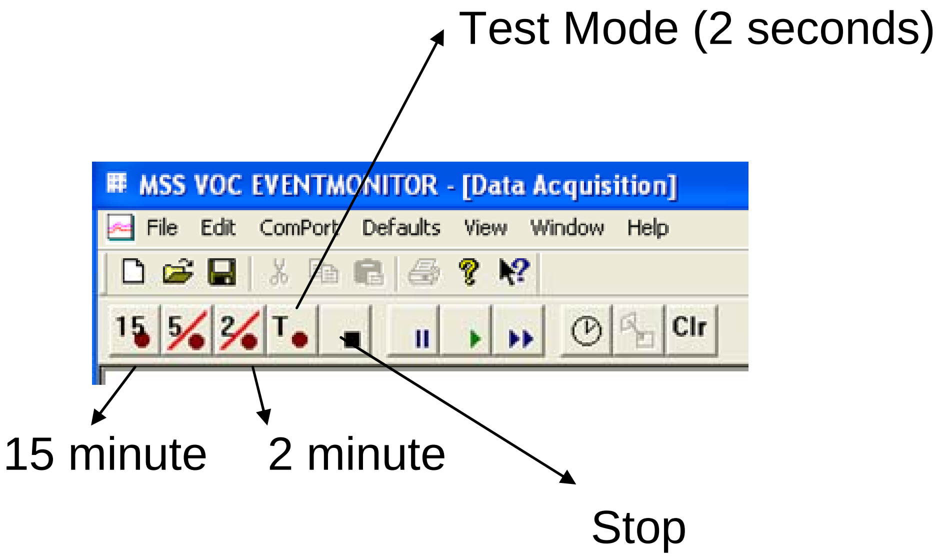


Figure 11 Select Com Port

Select the appropriate Com port – the computer creates a new Com Port number when the instrument is plugged in.

Once selected, the system is ready for use.



• Figure 12 Tool bar buttons

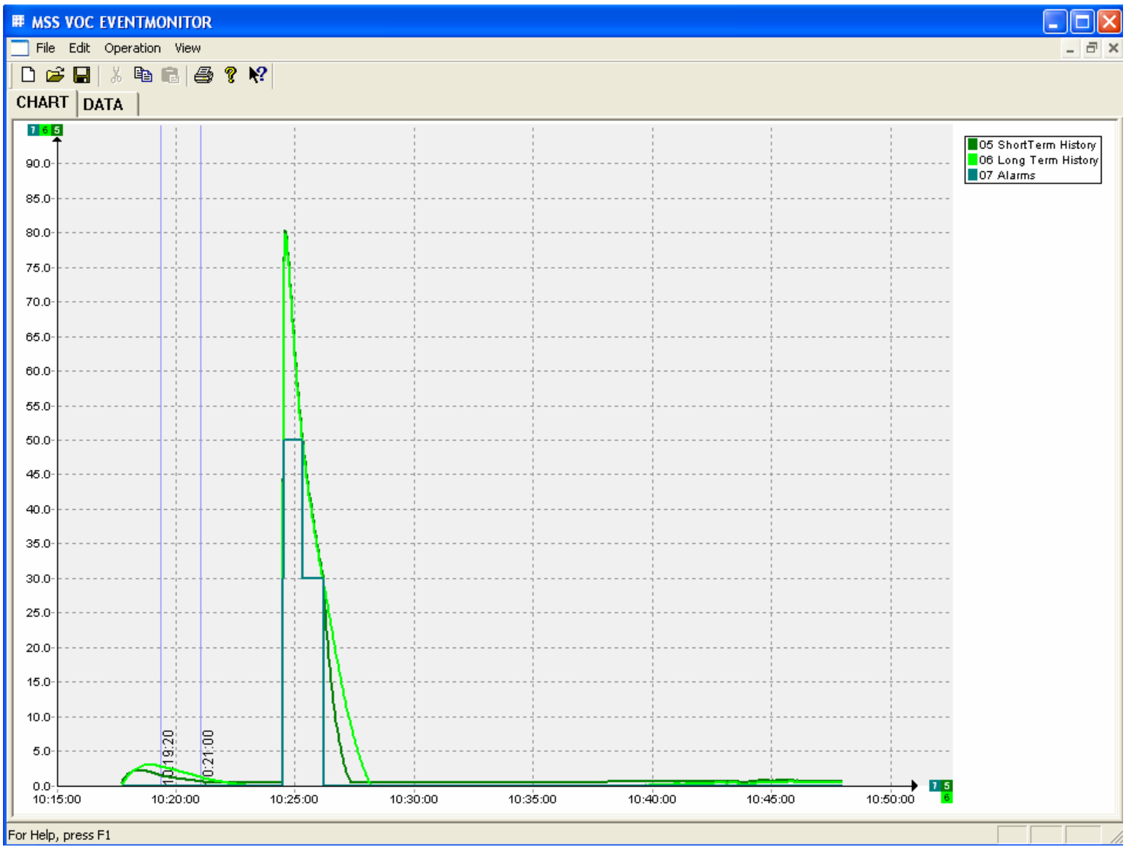
The buttons on the tool bar allow recording of data at different time intervals. The system attempts to sample at intervals on the clock, so there may be a delay before recording starts depending on which mode is selected. The Left block of buttons control recording, while the right block of three buttons control playback. The Clock button allows synchronisation of the instrument clock with the computer clock. The button to the right of the clock allows upload of data from the instrument to the computer that has been previously stored in memory. The Clr button clears data in memory of the instrument.

Press the Stop button – in case the system is aleady recording, then press one of the record buttons. The system will start to record after a short delay, and the data will be displayed on the strip chart.

In the fast 2 second mode, the system is continuously sampling from the inlet. In the other modes, it switches between the filter and the inlet to achieve a differential response. This will be shown as a zig-zag trace on the stripchart.

Internally the system is doing many things. It creates a short and long term history of points collected and compares the current data point with the average collected. The default short term history is 24 points x sample interval , while the default long term history is 24 x 24 points x sample interval (576 points). This at 15 minute intervals this is a 6 hour period for the short term history, and 6 days for the long term history.

The command View- Charts allows access to the screen below that gives an idea of what is appearing on the 4-20 mA loop.



For Help, press F1

Figure 13 Data Display

Different plots can be selected using Operation – Select Plots
Left and right cursors can be used to identify the time of an event
Right Clicking on the plot gives a popup menu, allowing zooming to a part of the plot, etc.

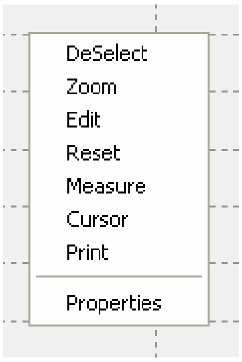
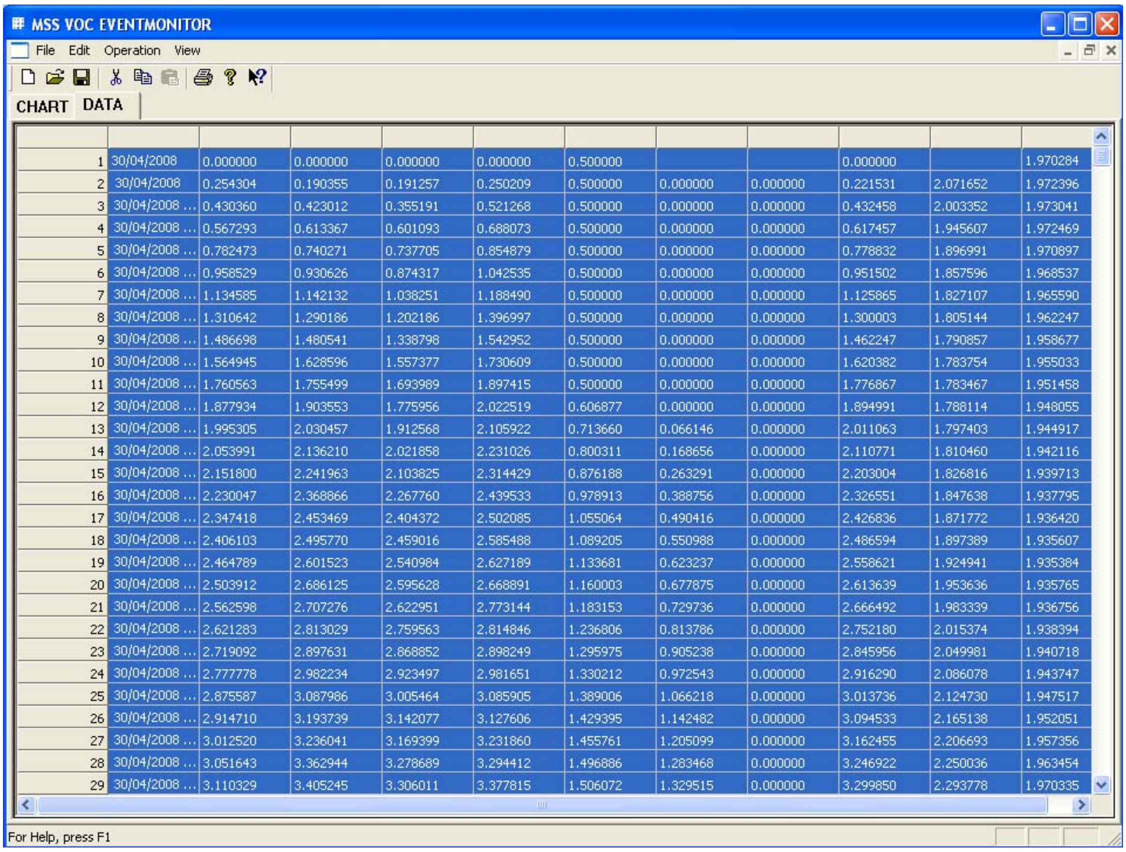


Figure 14 Plot Selection

Deselect – deselect current plot area
Zoom – zoom to the area selected by the cursor
Edit – not implemented (Fault)
Measure – distance – x and y – selected by mouse left button
Cursor – add cursor – not implemented (Fault)
Print – print graph
Properties – change chart colours and axis settings

On selecting the data tab, the raw data is displayed in spreadsheet format.



1	30/04/2008	0.000000	0.000000	0.000000	0.000000	0.500000			0.000000		1.970284
2	30/04/2008	0.254304	0.190355	0.191257	0.250209	0.500000	0.000000	0.000000	0.221531	2.071652	1.972396
3	30/04/2008 ...	0.430360	0.423012	0.355191	0.521268	0.500000	0.000000	0.000000	0.432458	2.003352	1.973041
4	30/04/2008 ...	0.567293	0.613367	0.601093	0.688073	0.500000	0.000000	0.000000	0.617457	1.945607	1.972469
5	30/04/2008 ...	0.782473	0.740271	0.737705	0.854879	0.500000	0.000000	0.000000	0.778832	1.896991	1.970897
6	30/04/2008 ...	0.958529	0.930626	0.874317	1.042535	0.500000	0.000000	0.000000	0.951502	1.857596	1.968537
7	30/04/2008 ...	1.134585	1.142132	1.038251	1.188490	0.500000	0.000000	0.000000	1.125865	1.827107	1.965590
8	30/04/2008 ...	1.310642	1.290186	1.202186	1.396997	0.500000	0.000000	0.000000	1.300003	1.805144	1.962247
9	30/04/2008 ...	1.486698	1.480541	1.338798	1.542952	0.500000	0.000000	0.000000	1.462247	1.790857	1.958677
10	30/04/2008 ...	1.564945	1.628596	1.557377	1.730609	0.500000	0.000000	0.000000	1.620382	1.783754	1.955033
11	30/04/2008 ...	1.760563	1.755499	1.693989	1.897415	0.500000	0.000000	0.000000	1.776867	1.783467	1.951458
12	30/04/2008 ...	1.877934	1.903553	1.775956	2.022519	0.606877	0.000000	0.000000	1.894991	1.788114	1.948055
13	30/04/2008 ...	1.995305	2.030457	1.912568	2.105922	0.713660	0.066146	0.000000	2.011063	1.797403	1.944917
14	30/04/2008 ...	2.053991	2.136210	2.021858	2.231026	0.800311	0.168656	0.000000	2.110771	1.810460	1.942116
15	30/04/2008 ...	2.151800	2.241963	2.103825	2.314429	0.876188	0.263291	0.000000	2.203004	1.826816	1.939713
16	30/04/2008 ...	2.230047	2.368866	2.267760	2.439533	0.978913	0.388756	0.000000	2.326551	1.847638	1.937795
17	30/04/2008 ...	2.347418	2.453469	2.404372	2.502085	1.055064	0.490416	0.000000	2.426836	1.871772	1.936420
18	30/04/2008 ...	2.406103	2.495770	2.459016	2.585488	1.089205	0.550988	0.000000	2.486594	1.897389	1.935607
19	30/04/2008 ...	2.464789	2.601523	2.540984	2.627189	1.133681	0.623237	0.000000	2.558621	1.924941	1.935384
20	30/04/2008 ...	2.503912	2.686125	2.595628	2.668891	1.160003	0.677875	0.000000	2.613639	1.953636	1.935765
21	30/04/2008 ...	2.562598	2.707276	2.622951	2.773144	1.183153	0.729736	0.000000	2.666492	1.983339	1.936756
22	30/04/2008 ...	2.621283	2.813029	2.759563	2.814846	1.236806	0.813786	0.000000	2.752180	2.015374	1.938394
23	30/04/2008 ...	2.719092	2.897631	2.868852	2.898249	1.295975	0.905238	0.000000	2.845956	2.049981	1.940718
24	30/04/2008 ...	2.777778	2.982234	2.923497	2.981651	1.330212	0.972543	0.000000	2.916290	2.086078	1.943747
25	30/04/2008 ...	2.875587	3.087986	3.005464	3.085905	1.389006	1.066218	0.000000	3.013736	2.124730	1.947517
26	30/04/2008 ...	2.914710	3.193739	3.142077	3.127606	1.429395	1.142482	0.000000	3.094533	2.165138	1.952051
27	30/04/2008 ...	3.012520	3.236041	3.169399	3.231860	1.455761	1.205099	0.000000	3.162455	2.206693	1.957356
28	30/04/2008 ...	3.051643	3.362944	3.278689	3.294412	1.496886	1.283468	0.000000	3.246922	2.250036	1.963454
29	30/04/2008 ...	3.110329	3.405245	3.306011	3.377815	1.506072	1.329515	0.000000	3.299850	2.293778	1.970335

Figure 15 Raw data display

Data can copied and pasted into a spreadsheet like Excel, for further processing or examination.

3 Technical

VOC Sensor System

Metal Oxide Semiconductors

SnO_2, ZnO, Fe_2O_3 and WO_3 are intrinsically n-type semiconductors. At elevated temperature of 200-500°C they respond to reducing gases with an increase their conductivity and this decreases in the presence of oxidising gases. The conductivity σ and resistivity ρ is given by:

$$\sigma = \frac{1}{\rho} = eu\mu \qquad (1)$$

e = charge on the electron (1.6022×10^{-19} C)
n = the carrier (electron or hole) concentration (cm^{-3})
µ = the carrier mobility ($cm^2 V^{-1} s^{-1}$)

When using metal-oxide array based sensors their selectivity is greatly influenced by the operating temperatures of the devices. This is due to the reaction rates of different volatiles and the stability of adsorbed oxygen species being a function of the surface temperature. Manipulation of the temperature-selectivity dependence is used to improve the performance of MOS sensors.

Instrumentation

The analyte is a mixture of volatile chemicals. The system has to transduce a signal from those molecules adsorbed onto the sensor array. The ability to convert the chemical molecules into electrical signals requires sampling.

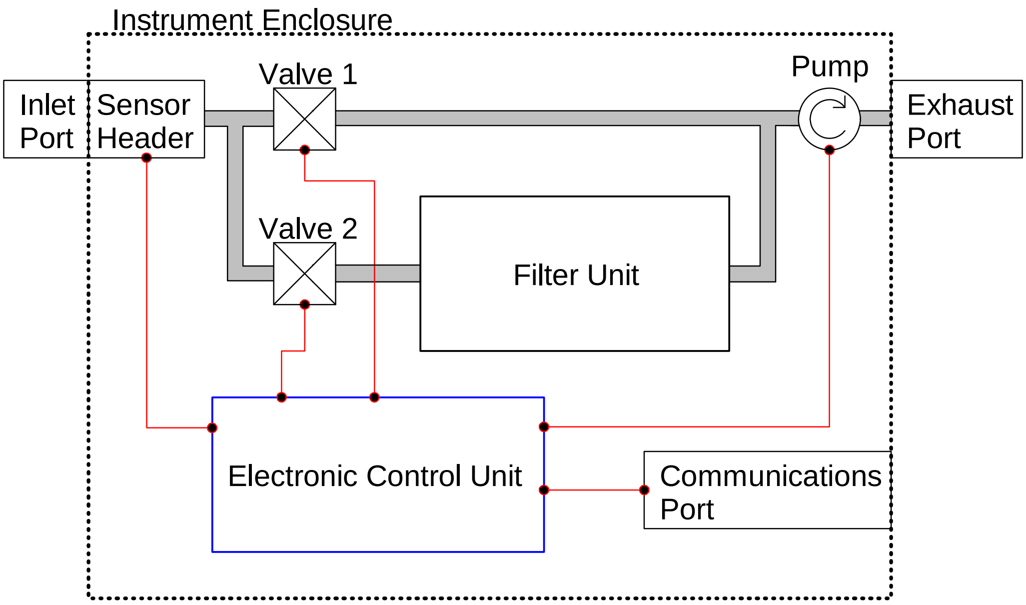
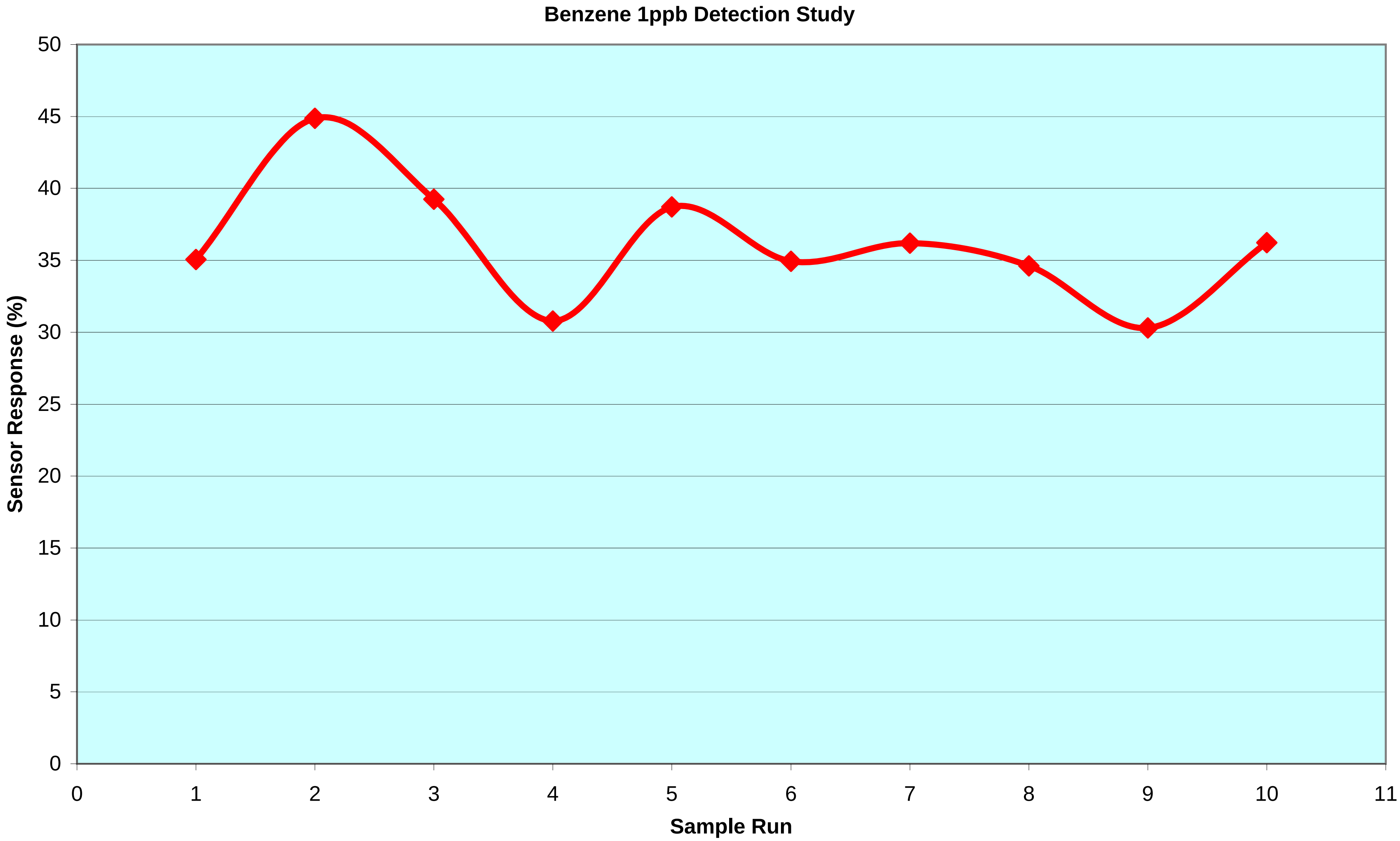


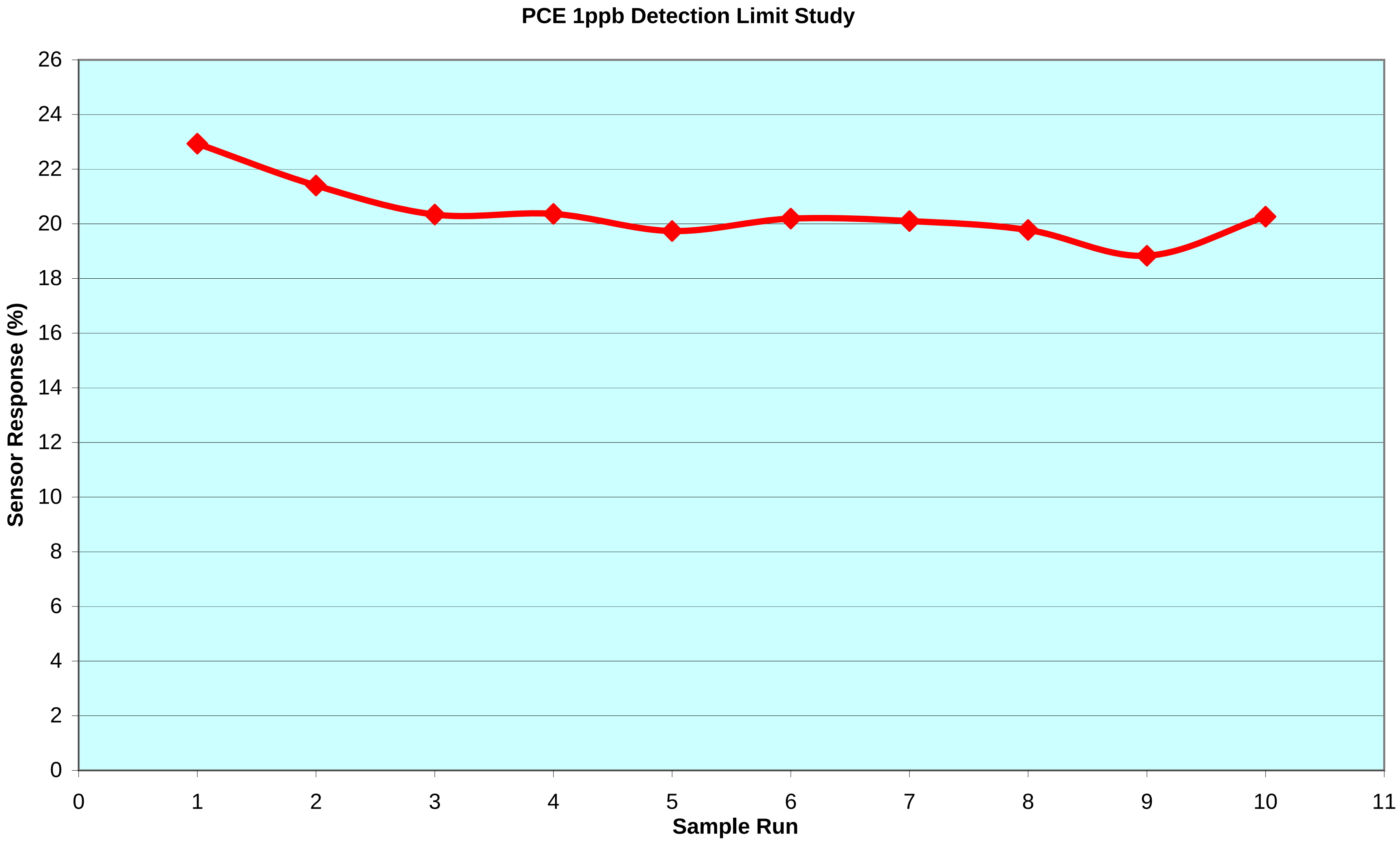
Figure 16 Block diagram of the Instrument

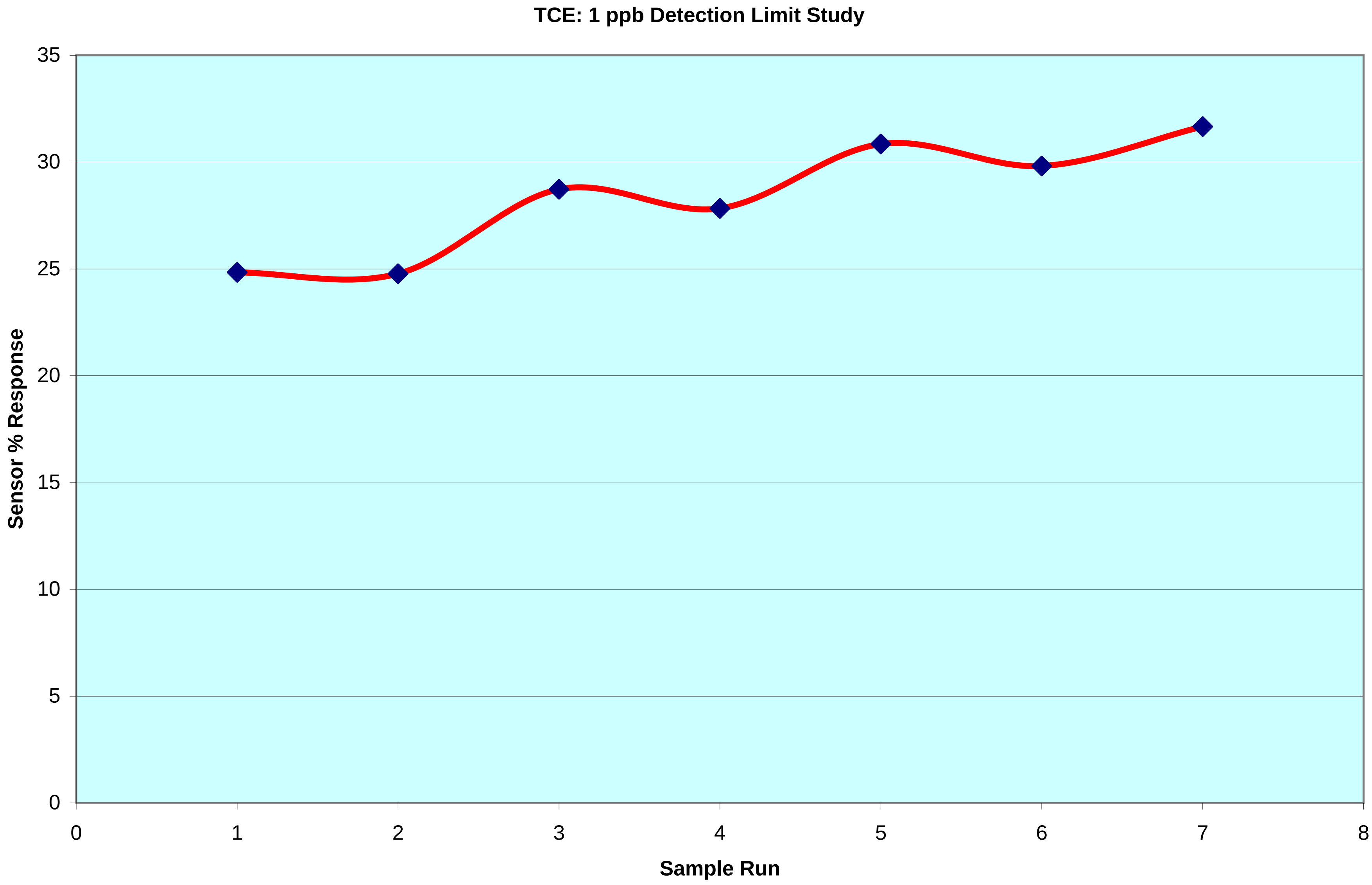
Air is first pulled through the filter to provide a baseline for the instrument. It then switches to sampling mode when air is pulled through the inlet to the sensor array.

The system is intended to be an EVENT monitor. It retains a short term and long term history of readings and compares the current reading against these before deciding whether a change has occurred. It adapts to slowly changing situations, where either the background or the sensor may be changing and signals ubrupt changes in the environment.

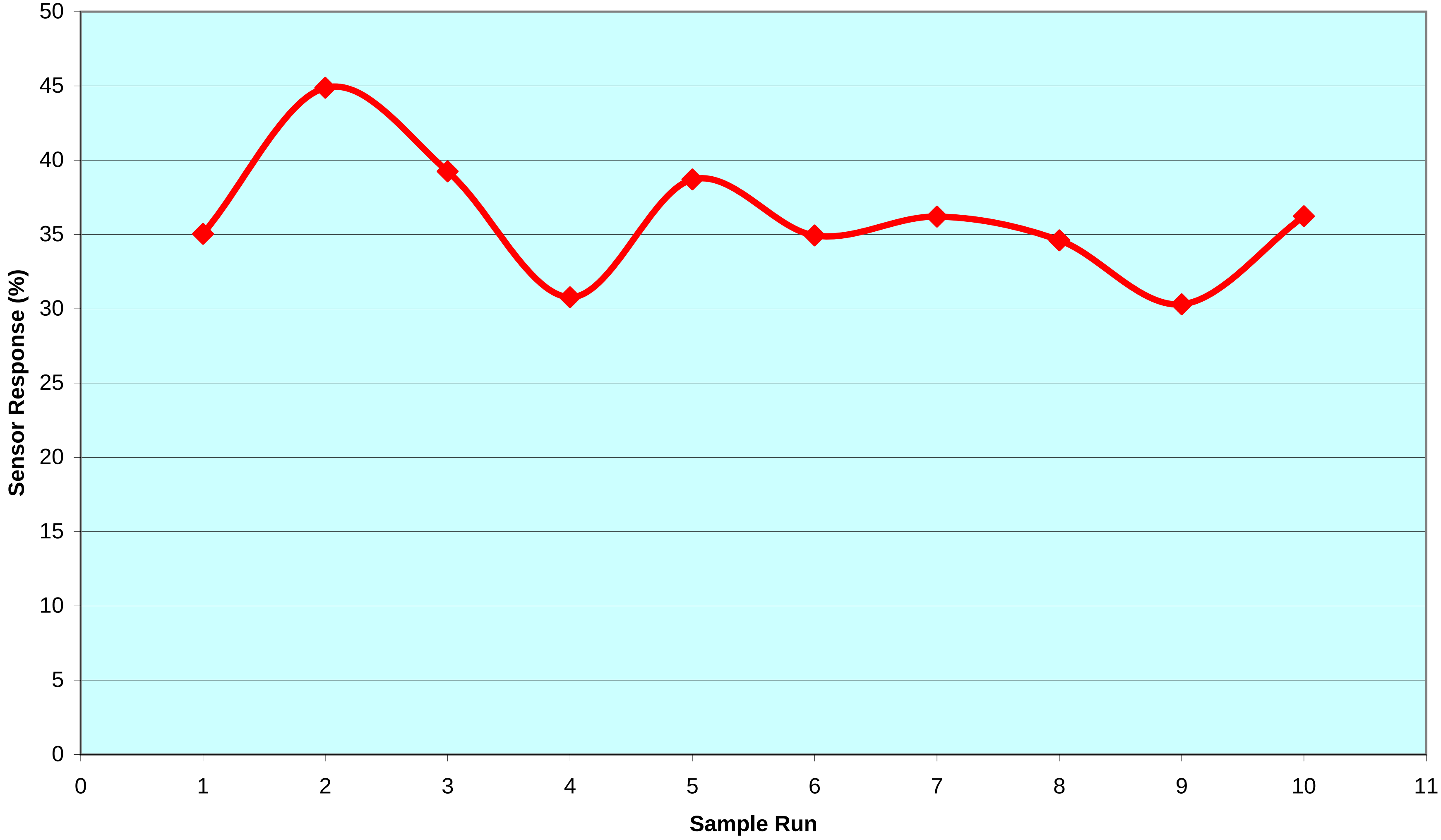
Attachment 3


Benzene 1ppb Detection Study
Sensor Response (%)
50
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
11
Sample Run

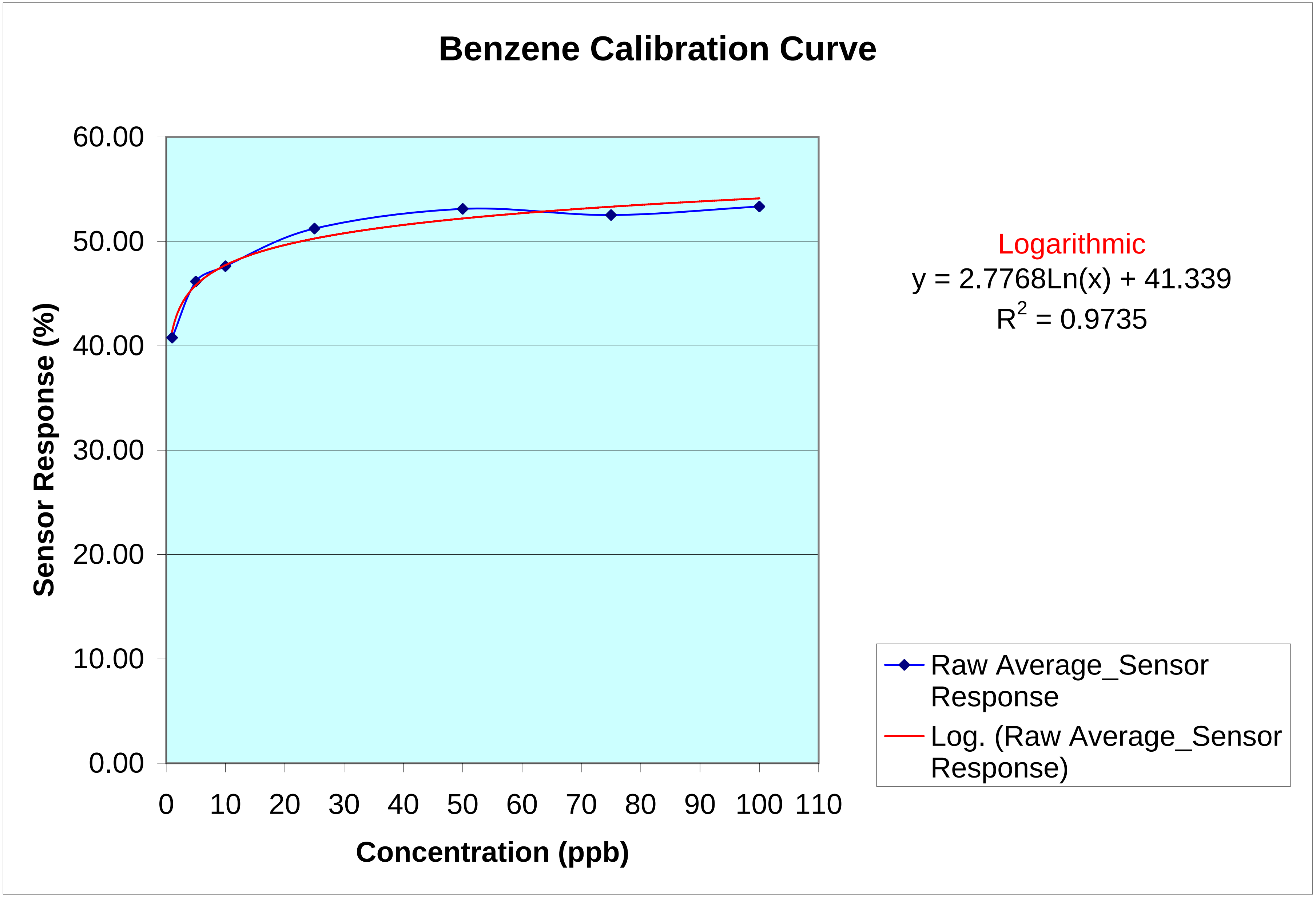

PCE 1ppb Detection Limit Study
Sensor Response (%)
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
1
2
3
4
5
6
7
8
9
10
11
Sample Run

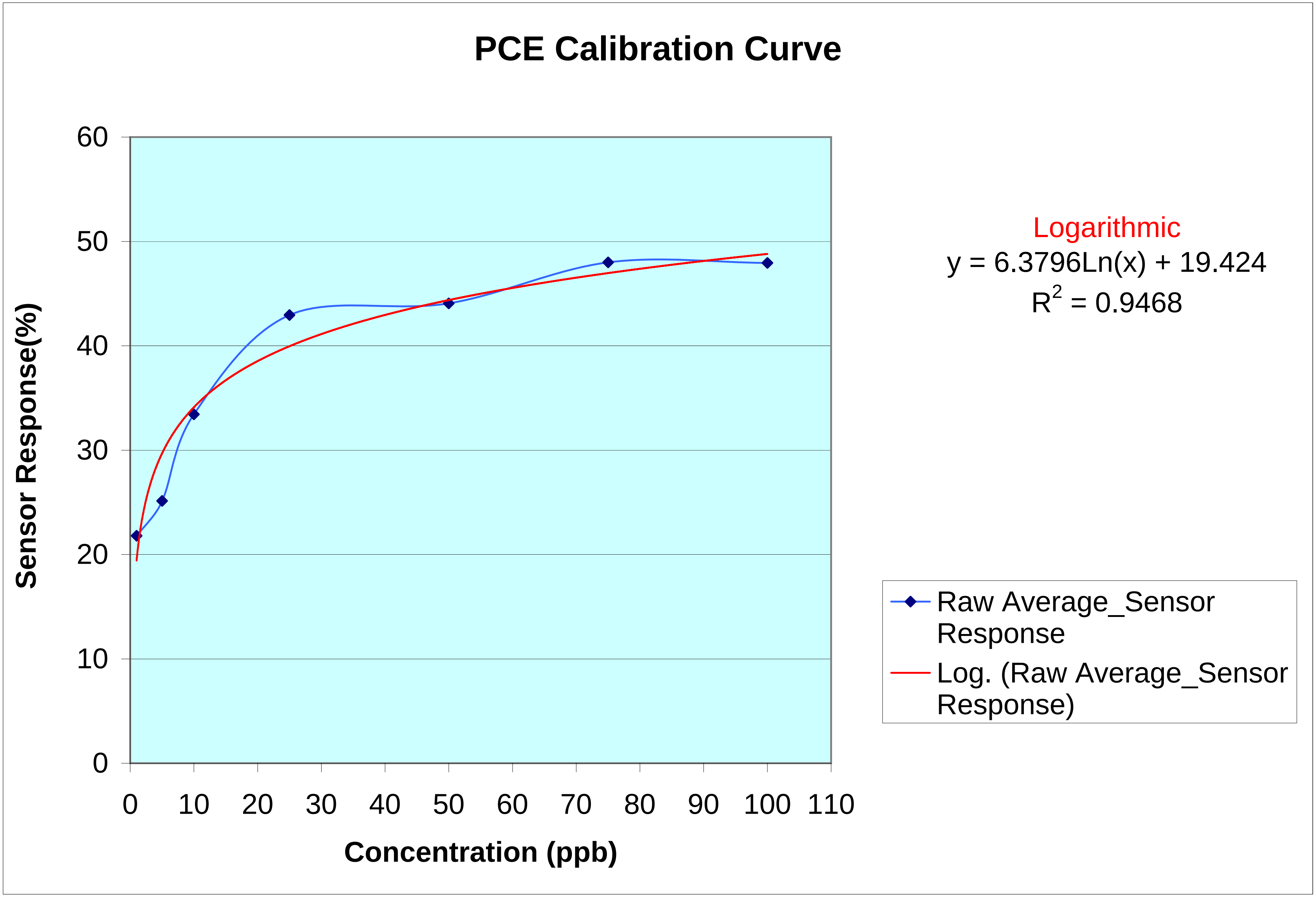

TCE: 1 ppb Detection Limit Study
Sensor % Response
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
Sample Run

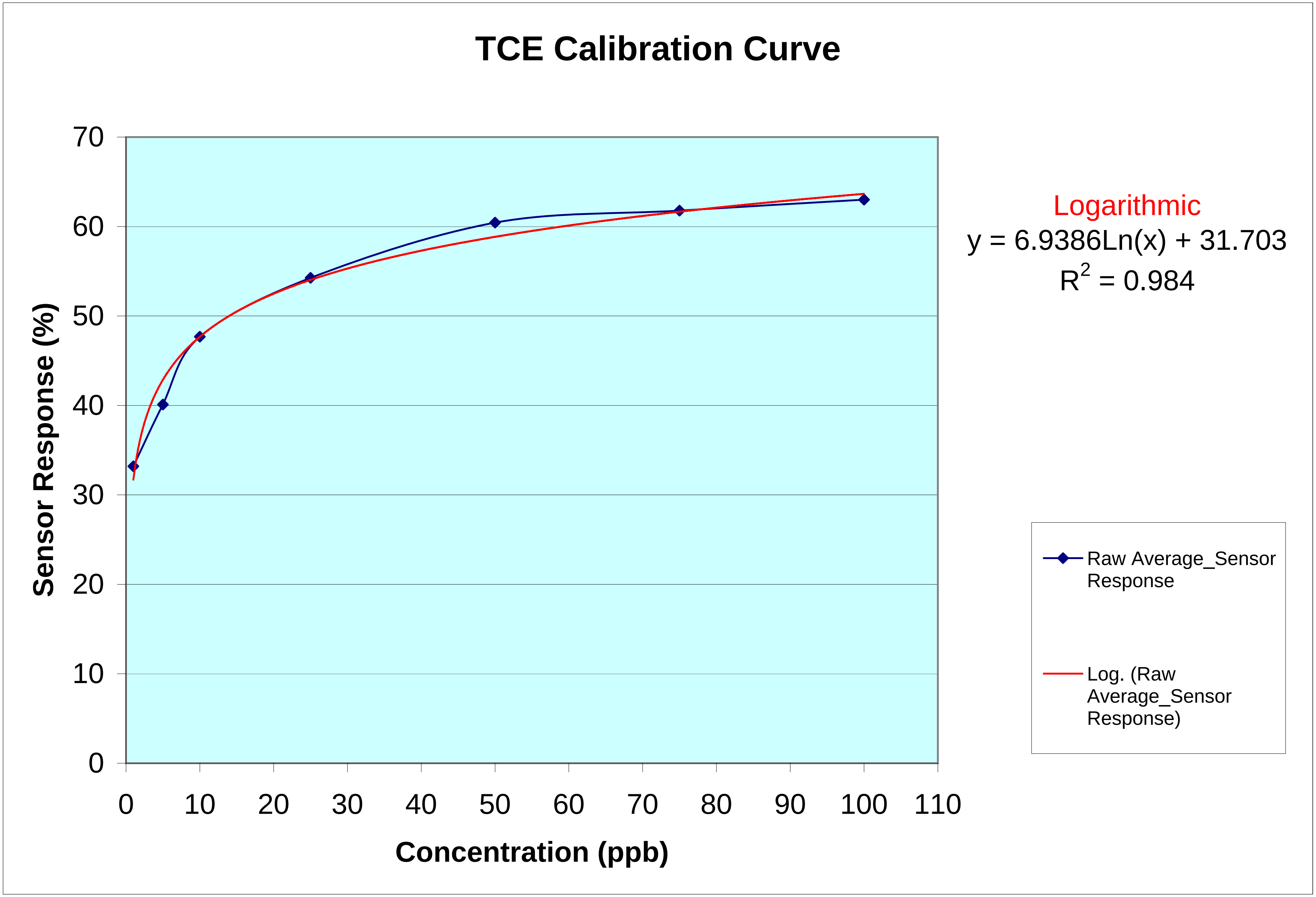
VC: 1 ppb Detection Limit Study

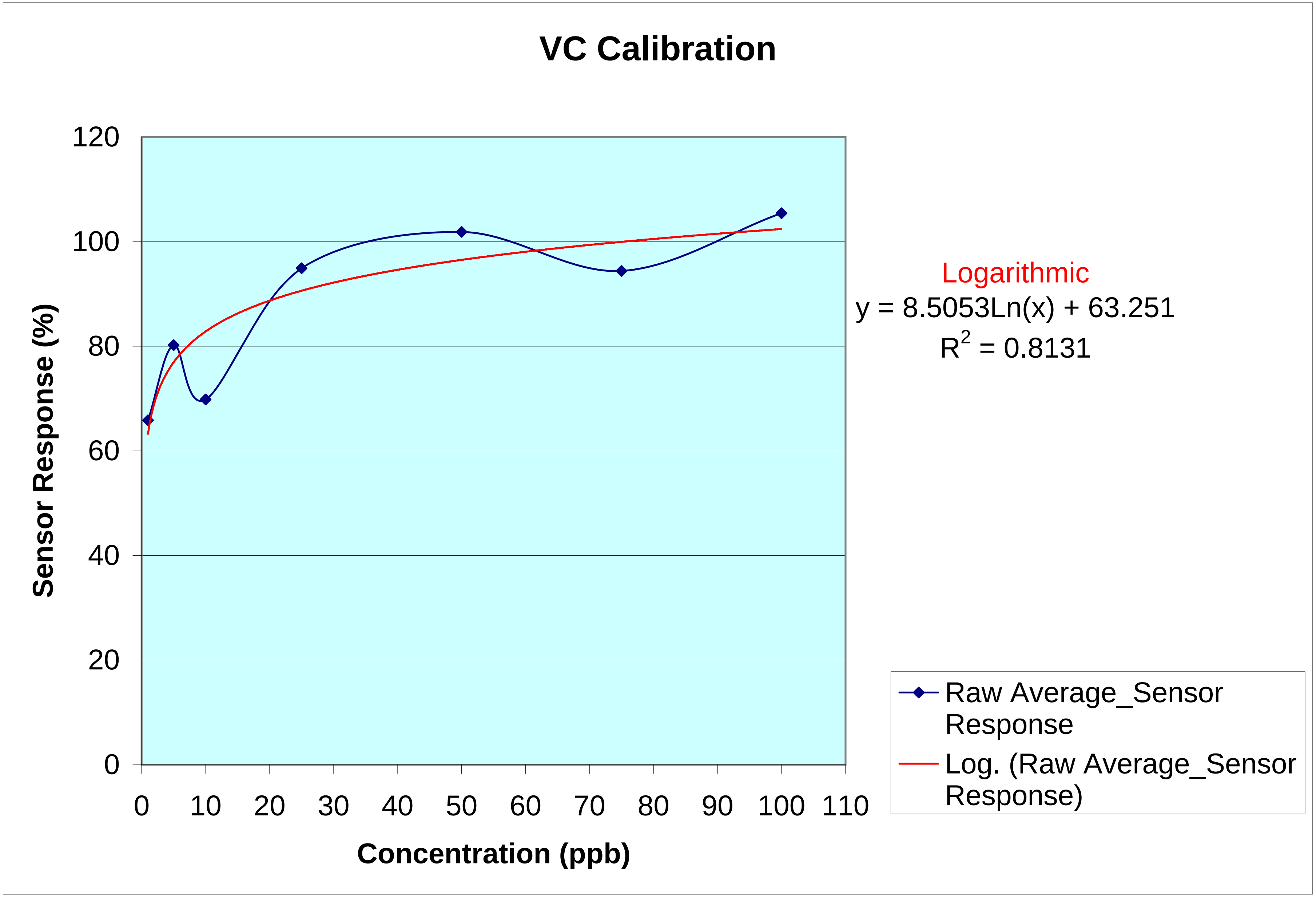


Attachment 4


Benzene Calibration Curve
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Sensor Response (%)
0
10
20
30
40
50
60
70
80
90
100
110
Concentration (ppb)
Logarithmic
y = 2.7768Ln(x) + 41.339
R2 = 0.9735
Raw Average_Sensor Response
Log. (Raw Average_Sensor Response)


PCE Calibration Curve
Sensor Response(%)
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
Concentration (ppb)
Logarithmic
y = 6.3796Ln(x) + 19.424
R2 = 0.9468
Raw Average_Sensor Response
Log. (Raw Average_Sensor Response)

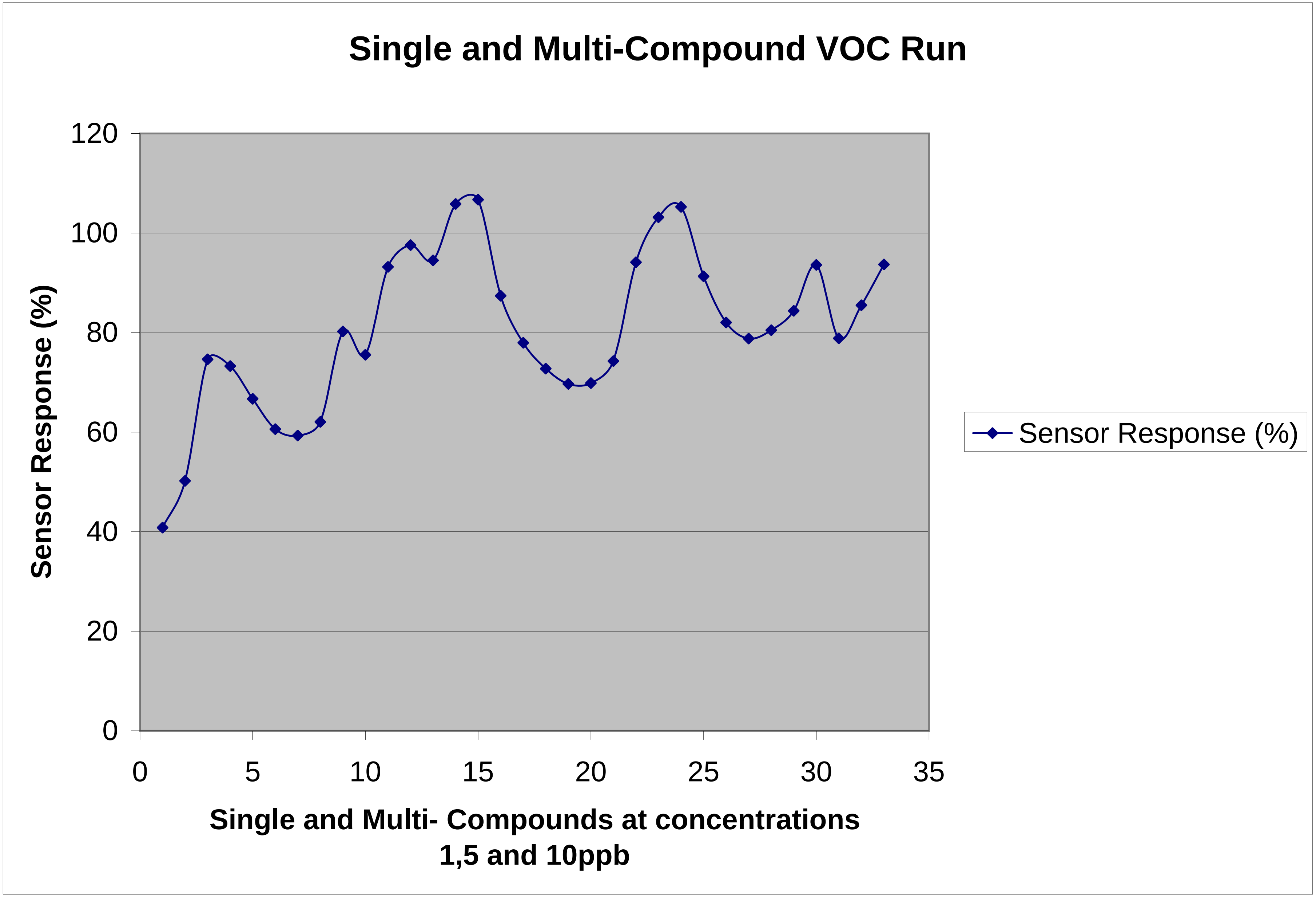

TCE Calibration Curve
Sensor Response (%)
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
110
Concentration (ppb)
Logarithmic
y = 6.9386Ln(x) + 31.703
R2 = 0.984
Raw Average_Sensor Response
Log. (Raw Average_Sensor Response)


VC Calibration
Sensor Response (%)
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
110
Concentration (ppb)
Logarithmic
y = 8.5053Ln(x) + 63.251
R2 = 0.8131
Raw Average_Sensor Response
Log. (Raw Average_Sensor Response)

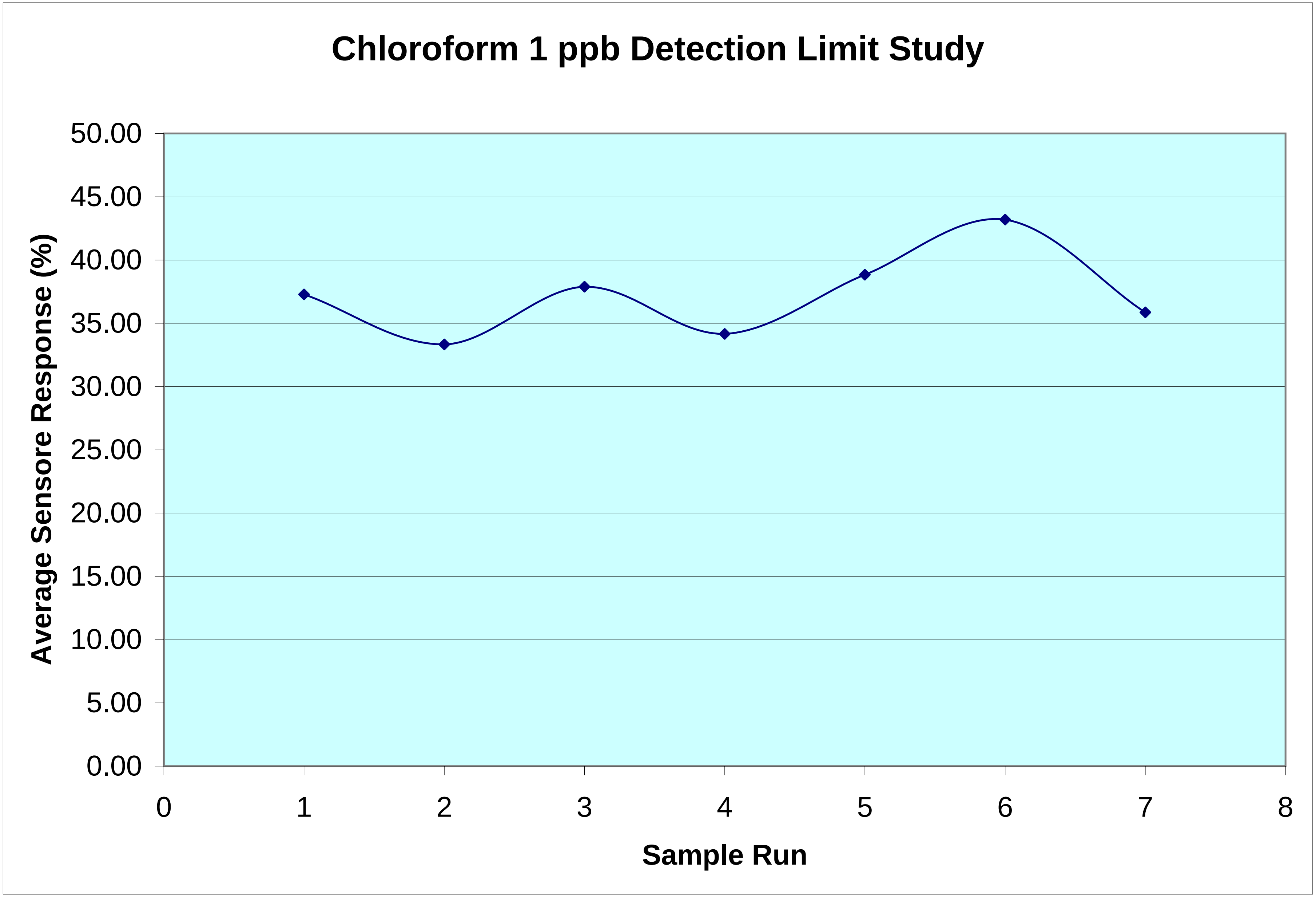
Attachment 5

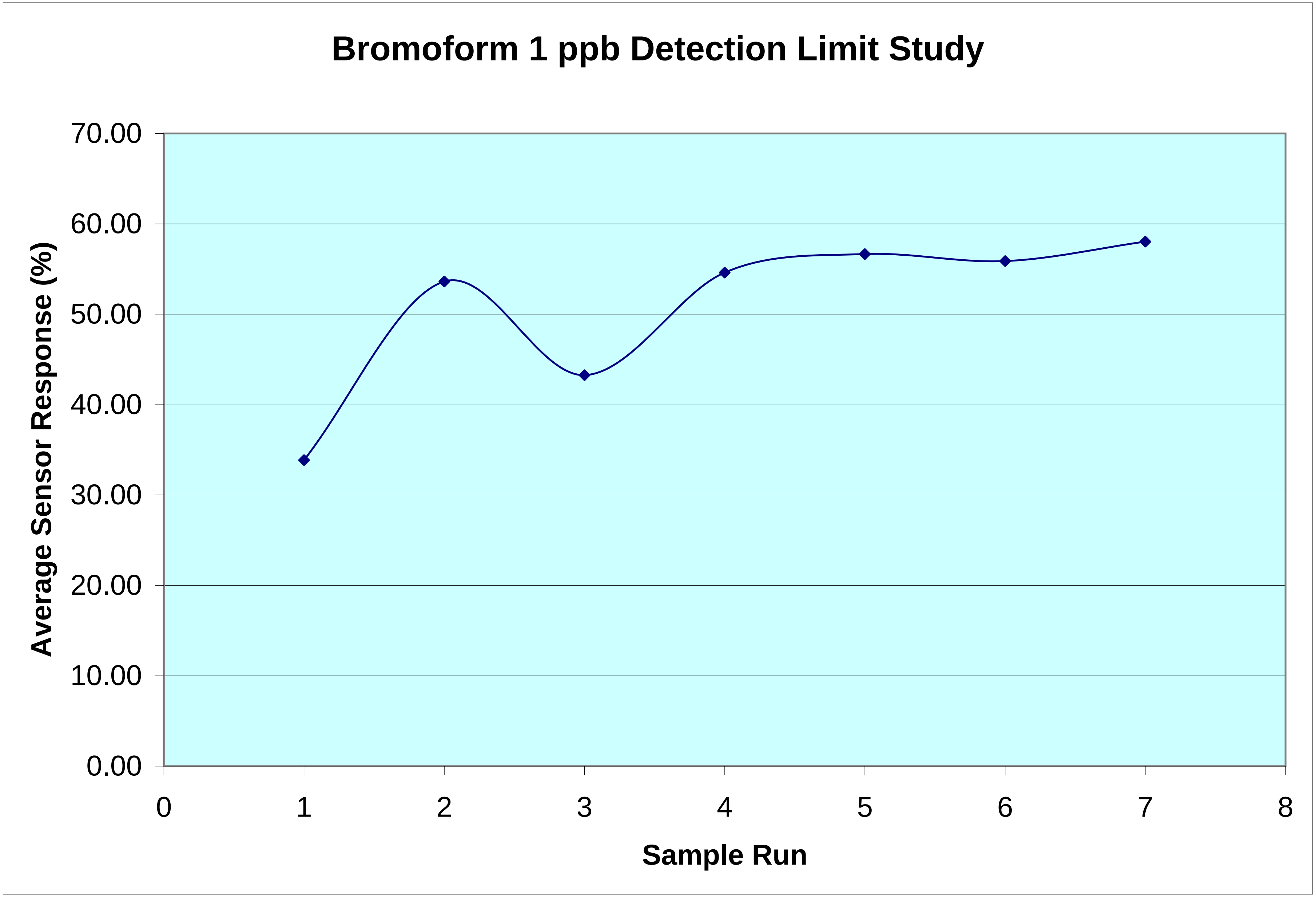
Run Schedule_Compounds of Concern

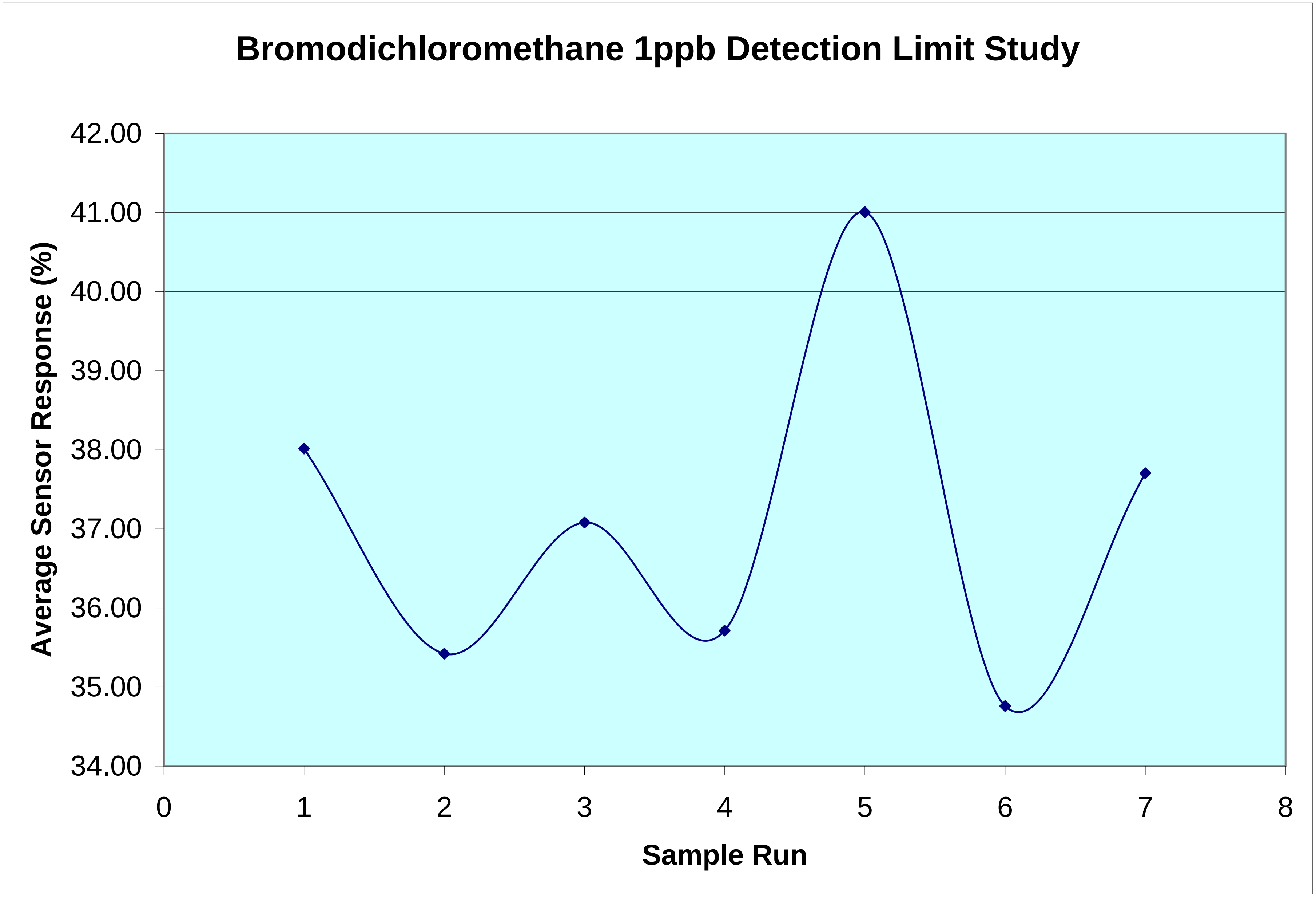
Compound	Concentration	Sample Time	Max. Peak Height
VC	1ppb	13:17	40.817
VC	5ppb	13:18	50.205
VC	10ppb	13:19	74.613
PCE	1ppb	13:20	73.271
PCE	5ppb	13:21	66.691
PCE	10ppb	13:22	60.594
TCE	1ppb	13:24	59.312
TCE	5ppb	13:25	62.05
TCE	10ppb	13:27	80.218
benzene	1ppb	13:29	75.533
benzene	5ppb	13:30	93.181
benzene	10ppb	13:32	97.578
TCE + benzene	1ppb	13:34	94.502
TCE + benzene	5ppb	13:37	105.839
TCE + benzene	10ppb	13:40	106.691
VC + PCE	1ppb	13:43	87.393
VC + PCE	5ppb	13:45	77.948
VC + PCE	10ppb	13:47	72.739
TCE + PCE	1ppb	13:48	69.671
TCE + PCE	5ppb	13:50	69.844
TCE + PCE	10ppb	13:51	74.27
benzene + PCE	1ppb	13:53	94.118
benzene + PCE	5ppb	13:55	103.169
benzene + PCE	10ppb	13:58	105.241
TCE + VC	1ppb	14:01	91.294
TCE + VC	5ppb	14:03	82.026
TCE + VC	10ppb	14:05	78.801
benzene + VC	1ppb	14:07	80.481
benzene + VC	5ppb	14:09	84.362
benzene + VC	10ppb	14:11	93.582
All 4 Compounds	1ppb	14:13	78.837
All 4 Compounds	5ppb	14:15	85.482
All 4 Compounds	10ppb	14:17	93.688

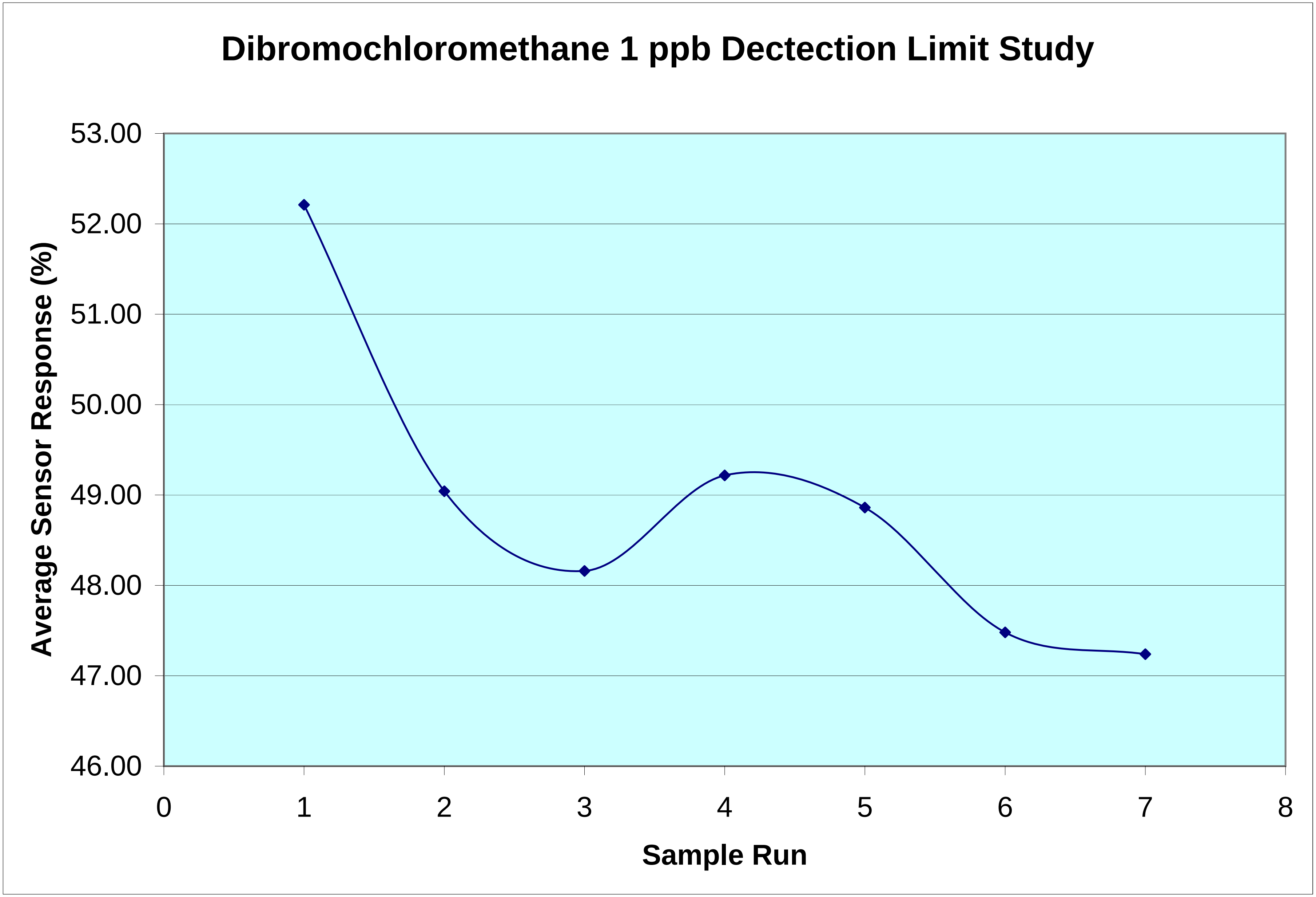

Single and Multi-Compound VOC Run
120
100
80
60
40
20
0
Sensor Response (%)
0
5
10
15
20
25
30
35
Single and Multi- Compounds at concentrations 1,5 and 10ppb
Sensor Response (%)

Attachment 6

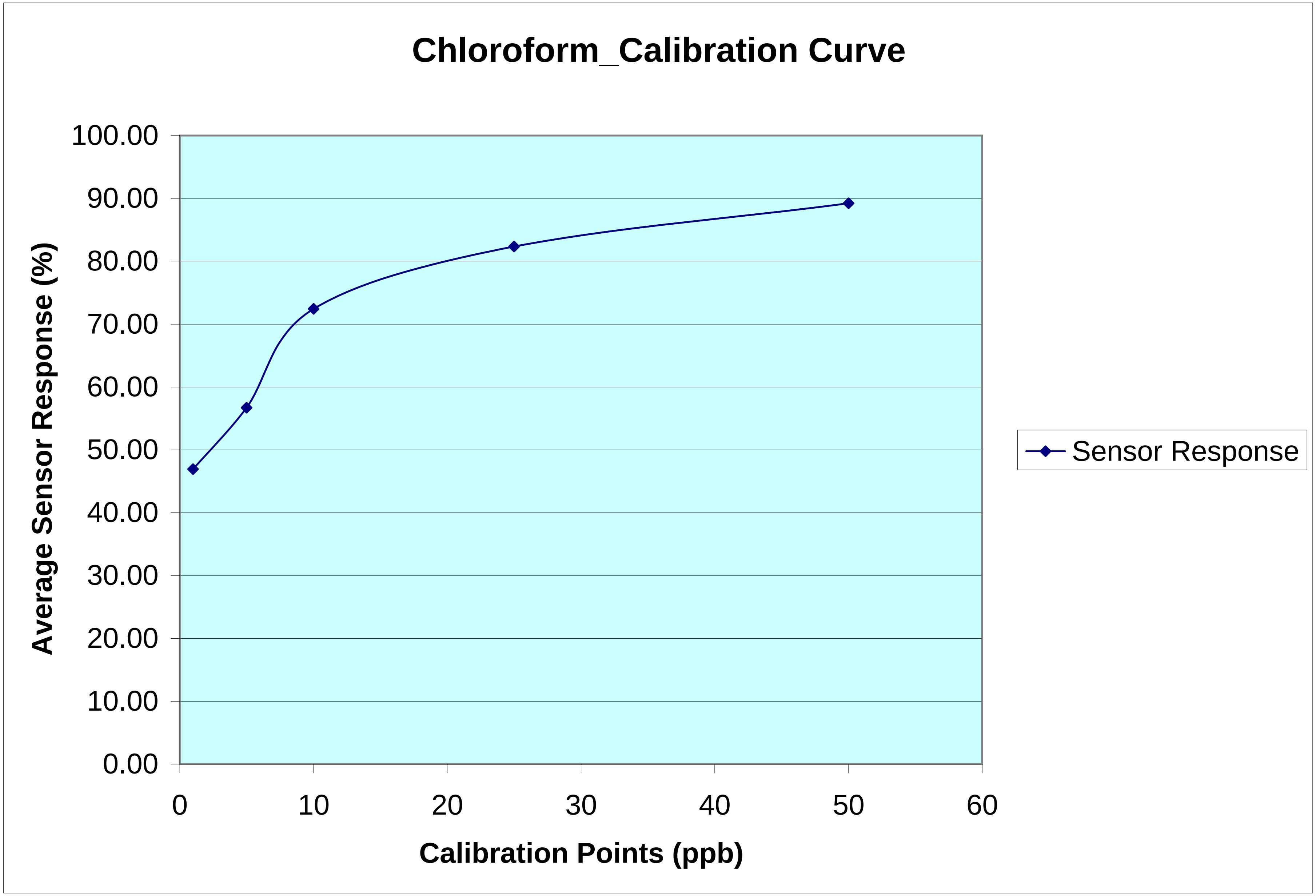

Chloroform 1 ppb Detection Limit Study
Average Sensore Response (%)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
1
2
3
4
5
6
7
8
Sample Run

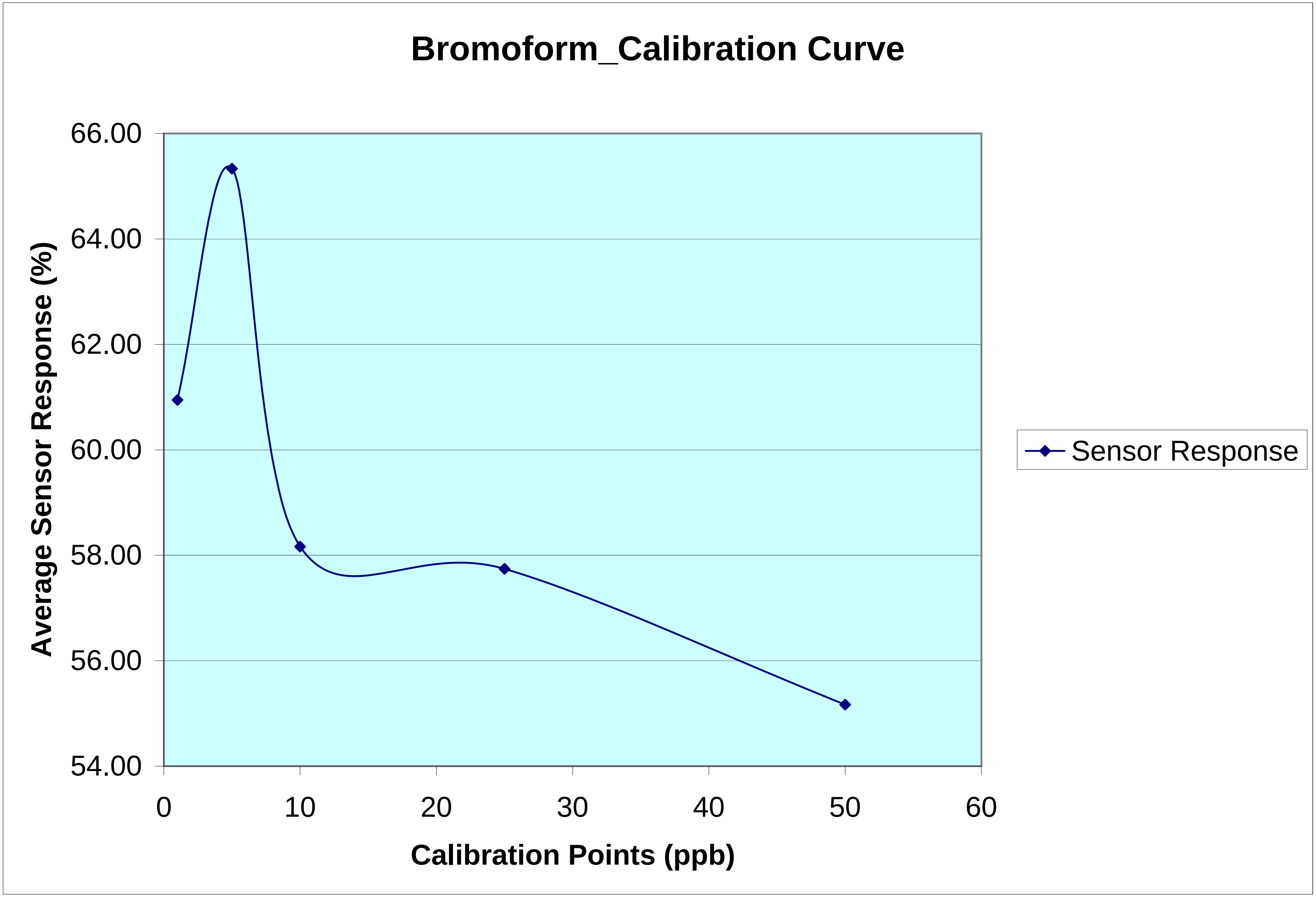

Bromoform 1 ppb Detection Limit Study
Average Sensor Response (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
1
2
3
4
5
6
7
8
Sample Run

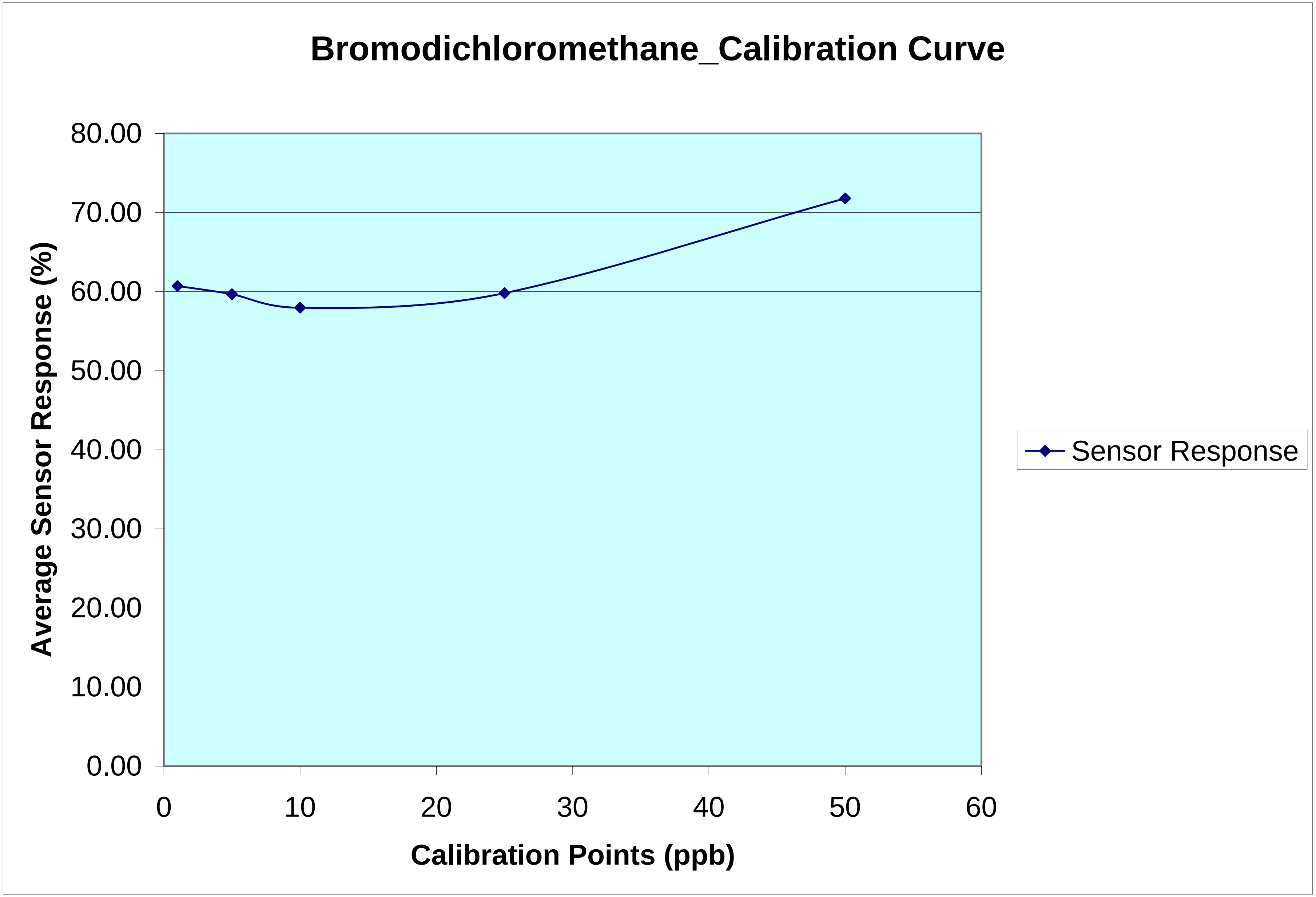
Bromodichloromethane 1ppb Detection Limit Study
Average Sensor Response (%)
42.00
41.00
40.00
39.00
38.00
37.00
36.00
35.00
34.00
0
1
2
3
4
5
6
7
8
Sample Run

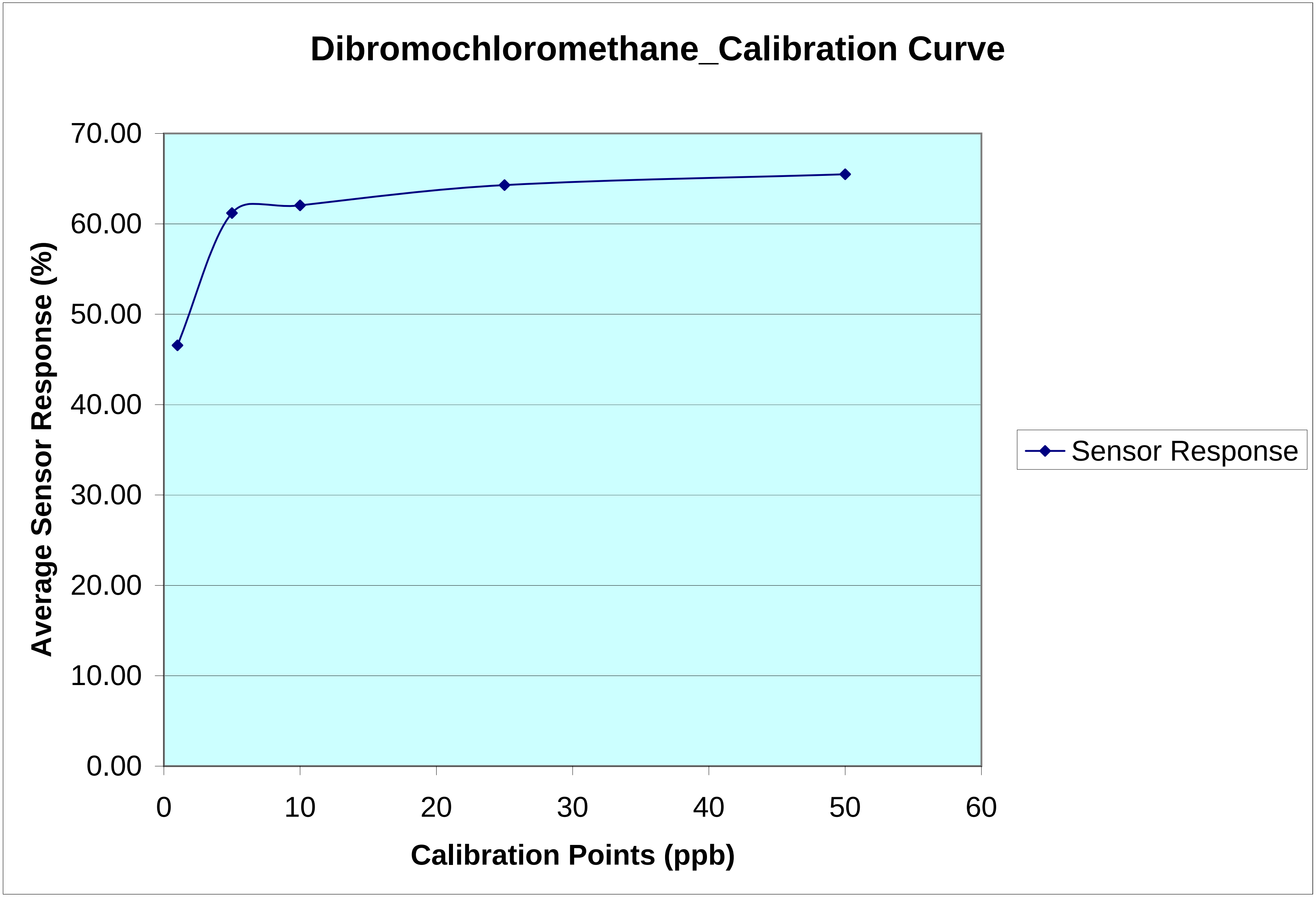

Dibromochloromethane 1 ppb Dectection Limit Study
Average Sensor Response (%)
53.00
52.00
51.00
50.00
49.00
48.00
47.00
46.00
0
1
2
3
4
5
6
7
8
Sample Run

Attachment 7


Chloroform_Calibration Curve
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Average Sensor Response (%)
0
10
20
30
40
50
60
Calibration Points (ppb)
Sensor Response

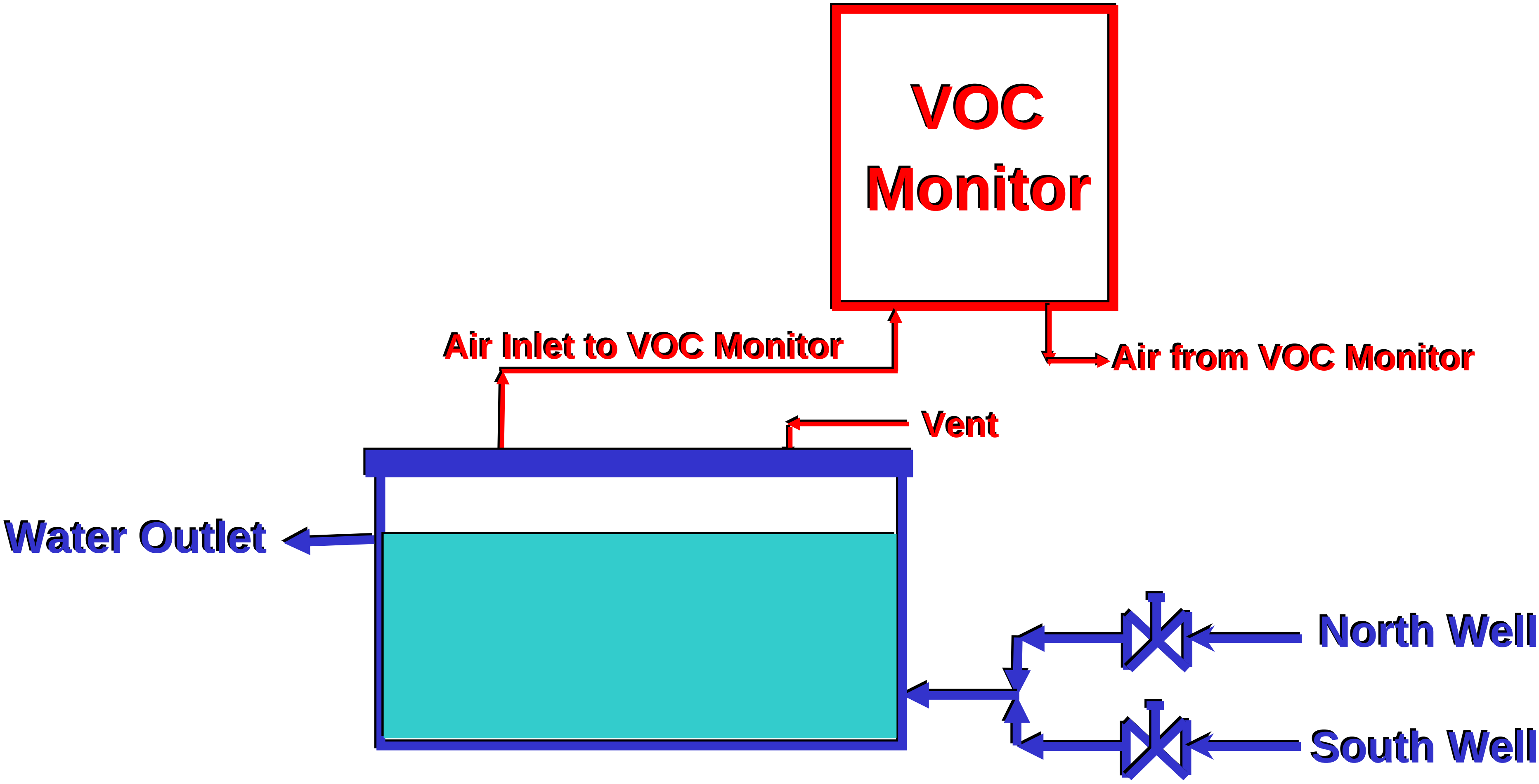

Bromoform_Calibration Curve
Average Sensor Response (%)
66.00
64.00
62.00
60.00
58.00
56.00
54.00
0
10
20
30
40
50
60
Calibration Points (ppb)
Sensor Response


Bromodichloromethane_Calibration Curve
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
Average Sensor Response (%)
Calibration Points (ppb)
Sensor Response


Dibromochloromethane_Calibration Curve
Average Sensor Response (%)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
10
20
30
40
50
60
Calibration Points (ppb)
Sensor Response

Attachment 8

Process Flow Diagram



Attachment 9

VOC Monitor Startup and Operation Procedure

The VOC Monitor is intended to be an EVENT monitor. It retains a short term and long term history of readings and compares the current reading against these before deciding whether a change has occurred. The sensors in the VOC Monitor are Metal Oxide Sensors (MOS) - the electrical resistance is dependent on volatile chemicals being detected. During data acquisition, the system compares % change in resistance across the sensor face against the resistance value established in filtered, dried, reference air collected during the same data acquisition.

The software supplied is an interface for downloading and reviewing data from the VOC Monitor. For operational stability, do not attempt to make changes to VOC Monitor run condition or download data from VOC Monitor memory unless the power is ON, but the pump & data acquisition states are OFF.

1. Obtain power to the VOC Monitor by plugging the power cord into a power receptacle.

The power plug provided with this equipment is a U.S. style plug. An adapter to the local power receptacle style has been supplied.

2. Turn on the VOC Monitor using the power switch on the upper left, side panel.

It is recommended that the VOC Monitor should not be turned on and off frequently. In case of a power failure, follow the guidelines presented below.

3. Allow the VOC Monitor to warm-up for up to 20 minutes.

After about 30-45 seconds the RUNNING light will start to flash at 5 second intervals for 5-10 minutes. The components and the sensors are warming up during this time. Data is being acquired at this time to provide a reference history for the internal calculations performed by the VOC Monitor. The value displayed on the VOC Monitor panel readout will drift somewhat after initial switch on and then stabilize. The system will typically stabilize at a baseline readings of between 0 and 0.5 units.

4. After the warm up period, the VOC Monitor will start to collect data at the previously selected sampling frequency.

The default sampling frequency is 15 minutes. The software allows you to change the sampling frequency to 2 or 5 minutes.

5. Allow the VOC Monitor to run continuously while acquiring data. Interruptions to system operation should be eliminated, unless a fault status or alarm condition requires a reset.

This will allow the VOC Monitor to stabilize quickly and provide reliable data.

Downloading Data Using the VOC Monitor Software

Connecting the VOC Monitor to a Computer

1. Ensure that the VOC Monitor is in operation and is acquiring data.
2. Turn on the computer and connect a USB cable to the VOC Monitor.
3. Open *MSS VOC Eventmonitor* software on the computer.
4. Click <Com Port>
    a. Click Open
    b. Click Com Port selection drop down box, and note the existing COM ports
    c. Click <Cancel>
5. Attach USB cable to computer USB port.
6. Click <Com Port>
    a. Click Open
    b. Click Com Port selection drop down box, and note the new COM port (e.g. COM 5)
    c. Select the new COM port
    d. Click <OK>
7. Returns to the strip chart recorder view (introductory screen).
8. Click STOP icon (turns off the VOC Monitor pump and stops data acquisition).
9. Click <Com Port>
    a. Upload Data
        i. Direct Upload
            1. Assign SAVE filename
            2. Click <Save> (will save data as a **.txt** filetype)
10. Click <File>
    a. Import Raw Data
        i. <Open> the saved **.txt** file
            1. Dialog “NEW FILE FOUND”

            2. Click <OK> (data rows are imported – see bottom left of the screen)
                a. If multiple on/off events have occurred since the last data download and memory clear event, then multiple files will be produced and saved automatically.

11. Click FAST FORWARD (>>) or PLAY (>) icon to load file into the *VOC Eventmonitor* software.
12. Click <File>
    a. Click <Save As>
    b. Assign SAVE filename
    c. Click <Save> (will save data as **.evr** filetype)
13. Click <View>
    a. Click <Charts>
        i. Click <DATA> tab
        ii. Click <File>
            1. Click <SAVE SPREADSHEET CSV FORMAT>
            2. Assign SAVE filename
            3. Click <Save> (will save data as a **.csv** filetype)

This final file (the **.csv** filetype) can be imported into Microsoft Excel, or other spreadsheet software which recognizes comma delimited dataset files. It is recommended that the imported data be saved in the Excel (or equivalent) filetype for further processing by the user.

Further manipulation of Chart view can be performed, if desired (See VOC Monitor Manual).

After file is saved in the last step, above, the following steps are recommended to safely return the VOC Monitor to operation, and to disconnect the computer.

14. Click <View>
    a. Click <Data Acquisition>
15. Click <CLR> icon (This step will clear the VOC Monitor memory and will allow for additional data acquisition.)
16. Restart data acquisition.
    a. Click <15> icon
17. Click <Com Port>
    a. Click <Close>
18. Close *MSS VOC Eventmonitor* software
19. Disconnect USB cable from VOC Monitor and the computer.

The data has been downloaded, saved, and the VOC Monitor memory has been cleared. The VOC Monitor data acquisition state has been restored.

Power Failure – System Restart Procedures

In case of a power failure, the following procedure should be followed to restart the VOC Monitor into a stable data acquisition state.

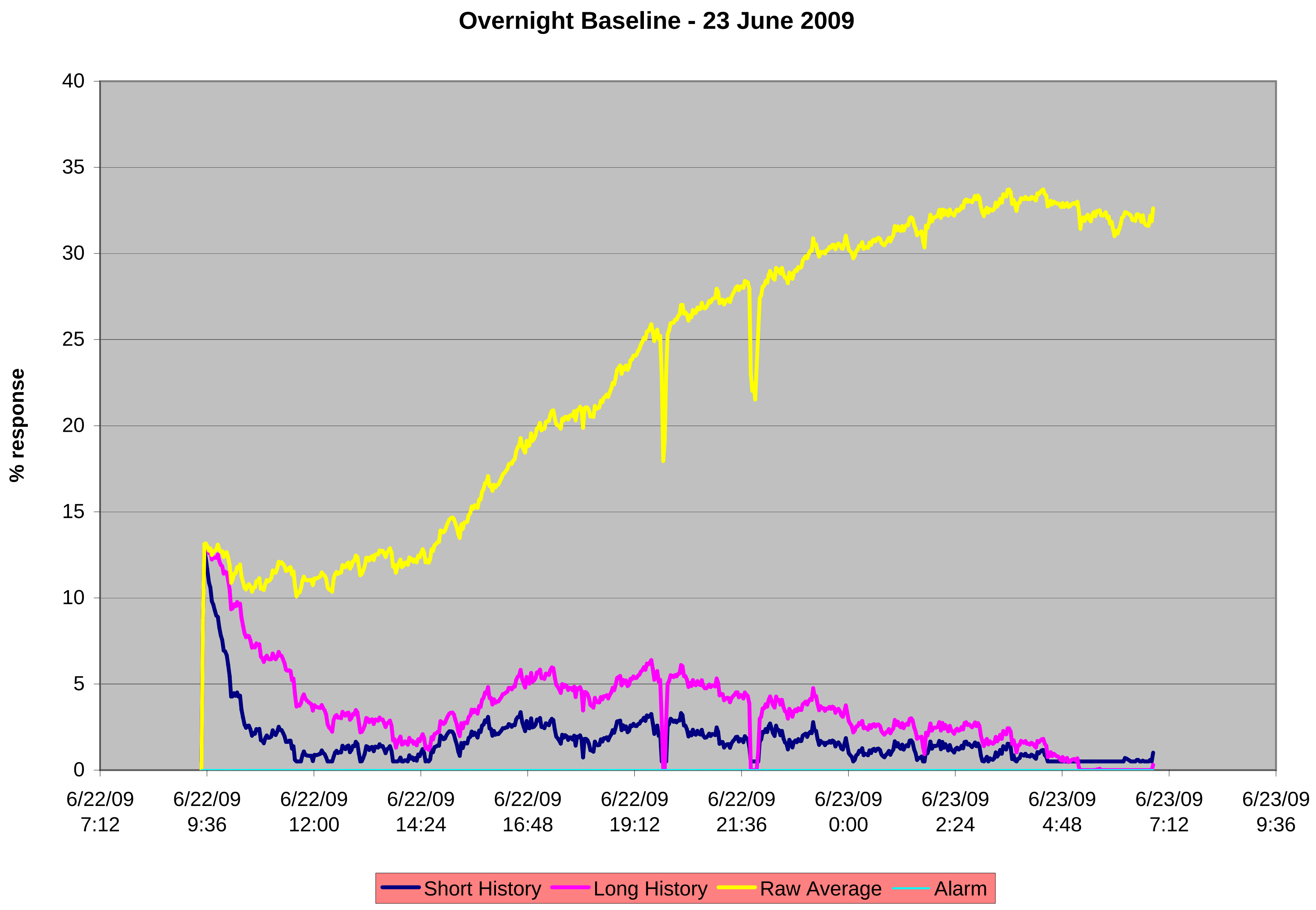
1. Turn VOC Monitor power switch to OFF position.
2. Leave the VOC Monitor off for 5 minutes.
3. Perform the following steps
   a. Verify that U.S. receptacle adapter is seated firmly into electrical receptacle.
   b. Verify that the VOC Monitor power cable plug is seated firmly into U.S. receptacle adapter.
   c. Turn VOC Monitor power switch to ON position.
   d. Follow steps 3 to 5 of the “VOC Monitor Startup and Operation Procedure” to allow the VOC Monitor to warm-up.
4. If a brief power interruption occurs, the VOC Monitor may respond by flashing both the RUNNING green LED and the FAULT red LED lights at an approximate frequency of 2-flash / second for each light. The following modified procedure can be followed to restore VOC Monitor stability and data acquisition:
   a. Turn on the computer and connect a USB cable to the VOC Monitor.
   b. Open *MSS VOC Eventmonitor* software on the computer.
   c. Click <Com Port>
      i. Click Open
      ii. Click Com Port selection drop down box, and note the existing COM ports
      iii. Click <Cancel>
   d. Attach USB cable to computer USB port.
   e. Click <Com Port>
      i. Click Open
      ii. Click Com Port selection drop down box, and note the new COM port (e.g. COM 5)
      iii. Select the new COM port

        iv. Click <OK>

    f. Returns to the strip chart recorder view (introductory screen).
    g. Click STOP icon (turns off the VOC Monitor pump and stops data acquisition).
    h. At this point, if the user needs to download the data. Follow steps 9 to 14 of “Downloading Data Using the VOC Monitor Software” section.
    i. Clear the memory
        i. Click <CLR> icon (This step will clear the VOC Monitor memory and will allow for additional data acquisition.)
        ii. Restart data acquisition.
            1. Click <15> icon
        iii. Click <Com Port>
        iv. Click <Close>
        v. Close *MSS VOC Eventmonitor* software

Disconnect USB cable from VOC Monitor and the computer.

Attachment 10


Overnight Baseline - 23 June 2009
% response
40
35
30
25
20
15
10
5
0
6/22/09 7:12
6/22/09 9:36
6/22/09 12:00
6/22/09 14:24
6/22/09 16:48
6/22/09 19:12
6/22/09 21:36
6/23/09 0:00
6/23/09 2:24
6/23/09 4:48
6/23/09 7:12
6/23/09 9:36
Short History
Long History
Raw Average
Alarm

Attachment 11

Background Interference Data

	Time	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Short History	Long History	Alarm	Raw Average	Short Term Baseline	Long Term Baseline
1	6/26/2009 10:57	0	0	0	0	0.5	0	0	0	0	0
2	6/26/2009 11:02	1.996	1.987	1.638	2.14	2.359	1.938	0	1.94	0.081	0.002
3	6/26/2009 11:07	0.333	0	0.218	0.225	0.608	0.191	0	0.194	0.086	0.003
4	6/26/2009 11:12	0.554	0.883	0.983	0.901	1.214	0.824	0	0.83	0.117	0.006
5	6/26/2009 11:17	6.208	5.408	5.24	6.982	6.1	5.947	0	5.96	0.36	0.013
6	6/26/2009 11:22	1.22	0.883	0.873	1.126	1.138	1.005	0	1.026	0.388	0.021
7	6/26/2009 11:27	0.333	0.883	0.655	0.563	0.711	0.58	0	0.608	0.397	0.029
8	6/26/2009 11:32	0.998	0.442	0.546	1.239	0.892	0.769	0	0.806	0.414	0.037

Attachment 12

Test Run- 0.0001% alcohol

	Time	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Short History	Long History	Alarm	Raw Average	Short Term Baseline	Long Term Baseline
1	6/25/09 15:07	0	0	0	0	0.5	0	0	0	0	0
2	6/25/09 15:09	3.119	3.024	2.49	3.55	3.419	3.043	0	3.046	0.127	0.003
3	6/25/09 15:11	2.147	1.865	1.423	2.586	2.3	1.998	0	2.005	0.205	0.007
4	6/25/09 15:13	2.863	2.671	2.337	3.296	2.979	2.779	0	2.792	0.313	0.013
5	6/25/09 15:15	3.528	3.478	2.947	4.006	3.544	3.467	0	3.49	0.445	0.022
6	6/25/09 15:17	3.528	3.377	2.896	3.955	3.369	3.405	0	3.439	0.57	0.034
7	6/25/09 15:19	3.528	3.427	2.947	4.057	3.298	3.442	0	3.49	0.692	0.047
8	6/25/09 15:21	3.885	3.679	3.303	4.31	3.474	3.731	0	3.795	0.821	0.063
9	6/25/09 15:23	3.988	3.831	3.404	4.412	3.459	3.827	0	3.909	0.95	0.082
10	6/25/09 15:25	5.675	5.544	5.183	6.237	5.014	5.556	0	5.66	1.146	0.104
11	6/25/09 15:27	5.93	5.696	5.234	6.491	4.996	5.708	0	5.838	1.341	0.13
12	6/25/09 15:29	5.521	5.292	4.878	5.984	4.408	5.26	0	5.419	1.511	0.159
13	6/25/09 15:31	5.521	5.393	4.827	5.984	4.257	5.241	0	5.431	1.675	0.19
14	6/25/09 15:33	4.959	4.788	4.319	5.274	3.529	4.611	0	4.835	1.806	0.224
15	6/25/09 15:35	4.755	4.637	4.116	5.223	3.257	4.423	0	4.683	1.926	0.259
16	6/25/09 15:37	4.499	4.335	3.963	4.919	2.899	4.133	0	4.429	2.03	0.296
17	6/25/09 15:39	4.448	4.284	3.811	4.817	2.713	4.006	0	4.34	2.127	0.334
18	6/25/09 15:41	4.397	4.234	3.913	4.868	2.633	3.979	0	4.353	2.219	0.374
19	6/25/09 15:43	4.294	4.183	3.811	4.767	2.459	3.85	0	4.264	2.305	0.414

Test Run 0.0018% Alcohol

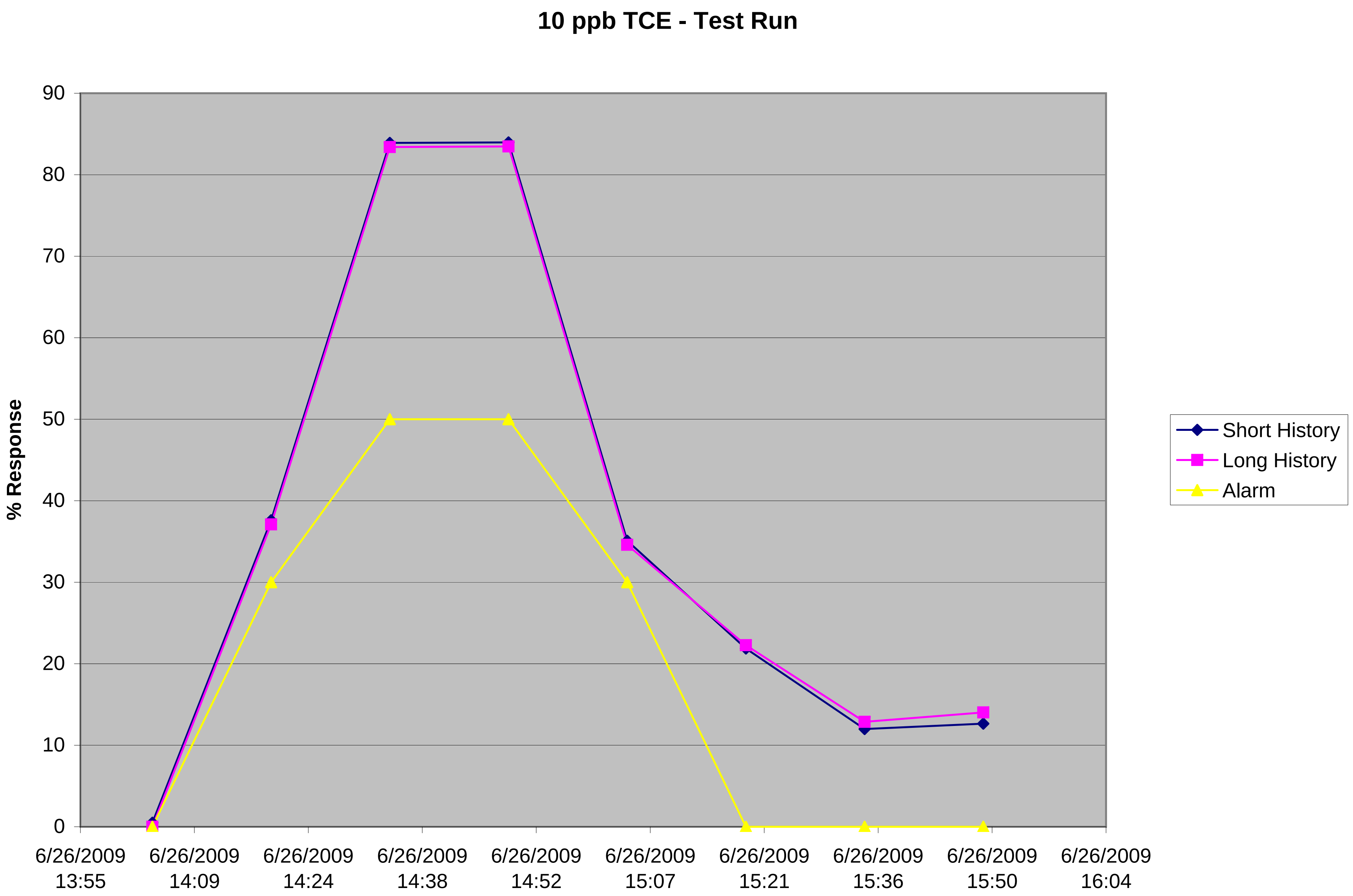
	Time	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Short History	Long History	Alarm	Raw Average	Short Term Baseline	Long Term Baseline
1	6/25/09 15:55	0	0	0	0	0.5	0	0	0	0	0
2	6/25/09 15:57	5.692	5.519	4.654	6.319	5.815	5.541	0	5.546	0.231	0.005
3	6/25/09 15:59	6.362	5.844	5.087	6.763	6.042	5.999	0	6.014	0.472	0.015
4	6/25/09 16:01	6.138	5.736	5.195	6.652	5.731	5.901	0	5.93	0.699	0.029
5	6/25/09 16:03	5.804	5.411	4.762	6.43	5.198	5.555	0	5.602	0.904	0.047
6	6/25/09 16:05	6.027	5.736	4.978	6.763	5.265	5.807	0	5.876	1.111	0.069
7	6/25/09 16:07	65.625	62.121	60.931	68.071	63.576	64.118	50	64.187	1.111	0.069
8	6/25/09 16:09	90.96	89.502	87.771	92.461	89.563	90.104	50	90.173	1.111	0.069
9	6/25/09 16:11	90.067	88.636	87.013	91.242	88.629	89.17	50	89.24	1.111	0.069
10	6/25/09 16:13	83.147	82.035	80.087	84.368	81.798	82.34	50	82.409	1.111	0.069
11	6/25/09 16:15	71.54	70.238	68.182	72.838	70.089	70.63	50	70.7	1.111	0.069
12	6/25/09 16:17	59.821	58.442	56.277	61.308	58.351	58.893	50	58.962	1.111	0.069
13	6/25/09 16:19	49.665	48.052	46.32	50.998	48.148	48.69	30	48.759	1.111	0.069
14	6/25/09 16:21	40.067	38.528	36.688	41.463	38.576	39.117	30	39.187	1.111	0.069
15	6/25/09 16:23	33.371	31.818	30.303	34.479	31.882	32.423	30	32.493	1.111	0.069
16	6/25/09 16:25	28.571	26.948	25.758	29.49	25.973	27.578	0	27.692	2.218	0.114
17	6/25/09 16:27	23.103	21.753	20.563	23.947	19.784	22.166	0	22.341	3.057	0.175
18	6/25/09 16:29	18.638	17.424	16.45	19.512	14.826	17.758	0	18.006	3.68	0.248
19	6/25/09 16:31	16.295	15.693	14.827	17.517	12.386	15.752	0	16.083	4.197	0.331
20	6/25/09 16:33	14.621	13.745	12.771	15.41	10.026	13.717	0	14.136	4.611	0.42
21	6/25/09 16:35	12.835	12.229	11.364	13.747	8.103	12.03	0	12.544	4.941	0.514
22	6/25/09 16:37	11.496	10.823	10.173	12.417	6.524	10.615	0	11.227	5.203	0.612
23	6/25/09 16:39	9.375	8.874	7.9	10.2	4.222	8.377	0	9.087	5.365	0.711
24	6/25/09 16:41	9.71	9.091	8.333	10.421	4.356	8.578	0	9.389	5.533	0.811
25	6/25/09 16:43	8.929	8.225	7.684	9.645	3.459	7.709	0	8.621	5.661	0.912
26	6/25/09 16:45	8.817	8.333	7.684	9.534	3.309	7.579	0	8.592	5.783	1.014
27	6/25/09 16:47	7.254	6.71	6.061	8.204	1.721	5.943	0	7.057	5.837	1.114
28	6/25/09 16:49	7.366	7.143	6.385	8.315	1.905	6.088	0	7.302	5.898	1.214

Attachment 13

50 ppb Cis DCE Run

	Time	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Short History	Long History	Alarm	Raw Average	Short Term Baseline	Long Term Baseline
1	6/26/...:05 AM	0	0	0	0	0.5	0	0	0	0	0
2	6/26/2009 1...	2.59	2.756	2.505	2.59	3.001	2.608	0	2.61	0.109	0.002
3	6/26/2009 1...	17.032	16.634	16.132	17.43	16.503	16.788	0	16.807	0.805	0.019
4	6/26/2009 1...	35.259	35.728	34.469	35.757	34.999	35.284	30	35.303	0.805	0.019
5	6/26/2009 1...	28.187	28.346	27.455	28.586	26.7	28.084	0	28.144	1.944	0.059
6	6/26/2009 1...	17.43	17.52	16.834	17.43	15.22	17.192	0	17.303	2.584	0.112
7	6/26/2009 1...	13.347	13.287	12.926	13.347	10.7	13.054	0	13.227	3.027	0.172
8	6/26/2009 1...	10.657	10.433	10.12	10.657	7.63	10.229	0	10.467	3.337	0.238
9	6/26/2009 1...	9.363	9.055	8.717	9.163	5.998	8.767	0	9.075	3.576	0.308

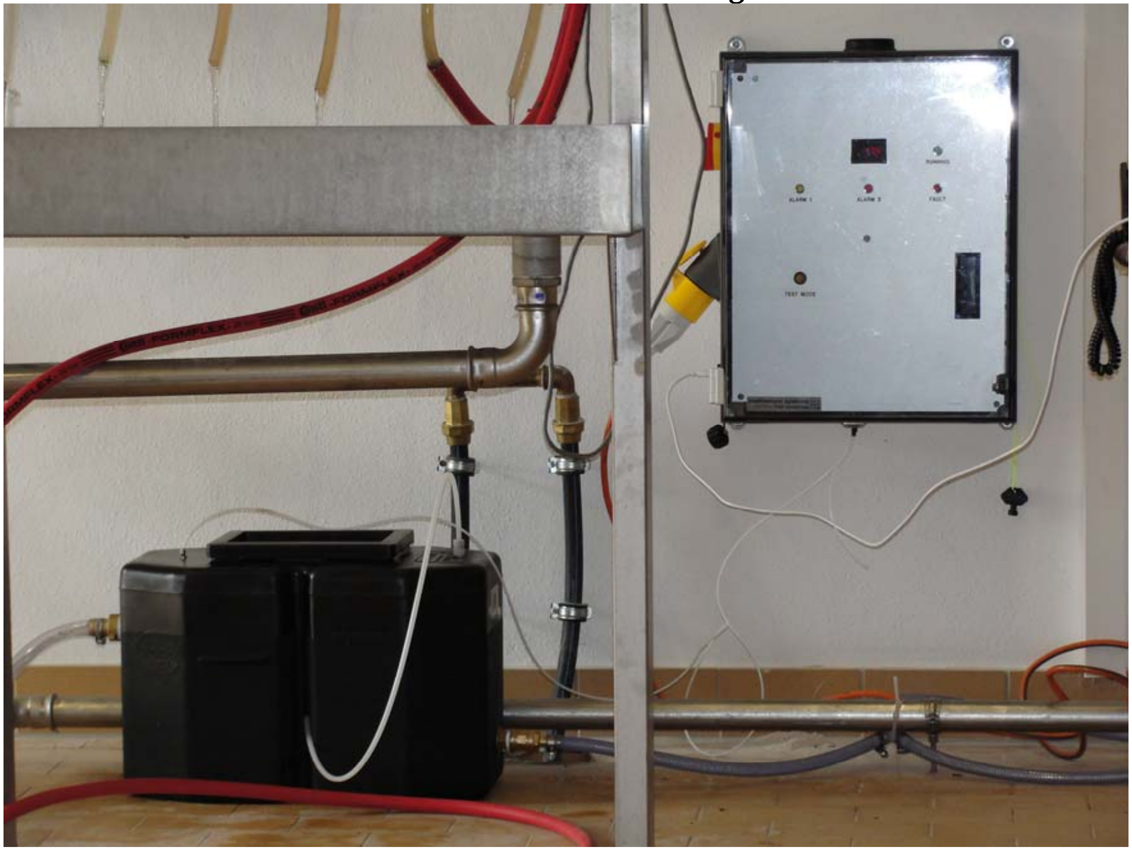
Attachment 14



10 ppb TCE - Test Run
% Response
90
80
70
60
50
40
30
20
10
0
6/26/2009 13:55
6/26/2009 14:09
6/26/2009 14:24
6/26/2009 14:38
6/26/2009 14:52
6/26/2009 15:07
6/26/2009 15:21
6/26/2009 15:36
6/26/2009 15:50
6/26/2009 16:04
Short History
Long History
Alarm

Attachment 15

VOC Monitor and Flow Through Cell



North and South Wells - Valves/Connections (Red valve handles with clear/braided tubing)

Down-Well Transducers/Dataloggers

APPENDIX B
Summary of Estimated Costs - Down-Well Transducers/Dataloggers
Pinewood Landfill
Pinewood, South Carolina

Vendors: See Below:					
Number	**Manufacturer**	**Item Description**	**Quantity**	**Each**	**Total**
1	In-Situ	Rugged Troll 200 (NON VENTED)	25	$535.00	$13,375.00
		75' cables	25	$254.70	$6,367.50
		com adapter	1	$24.10	$24.10
		Baro Troll	1	$850.00	$850.00
				Subtotal	**$20,616.60**
2	In-Situ *	Level Troll 500 vented	25	$994.50	$24,862.50
		75' Vented cable	25	$483.00	$12,075.00
		com adapter	1	$410.00	$410.00
				Subtotal	**$37,347.50**
3	In-Situ	Level troll 700 vented	25	$1,274.15	$31,853.75
		75' Vented cable	25	$483.00	$12,075.00
		com adapter	1	$410.00	$410.00
				Subtotal	**$44,338.75**
4	Solinst	Levelogger Jr. (NON VENTED)	25	$385.00	$9,625.00
		75' cable	25	$110.00	$2,750.00
		com cable	1	$356.00	$356.00
		Baro logger	1	$435.00	$435.00
				Subtotal	**$13,166.00**
5	Solinst	Levelogger 3001 gold (NON VENTED)	25	$535.00	$13,375.00
		75' cable	25	$110.00	$2,750.00
		com cable	1	$356.00	$356.00
		Baro logger	1	$435.00	$435.00
				Subtotal	**$16,916.00**
6	Instrumentation Northwest*	Aquistar Pt2x Vented	25	$940.00	$23,500.00
		vented cables	25	$158.00	$3,950.00
		com cable	1	$265.00	$265.00
				Subtotal	**$27,715.00**
7	YSI	Levelscout vented	25	$1,327.50	$33,187.50
		75' vented cable	25	$210.00	$5,250.00
		com cable	1	$337.00	$337.00
				Subtotal	**$38,774.50**

In-Situ Inc.®

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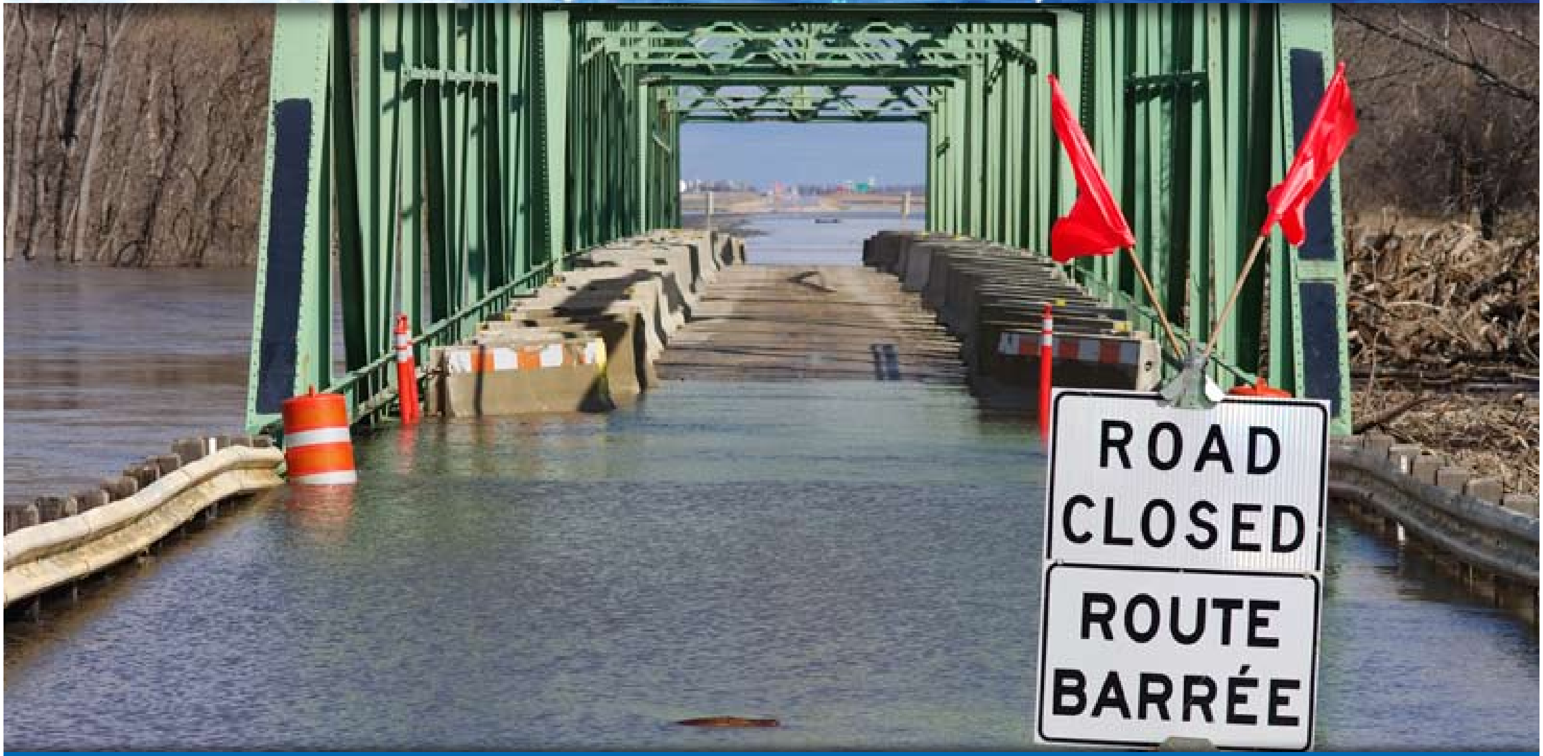

Rugged **TROLL**® 100 and 200 Instruments

The Rugged TROLL 100 and 200 instruments are designed for long- and short-term groundwater and surface-water monitoring. The non-vented (absolute) instruments monitor and record changes in water level, pressure, and temperature. Use with a Rugged BaroTROLL® instrument for optimum accuracy. All instruments are compatible with the user-friendly Win-Situ® 5 or Win-Situ® Mobile software platform for programming and data retrieval.

Affordable Titanium Data Loggers

- Use instruments in harsh environments – Titanium construction offers chemical- and corrosion-resistance.
- Customize data logs for your application – Linear, fast linear, and event logging modes are available.

Simplified Setup and Data Retrieval

- Program and download data from a Rugged TROLL 100/200 or Rugged BaroTROLL with the Rugged TROLL® docking station.
- Communicate with a deployed Rugged TROLL 200 by using the low-cost Rugged TROLL® Com device, which connects to either a RuggedReader® handheld PC or a desktop/laptop computer.

Flexible Deployment Options

- Use suspension wire with hanger for long-term deployments requiring minimal instrument access (for all instruments).
- Use direct-read cable with the Rugged TROLL 200 or Rugged BaroTROLL for applications requiring real-time data access.
- Access data when you need it — The Rugged TROLL 200 or Rugged BaroTROLL can be connected to a TROLL® Link telemetry system or SCADA system via Modbus/RS485 or SDI-12.

Applications

- Coastal wetland and estuary research
- Crest stage gaging
- Drilling and well development
- Flood and storm surge monitoring
- Landfill monitoring

Rugged **TROLL**® 100 and 200 Instruments

General	*Rugged TROLL 100 & 200*	*Rugged BaroTROLL®*
Temperature ranges	Operational: 32-122° F (0-50° C) Storage: -40-176° F (-40-80° C) Calibrated: 32-122° F (0-50° C)	Operational: 32-122° F (0-50° C) Storage: -40-176° F (-40-80° C) Calibrated: 32-122° F (0-50° C)
Diameter	1.03 in (2.62 cm)	1.03 in (2.62 cm)
Length	5.68 in (14.43 cm)	5.68 in (14.43 cm)
Weight	0.37 lb (170 g)	0.37 lb (170 g)
Materials	Titanium body; Delrin® nose cone, hanger, backend	Titanium body; Delrin nose cone, hanger, backend
Output options	Rugged TROLL 100: USB or RS232 via docking station Rugged TROLL 200: USB or RS232 via docking station; Modbus/RS485 or SDI-12 via Rugged TROLL 200 cable	USB or RS232 via docking station; Modbus/RS485 or SDI-12 via Rugged TROLL 200 cable
Battery type & life	3.6V lithium; 5 years or 2M readings[1]	3.6V lithium; 5 years or 2M readings[1]
External power	Rugged TROLL 100: NA Rugged TROLL 200: 8-36 VDC	8-36 VDC
Measurement current	14 mA typical	14 mA typical
Sleep current	20 µA typical	20 µA typical
Memory	1.0 MB	1.0 MB
Data records[2]	65,000	65,000
Data logs	Rugged TROLL 100: 1 log Rugged TROLL 200: 2 logs	2 logs
Fastest logging rate	1 per second	1 per minute
Fastest output rate	Rugged TROLL 200 only Modbus & SDI-12: 1 per second	Modbus & SDI-12: 1 per second
Log types	Linear, Fast Linear, and Event	Linear
Sensor Type/Material	Piezoresistive; Ceramic	Piezoresistive; Ceramic
Range	30 ft (9.0 m) (Burst: 60 ft) 100 ft (30 m) (Burst: 134 ft) 250 ft (76 m) (Burst: 368 ft)	7.0 to 30.0 psi; 0.5 to 2 bar
Accuracy @ 15° C	Typical ±0.1% full scale (FS)	Typical ±0.1% FS
Accuracy (FS)	±0.3% FS max.[3]	±0.3% FS max.[3]
Resolution	±0.01% FS or better	±0.01% FS or better
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg
Temperature Sensor	Silicon	Silicon
Range	Calibrated: 32-122° F (0-50° C)	Calibrated: 32-122° F (0-50° C)
Accuracy	±0.3° C	±0.3° C
Resolution	0.01° C or better	0.01° C or better
Units of measure	Fahrenheit, Celsius	Fahrenheit, Celsius
Warranty	1 year	1 year

[1] Battery life guaranteed when used within the factory-calibrated temperature range.

[2] 1 record = date/time plus 2 parameters logged (no wrapping) from device within the factory-calibrated temperature range.

[3] Across factory-calibrated temperature range.

Specifications are subject to change without notice. Delrin is a registered trademark of E.I. du Pont de Nemours & Co.

Accessories

Rugged Baro**TROLL** Instrument

Use the economical, titanium Rugged BaroTROLL instrument with either a Rugged TROLL 100 or 200 instrument. Win-Situ Baro Merge™ software simplifies post-correction of non-vented water level data.

Rugged **TROLL**® 200 Cable

Use the non-vented Rugged TROLL 200 cable to access a Rugged TROLL 200 or Rugged BaroTROLL. Use the Rugged TROLL 200 cable suspension kit to anchor the cable in place. The following configurations are available:

- Modbus/RS485 stripped and tinned cable or SDI-12 stripped and tinned cable — Use with PLC, telemetry system, or logger
- Modbus/RS485 top-of-well cable — Use with Rugged TROLL Com and laptop PC or RuggedReader® handheld PC

Jacket options	TPU (thermoplastic polyurethane)
Conductors	4 conductors, 24 AWG, polypropylene insulation
Diameter	Cable: 0.200 in (5.1 mm) Connector: 1.03 in (26.1 mm)
Minimum bend radius	5X cable diameter
Break strength	150 lb (68 kg)

Rugged **TROLL**® Com Communication Device

Use the Rugged TROLL Com device for communication between a cabled Rugged TROLL 200 or Rugged BaroTROLL instrument and a RuggedReader handheld PC or a desktop/laptop computer. The Rugged TROLL Com communicates via Modbus/RS485.

Operating temp. range	-4-122° F (0-50° C)
Storage temp. range	-40-176° F (-40-80° C)
Materials	Delrin, rubber, copper pins
Environmental rating	IP67 with battery cover closed
Dimensions (LxWxH)	3.5 x 1.14 x 1.88 in (8.9 x 2.9 x 4.8 cm)
Input connection	Modbus/RS485
Output connection	Available with either USB or RS232
Power source	9V alkaline battery, user-replaceable
Cable	Black polyurethane, 3 ft (91 cm) long

Rugged **TROLL**® Docking Station

Use the docking station to program and download data from the Rugged TROLL 100 or 200 or from the Rugged BaroTROLL. The docking station is available with either a USB or RS232 communication interface. USB communication allows fast data transfer to a PC. The RS232 version is used with a PC or a RuggedReader handheld PC.

In-Situ Inc.®

Call to purchase — www.in-situ.com

221 East Lincoln Avenue, Fort Collins, CO 80524
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1-970-498-1500 (international & domestic)

In-Situ Inc.

Innovations in
Water Monitoring

Level **TROLL**® Instruments

Water Level Instruments for Every Application & Budget

*Level **TROLL**® 700 Instrument*

- Designed for aquifer characterization
- Vented (gauged) and non-vented (absolute) instruments
- Linear, fast linear, linear average, event, step linear, and true logarithmic logging modes
- Titanium construction for all applications (0.72" OD)

*Level **TROLL**® 500 Instrument*

- Designed for groundwater and surface-water monitoring
- Vented or non-vented instrument
- Linear, fast linear, and event logging modes
- Titanium body ideal for harsh environments (0.72" OD)

*Level **TROLL**® 300 Instrument*

- Designed for fresh water and industrial monitoring
- Non-vented instrument
- Linear, fast linear, and event logging modes
- Stainless steel construction (0.82" OD)

Powerful, Accurate, Reliable Performance

- **Low-power consumption** – Extend deployments and get the only industry guarantee for battery life — minimum of 5 years or 2 million readings. External power or battery packs can be used.
- **Telemetry and SCADA integration** – Access data when you need it. No adapters or confusing proprietary protocols required — fully compliant Modbus/RS485, SDI-12, and 4-20 mA.
- **Superior accuracy** – Get guaranteed accuracy under all operating conditions — instruments undergo extensive calibration procedures for pressure and temperature. Each instrument includes a serialized calibration report.
- **Intuitive interface** – Simplify data collection and management with Win-Situ® 5 and Win-Situ® Mobile software. Software features setup wizards, fast data download rates, multiple water level reference options, and more.

Applications

- Aquifer characterization
- Coastal deployments — tide/harbor levels, storm surge systems, and wetlands research
- Construction and mine dewatering
- River, lake, and reservoir monitoring
- Stormwater management

Level **TROLL**® *300, 500 & 700 Instruments*

General	***Level TROLL 300***	***Level TROLL 500***	***Level TROLL 700***	***BaroTROLL***
Temperature ranges	Operational: -4-176° F (-20-80° C) Storage: -40-176° F (-40-80° C) Calibrated: 23-122° F (-5-50° C)	Operational: -4-176° F (-20-80° C) Storage: -40-176° F (-40-80° C) Calibrated: 23-122° F (-5-50° C)	Operational: -4-176° F (-20-80° C) Storage: -40-176° F (-40-80° C) Calibrated: 23-122° F (-5-50° C)	Operational: -4-176° F (-20-80° C) Storage: -40-176° F (-40-80° C) Calibrated: 23-122° F (-5-50° C)
Diameter	0.82 in (2.08 cm)	0.72 in (1.83 cm)	0.72 in (1.83 cm)	0.72 in (1.83 cm)
Length	9.0 in (22.9 cm)	8.5 in (21.6 cm)	8.5 in (21.6 cm)	8.5 in (21.6 cm)
Weight	0.54 lb (245 g)	0.43 lb (197 g)	0.43 lb (197 g)	0.43 lb (197 g)
Materials	Stainless steel body; Delrin® nose cone	Titanium body; Delrin nose cone	Titanium body; Delrin nose cone	Titanium body; Delrin nose cone
Output options	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA	Modbus/RS485, SDI-12, 4-20 mA
Battery type & life	3.6V lithium; 5 years or 2M readings[1]	3.6V lithium; 5 years or 2M readings[1]	3.6V lithium; 5 years or 2M readings[1]	3.6V lithium; 5 years or 2M readings[1]
External power	8-36 VDC	8-36 VDC	8-36 VDC	8-36 VDC
Measurement current	4 mA	4 mA	4 mA	4 mA
Sleep current	180 µA	180 µA	180 µA	180 µA
Memory	1.0 MB	2.0 MB	4.0 MB	1.0 MB
Data records[2]	65,000	130,000	260,000	65,000
Data logs	2	50	50	2
Fastest logging rate & Modbus rate	2 per second	2 per second	4 per second	1 per minute
Fastest SDI-12 & 4-20 mA output rate	1 per second	1 per second	1 per second	1 per second
Log types	Linear, Fast Linear, and Event	Linear, Fast Linear, and Event	Linear, Fast Linear, Linear Average, Event, Step Linear, True Logarithmic	Linear
Real-time clock	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period	Accurate to 1 second/24-hr period
Sensor Type/Material	Piezoresistive; stainless steel	Piezoresistive; titanium	Piezoresistive; titanium	Piezoresistive; titanium
Range	*Non-vented* 30 psia: 35.8 ft (10.9 m) 100 psia: 197.3 ft (60.1 m) 300 psia: 658.7 ft (200.7 m)	*Non-vented* 30 psia: 35.8 ft (10.9 m) 100 psia: 197.3 ft (60.1 m) 300 psia: 658.7 ft (200.7 m) 500 psia: 1120 ft (341.3 m) *Vented* 5 psig: 11.5 ft (3.5 m) 15 psig: 35 ft (11 m) 30 psig: 69 ft (21 m) 100 psig: 231 ft (70 m) 300 psig: 692 ft (211 m) 500 psig: 1153 ft (351 m)	*Non-vented* 30 psia: 35.8 ft (10.9 m) 100 psia: 197.3 ft (60.1 m) 300 psia: 658.7 ft (200.7 m) 500 psia: 1120 ft (341.3 m) 1000 psia: 2306.4 ft (703 m) *Vented* 5 psig: 11.5 ft (3.5 m) 15 psig: 35 ft (11 m) 30 psig: 69 ft (21 m) 100 psig: 231 ft (70 m) 300 psig: 692 ft (211 m) 500 psig: 1153 ft (351 m)	0 to 16.5 psi; 0 to 1.14 bar
Burst pressure	Maximum 2x range; burst 3x range	Maximum 2x range; burst 3x range	Maximum 2x range; burst 3x range	Vaccum/over-pressure above 16.5 psi damages sensor
Accuracy @ 15° C	±0.1% full scale (FS)	±0.05% FS	±0.05% FS	±0.1% FS
Accuracy (FS)	±0.2% FS[3]	±0.1% FS[3]	±0.1% FS[3]	±0.2% FS[3]
Resolution	±0.01% FS or better	±0.005% FS or better	±0.005% FS or better	±0.005% FS or better
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH$_2$O, inH$_2$O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH$_2$O, inH$_2$O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH$_2$O, inH$_2$O Level: in, ft, mm, cm, m	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH$_2$O, inH$_2$O
Temperature Sensor	Silicon	Silicon	Silicon	Silicon
Range	Calibrated: 23-122° F (-5-50° C)	Calibrated: 23-122° F (-5-50° C)	Calibrated: 23-122° F (-5-50° C)	Calibrated: 23-122° F (-5-50° C)
Accuracy & resolution	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better	±0.1° C; 0.01° C or better
Units of measure	Fahrenheit, Celsius	Fahrenheit, Celsius	Fahrenheit, Celsius	Fahrenheit, Celsius
Warranty	Level TROLL and BaroTROLL instruments come with a 1-year warranty. Up to 5-year extended warranties are available.			

*Baro**TROLL**® Instrument*

The titanium BaroTROLL instrument measures and logs barometric pressure and temperature. Use the BaroTROLL in conjunction with Level TROLL instruments.

Win-Situ Baro Merge™ software simplifies post-correction of water level data. Barometric readings are automatically subtracted from data collected by a Level TROLL to compensate for changes in water level due to barometric fluctuations.

24/7 Support

In-Situ technical experts assist with instrument setup, application support, and troubleshooting. Fast, friendly, and always free, technical answers are a phone call away.

---

[1] Battery life guaranteed when used within the factory-calibrated temperature range.

[2] 1 record = date/time plus 2 parameters logged (no wrapping) from device within the factory-calibrated temperature range.

[3] Across factory-calibrated temperature range.

Specifications are subject to change without notice. Delrin is a registered trademark of E.I. du Pont de Nemours and Company.

In-Situ Inc.®

Call to purchase or rent — www.in-situ.com

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Sept. 2010

Solinst®

Levelogger Junior

Model 3001 Data Sheet

Levelogger Junior

Model 3001

The Levelogger Junior provides an inexpensive alternative for measuring groundwater and surface water levels. It combines a datalogger, temperature sensor, pressure transducer, and 5-year battery, in a small, maintenance free, waterproof stainless steel housing.

The Levelogger Junior features a non-volatile memory, with a capacity of 32,000 sets of temperature and water level data points. Readings are linear at a user-defined interval between 0.5 second to 99 hours. Accuracy is 0.1% FS, with a lifetime factory calibration.

If greater accuracy, sampling options, or ranges are required, the Solinst Levelogger Gold has the functionality to suit your application. (See Model 3001 Data Sheet.) For conductivity datalogging, Solinst also offers the LTC Levelogger Junior (See Model 3001 LTC Levelogger Junior Data Sheet).

Compatible with Levelogger Gold software and accessories, the Levelogger Junior is also SDI-12 compatible, can communicate using a Leveloader Gold data transfer unit, and is able to integrate into Solinst Telemetry Systems. (See Model 9100 and 9200 Data Sheets)

Technical Specifications	
Level Sensor:	Piezoresistive Silicon in 316L SS
Ranges:	F15/M5, F30/M10
Accuracy (typical):	0.1% FS
Resolution:	M5/F15 - 0.028%, F30/M10 - 0.021%
Normalization:	Automatic Temp Compensation
Temperature Sensor:	Platinum RTD
Accuracy:	± 0.1°C
Resolution:	0.1°C
Temp Compensation Range:	- 10°C to 40°C
Battery Life:	5 Years
Clock Accuracy:	± 1 minute/year
Operating Temperature:	- 20°C to 80°C
Memory:	Non-volatile EEPROM, FRAM back-up
Maximum # Readings:	32,000 sets of readings
Communication:	Optical Infra-Red to USB or RS232
Size:	7/8" x 5.5" (22 mm x 140 mm)
Weight:	154 g (5.4 oz)
Wetted Materials:	316L Stainless Steel, Delrin®, Viton®, Buna-N
Sampling Mode:	Linear, SDI-12, Real Time View (from 0.5 sec to 99 hrs)
Barometric Compensation:	Software Wizard and Barologger Gold

Features

- Low cost
- 5 year battery life
- 32,000 data points
- Accuracy of 0.1% FS
- Real Time View
- Compatible with Levelogger Gold Series software and accessories

Operation

Programming the Levelogger Junior is the same as with the Levelogger Gold. An Optical Reader or PC Interface Cable connects the Levelogger to a laptop or desktop PC. The intuitive Levelogger Gold Software automatically detects the type of Levelogger that is connected. Programming, downloading, data management and export are easy. The Real Time View option allows immediate viewing of live water level and temperature readings. These compact dataloggers are very easy to deploy. Installation can be with direct read cables or by stainless steel wireline or Kevlar® cord suspension, avoiding the use of vented cables. (See Model 3001 Data Sheet.)

The Levelogger Junior outputs temperature and compensated water level readings. The Barologger Gold and Levelogger software allow easy barometric compensation.

The Levelogger Junior also features helpful utilities such as self-test capability, a robust, non-volatile EEPROM memory and FRAM back-up memory for increased data integrity, also the ability to upgrade firmware for increased function and features.

Applications

- Pump and slug tests
- Reservoir and stormwater runoff management
- Watershed and drainage basin monitoring
- Stream gauging, lake and wetland monitoring
- Tank level measurement
- Monitoring water levels in wells and surface water

Solinst®

Levelogger Comparison

Model 3001

Model 3001	 CE WEEE	 CE WEEE
	Levelogger Gold	**Levelogger Junior**
Backward Compatible	YES See http://www.solinst.com/Downloads/	YES See http://www.solinst.com/Downloads/
Warranty	3 Years	1 Year
Pressure Transducer	Piezoresistive Silicon in 316L Stainless Steel	Piezoresistive Silicon in 316L Stainless Steel
Calibrated Ranges:	15, 30, 65, 100, 300 ft, Atmospheric Barologger 5, 10, 20, 30, 100 m, Atmospheric Barologger	15, 30 ft 5, 10 m
Accuracy (typical)	0.05% FS ± 0.010, 0.016, 0.032, 0.064, 0.328 ft (± 0.3, 0.5, 1, 1.5, & 5 cm) Barologger: ± 0.003 ft (0.1 cm)	0.1% FS ± 0.02, 0.03 ft (± 0.5, 1 cm)
Resolution	M5/F15: 0.001 % FS, Other Ranges: 0.0006 % FS, Baro: 0.002% FS	M5/F15: 0.028 % FS M10/F30: 0.021 % FS
Calibration	Factory – Lifetime calibration	Factory – Lifetime calibration
Temp Comp Range	-10 to +40°C	-10 to +40°C
Temperature Sensor	Platinum RTD	Platinum RTD
Temperature Accuracy	± 0.05°C	± 0.1°C
Temperature Resolution	0.003°C	0.1°C
Operating Temp Range	-20 to +80°C	-20 to +80°C
Clock Accuracy	± 1 minute / year	± 1 minute / year
Battery Life	10 Years (based on 1 reading/minute)	5 Years (based on 1 reading/minute)
Size	7/8" x 6" (22 mm x 154 mm)	7/8" x 5.5" (22 mm x 140 mm)
Weight	6.3 oz (179 grams)	5.4 oz (154 grams)
Memory	40,000 Readings of Level and Temperature Superior Reliability EEPROM Memory with redundant backup of last 1200 logs	32,000 Readings of Level and Temperature Superior Reliability EEPROM Memory with redundant backup of last 1200 logs
Logging Rates	0.5 sec to 99 hours	0.5 sec to 99 hours
Logging Modes	Linear, Event & User-Selectable Schedules with 30 items, each with Sec, Min, Hours, Days or Weeks duration. SDI-12, Real Time View	Linear, SDI-12, Real Time View
Barometric Compensation	High accuracy, air-only, Barologger Gold	Use Barologger Gold
Altitude Input	Range = -980 to 16,400 ft (-300 to 5,000 m)	Range = -980 to 16,400 ft (-300 to 5,000 m)
Corrosion Resistant Coating	Zirconium Nitride (ZrN) PVD	None
Other Wetted Materials	Delrin®, Viton®, 316 L Stainless Steel, Buna-N	Delrin, Viton, 316 L Stainless Steel, Buna-N
Direct Read Capability	Yes	Yes
Leveloader Gold Compatible	Yes	Yes
Offset	Allows input in range equal to Altitude Range = -980 to 16,400 ft (-300 to 5,000 m)	Allows input in range equal to Altitude Range = -980 to 16,400 ft (-300 to 5,000 m)

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Solinst®

Levelogger Gold

Model 3001

The Levelogger® Gold is completely designed, developed and manufactured in-house, in the tradition of all Solinst high quality products. Due to the Solinst commitment to providing leading-edge instruments designed for repeatable accuracy, the Levelogger Gold is always advancing.

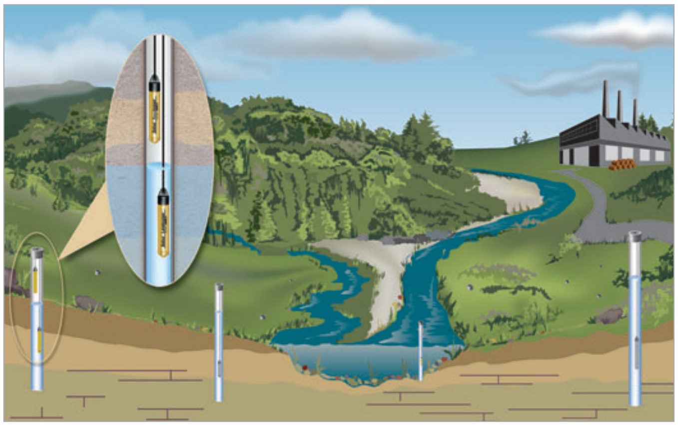
The Levelogger Gold is a water level and temperature recording device. It combines a datalogger, 10-year battery, pressure transducer and temperature sensor, in a small, minimal maintenance, 7/8" x 6" (22 mm x 154 mm) stainless steel housing. The sealed Faraday cage design greatly simplifies maintenance and provides protection against electrical spikes caused by lightning. A Zirconium Nitride coating resists corrosion.

The Levelogger Gold offers high resolution and reliability with an accuracy of 0.05%. The Levelogger Gold has excellent transducer, temperature and clock accuracies. Altitude, water density, temperature and barometric compensations also add to the accuracy and instrument stability.

High accuracy, long-term stability and an internal battery that lasts for 10 years when reading every minute, make Leveloggers the ideal devices for recording water levels. A Barologger provides the easiest and most accurate method of barometric compensation.

Applications

- Pumping and slug tests
- Watershed, drainage basin and recharge monitoring
- Stream gauging, lake and reservoir measurement
- Harbor and tidal fluctuation monitoring
- Wetlands and stormwater run-off monitoring
- Tank level monitoring
- Input water level data to SCADA/PLC systems
- Long-term water level monitoring in wells, surface water bodies and seawater environments



® Solinst and Levelogger are registered trademarks of Solinst Canada Ltd.

Features

- Self-test capability
- Maintenance-free, waterproof design
- Protected from power surges, such as lightning
- Real-time viewing; data can be exported
- Radio, satellite or cellular telemetry
- SDI-12 compatible, up to 1500 ft (450 m)
- User-selectable, 30 line sampling schedule

Robust Memory

The Levelogger Gold memory allows a maximum of 40,000 readings of level and temperature, set up in individual logs. The user has a choice of slate or continuous logging when operating in linear mode. In event-based and schedule sampling, memory is a form of circular slate, which starts logging from the end of the last log and wraps around to eventually overwrite older logs, but which will stop at the start of the current log. A separate redundant memory provides backup of the last 1200 readings, which can be accessed by a Diagnostic Utility program.

Downloading Options

The Levelogger Gold offers 4 download options: 'All Data' downloads the complete log, or the user can save time by selecting 'Append Data', when only new data is desired. A selected period of time prior to the last date stamp can be downloaded using 'Partial Download'. 'Recover Previous Log' is a safeguard in case the Levelogger has been restarted without downloading data. A complete data dump is also available as a feature of the Diagnostic Utility, which downloads all available memory in the Levelogger Gold.

High Accuracy

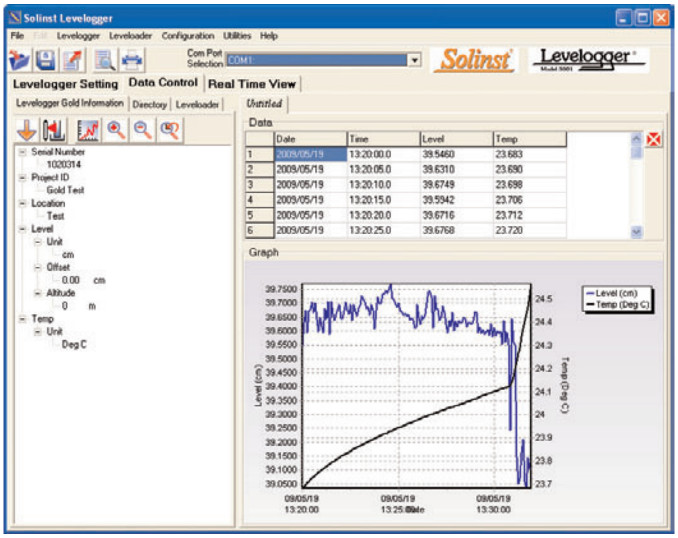
The Levelogger Gold has an accuracy of at least 0.05% net FS, a resolution of 0.0006 to 0.002% depending on range, a Barologger with algorithms based on air not water, enhanced altitude, density, temperature and barometric compensation, as well as a very accurate clock.

Levelogger Operation

Solinst has made programming the Levelogger Series extremely intuitive. Simply place the Levelogger in the optical reader or connect to the direct read cable. All in one screen, fill in the information fields for location, project ID, sample mode and rate, altitude, density adjustment and any desired offset.

Levelogger time may be synchronized to the computer clock, or the Leveloader Gold clock, or it can be user defined. There are options for immediate start or a future start time. The percentage battery life remaining and the amount of free memory are indicated on the settings screen.

A manual measurement of the initial water depth is usually taken at each location, and noted as a base line measurement. When a Barologger is used for barometric pressure measurement, it is set above high water level in one location on site. If direct read cables are being used, data can also be viewed, logged on demand and retrieved from the Levelogger at any time using a Leveloader or a portable computer.



Com Port Selection: COM1:

- Serial Number
  - 1020314
- Project ID
  - Gold Test
- Location
  - Test
- Level
  - Unit
    - cm
  - Offset
    - 0.00 cm
  - Altitude
    - 0 m
- Temp
  - Unit
    - Deg C

	Date	Time	Level	Temp
1	2009/05/19	13:20:00.0	39.5460	23.683
2	2009/05/19	13:20:05.0	39.6310	23.690
3	2009/05/19	13:20:10.0	39.6749	23.698
4	2009/05/19	13:20:15.0	39.5942	23.706
5	2009/05/19	13:20:20.0	39.6716	23.712
6	2009/05/19	13:20:25.0	39.6768	23.720

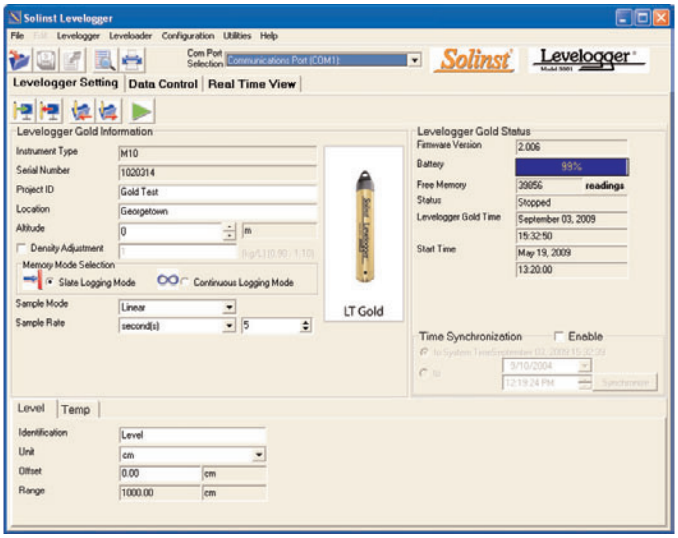
Real Time View Window

Convenient Sampling Options

Solinst includes a very flexible, user-selectable sampling schedule, as well as the standard linear and event-based sampling options. Linear sampling can be anywhere from 0.5 seconds to 99 hours.

Event-based sampling can be set to record when the level changes anywhere from 0.1% up to 25% of the full range of the logger. Readings will be checked at the selected time interval, but only recorded in memory if the condition has been matched or exceeded.

The Schedule option allows up to 30 schedule items, each with its own sampling rate of seconds, minutes or hours, and a duration of seconds, minutes, hours, days or weeks. A running total of sample time and number of readings available are indicated and updated. Templates of these Schedules, and Levelogger Settings, can be saved for easy re-use.



Com Port Selection: Communications Port (COM1)

Instrument Type: M10
Serial Number: 1020314
Project ID: Gold Test
Location: Georgetown
Altitude: 0 m
☐ Density Adjustment: 1 (kg/L) (0.90 : 1.10)
Memory Mode Selection: ● Slate Logging Mode ○ Continuous Logging Mode
Sample Mode: Linear
Sample Rate: second(s) 5

Firmware Version: 2.006
Battery: 99%
Free Memory: 39056 readings
Status: Stopped
Levelogger Gold Time: September 03, 2009 15:32:50
Start Time: May 19, 2009 13:20:00

Time Synchronization ☐ Enable

Identification: Level
Unit: cm
Offset: 0.00 cm
Range: 1000.00 cm

Levelogger Settings Window

Data Download, Viewing and Export

Data is downloaded to a PC with the click of a screen icon or with the push of a button on the Leveloader. Collected data is retained in the Levelogger until it has been written over. The level data downloaded from a Levelogger has already been automatically compensated for temperature and altitude and the temperature data is also downloaded.

Barometric compensation of the Levelogger data is performed by a Wizard that can be used to input elevation offsets and adjust for Barometric efficiency. The software allows immediate viewing of the data in graph or table format using the 'Real Time View' option. It also allows easy export into a spreadsheet or database for further processing.

Use of Direct Read Cables

When it is desired to get real-time data and communicate with Leveloggers without removal from the water, they can be deployed using direct read cables.

The lower end of the direct read cable has a miniaturized infra-red optical reader. The top cap of the Levelogger is removed and the direct read cable is threaded in its place. In turn, the upper end of the cable is attached to a portable computer or Leveloader, via a USB or RS232 PC Interface Cable. This allows viewing of the data, downloading and/or programming in the field.

Leveloggers can also be connected to an SDI-12 datalogger using the Solinst SDI-12 Interface Cable attached to a direct read cable.

The full benefits of a sealed Levelogger with no vent tube or electrical cable connection are also maintained. The logger is still sealed from all electrical interference through a Faraday cage design. Cable handling problems are minimized.

A Direct Read Cable with a Levelogger connected, attaches to a PC Interface Cable at a 2" Well Cap

PC Interface Cable connected to the Direct Read Cable

Enviro Cap™ lockable cap and key used with Wireline and Hooks

Helpful Utilities

The 'Self-Test Diagnostic Utility' can be used in case of an unexpected problem. It checks the functioning of the program, calibration, backup and logging memories, the pressure transducer, temperature sensor and battery voltage, as well as enabling a complete Memory Dump, if required. A Firmware Upgrade will be available from time to time, to allow upgrading of the Levelogger Gold, as new features are added.

Direct Read Cable Specifications

Direct read cables are available for attachment to any Levelogger, new or old, in standard lengths of: 15', 50', 100', 200', 250', 300' and 5m, 15 m, 30 m, 60 m, 80 m, 100 m. Custom cable lengths up to 1500 ft (450 m) are also available to fit particular monitoring situations, as required. Cable markings are available upon request.

The 1/10" dia. (2.54 mm) coaxial cable has an outer polyethylene jacket for strength and durability. A stranded stainless steel braided conductor gives non-stretch accuracy.

The upper end of the direct read cable is fitted with a connector that can act as a well cap for a 1" well. This connector fits Solinst Levelogger well caps designed for 2" or 4" wells, and can easily be tethered at surface in other situations.

Use of Suspension Wireline and Kevlar Cord

Leveloggers may also be suspended in the water on a stainless steel wireline or Kevlar® cord. This is a very inexpensive method of deployment, and if in a well, allows the Levelogger to be easily locked, out of sight and inaccessible to anyone without a special key.

Solinst has adapted the Enviro Cap™ by adding a vent hole in the cap to allow for the equalization of barometric pressure in the well. The well cap has a convenient eyelet from which to suspend the Levelogger. It slips into the casing and is locked in place with the tamper-proof key, as shown.

The Enviro Caps are available sized for 2" and 4" wells. Well caps for other sizes of well can also be used.

Accurate Barometric Compensation

Leveloggers measure absolute pressure (water pressure + atmospheric pressure) expressed in feet, meters or centimeters of water column.

The most accurate method of obtaining changes in water level is to compensate for atmospheric pressure fluctuations using a Barologger. This avoids any time lag in the compensation calculation and any errors introduced due to moisture buildup, kinking or damage to vented cable. The new Barologger Gold uses algorithms based on air rather than water pressure, which gives superior accuracy. The recorded barometric information can also be very useful to help determine barometric lag and/or barometric efficiency of the monitored aquifer.

The Data Compensation Wizard in the Levelogger software greatly simplifies the barometric adjustment of the water level measurements by using the synchronized data from one on-site Barologger with all the Leveloggers.

The overall results give more reliable, highly accurate level data than that obtained when using high maintenance and expensive vented cable.

® Kevlar is a registered trademark of DuPont Corp.

Levelogger Gold Specifications

Level Sensor:	Piezoresistive Silicon in 316L Stainless Steel
Accuracy:	0.05% net FS
Stability of Readings:	Superior, low noise
Resolution:	0.002 to 0.0006% FS
Normalization:	Automatic Temp Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector
Temp. Sensor Accuracy:	± 0.05°C
Temp. Sensor Resolution:	0.003°C
Temp. Comp. Range:	-10°C to +40°C
Battery Life:	10 Years - based on one reading/min
Clock Accuracy:	± 1 minute/year
Operating Temperature:	-20°C to 80°C
Maximum # Readings:	40,000 of level and temperature
Memory:	Superior reliability EEPROM (Slate, or Continuous) plus redundant backup of last 1200 logs
Communication:	Optical Infra-Red Interface, Serial at 9600 Baud, Conversion to RS232 or USB Computer Connection
Size:	7/8" x 6" (22 mm x 154 mm)
Weight:	6.3 oz (179 grams)
Backwards Compatibility:	Full
Corrosion Resistance:	Zirconium Nitride (ZrN) Coating
Other Wetted Materials:	316-L Stainless Steel, Delrin®, Viton®
Sampling Modes:	Linear, Event and User-Selectable with 30 separate line items
Measurement Rates:	0.5 sec to 99 hrs
Barometric Compensation:	Software Wizard and one Barologger in local area (approx. 20 miles/30 km) radius

Models	Full Scale (FS)	Accuracy (typical)	Resolution
Barologger	4.92 ft., 1.5 m	± 0.003 ft., 0.1 cm	0.002% FS
F15, M5	16.4 ft., 5 m	± 0.010 ft., 0.3 cm	0.001% FS
F30, M10	32.8 ft., 10 m	± 0.016 ft., 0.5 cm	0.0006% FS
F65, M20	65.6 ft., 20 m	± 0.032 ft., 1 cm	0.0006% FS
F100, M30	98.4 ft., 30 m	± 0.064 ft., 1.5 cm	0.0006% FS
F300, M100	328.1 ft., 100 m	± 0.164 ft., 5 cm	0.0006% FS

Levelogger Junior: See Model 3001 Junior Data Sheet for details
Conductivity: See Model 3001 LTC Levelogger Junior Data Sheet

Leveloader Gold

The Leveloader Gold is a data transfer unit designed for use with all versions of the Solinst Levelogger, Barologger and Rainlogger. It is used to download and store multiple data files.

The 8 Mb FLASH memory stores up to 1,390,000 LT readings, 930,000 LTC readings, or 34 full Levelogger downloads. It can also be used to display data in real-time, and has optional password protection.

Simply use the connector cables for attachment to a Levelogger, or to a direct read cable, to allow downloading or reprogramming of the Levelogger settings in the field. It comes with cables for USB and RS232 connection to a PC for data transfer. (See Model 3001 Leveloader Gold Data Sheet.)

STS Telemetry

The STS Gold Telemetry System provides an economical and efficient method to access remote data instantly. Built for the Levelogger Series, the system combines high quality dataloggers, intuitive software and a variety of wireless communication options to create a remote monitoring solution.

CDMA and GSM digital cellular, satellite and radio wireless communication options give the flexibility to suit any project. Systems are suitable for both small to large networks. The STS Gold is designed to save costs by enabling the self-management of data, as well as remote collection of the data. Alarm notification, remote firmware upgrades and diagnostic reporting make system maintenance simple. (See Model 9100 Data Sheet.)

RRL Telemetry

The inexpensive RRL Radio Telemetry is ideal for short range applications up to 1000 ft (300 m). Distances can be increased by using some radios as ‘repeater’ stations. (See Model 9200 Data Sheet.)

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Levelogger Junior

Model 3001 Levelogger® Junior (Level, Temperature)

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Comparison Sheet PDF (102kb) (Gold vs Previous Model)
Tech Bulletin PDF (86kb) (Absolute vs Vented)
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Related Products
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Model 9100 STS Telemetry

Model 3001 Levelogger Junior > Datasheet > Comparison: Gold VS Junior << Previous

Levelogger Comparison

Model 3001		
	Levelogger Gold	Levelogger Junior
Backward Compatible	YES See http://www.solinst.com/Downloads/	YES See http://www.solinst.com/Downloads/
Warranty	3 Years	1 Year
Pressure Transducer	Piezoresistive Silicon in 316L Stainless Steel	Piezoresistive Silicon in 316L Stainless Steel
Calibrated Ranges:	15, 30, 65, 100, 300 ft, Atmospheric Barologger 5, 10, 20, 30, 100 m, Atmospheric Barologger	15, 30 ft 5, 10 m
Accuracy (typical)	0.05% FS ± 0.010, 0.016, 0.032, 0.064, 0.328 ft (± 0.3, .5, 1, 1.5, & 5 cm) Barologger: ± 0.003 ft (0.1 cm)	0.1% FS ± 0.02, 0.03 ft (± 0.5, 1 cm)
Resolution	M5/F15: 0.001 % FS, Other Ranges: 0.0006 % FS, Baro: 0.002% FS	M5/F15: 0.028 % FS M10/F30: 0.021 % FS
Calibration	Factory – Lifetime calibration	Factory – Lifetime calibration
Temp Comp Range	-10 to +40°C	-10 to +40°C
Temperature Sensor	Platinum RTD	Platinum RTD
Temperature Accuracy	± 0.05°C	± 0.1°C
Temperature Resolution	0.003°C	0.1°C

Operating Temp Range	-20 to +80°C	-20 to +80°C
Clock Accuracy	± 1 minute / year	± 1 minute / year
Battery Life	10 Years (based on 1 reading/minute)	5 Years (based on 1 reading/minute)
Size	7/8" x 6" (22 mm x 154 mm)	7/8" x 5.5" (22 mm x 140 mm)
Weight	6.3 oz (179 grams)	5.4 oz (154 grams)
Memory	40,000 Readings of Level and Temperature Superior Reliability EEPROM Memory with redundant backup of last 1200 logs	32,000 Readings of Level and Temperature Superior Reliability EEPROM Memory with redundant backup of last 1200 logs
Logging Rates	0.5 sec to 99 hours	0.5 sec to 99 hours
Logging Modes	Linear, Event & User-Selectable Schedules with 30 items, each with Sec, Min, Hours, Days or Weeks duration. SDI-12, Real Time View	Linear, SDI-12, Real Time View
Barometric Compensation	High accuracy, air-only, Barologger Gold	Use Barologger Gold
Altitude Input	Range = -980 to 16,400 ft (-300 to 5,000 m)	Range = -980 to 16,400 ft (-300 to 5,000 m)
Corrosion Resistant Coating	Zirconium Nitride (ZrN) PVD	None
Other Wetted Materials	Delrin, Viton, 316 L Stainless Steel, Buna-N	Delrin, Viton, 316 L Stainless Steel, Buna-N
Direct Read Capability	Yes	Yes
Leveloader Gold Compatible	Yes	Yes
Offset	Allows input in range equal to Altitude Range = -980 to 16,400 ft (-300 to 5,000 m)	Allows input in range equal to Altitude Range = -980 to 16,400 ft (-300 to 5,000 m)

top

High Quality Groundwater & Surface Water Monitoring Instrumentation

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WITH DATALOGGING

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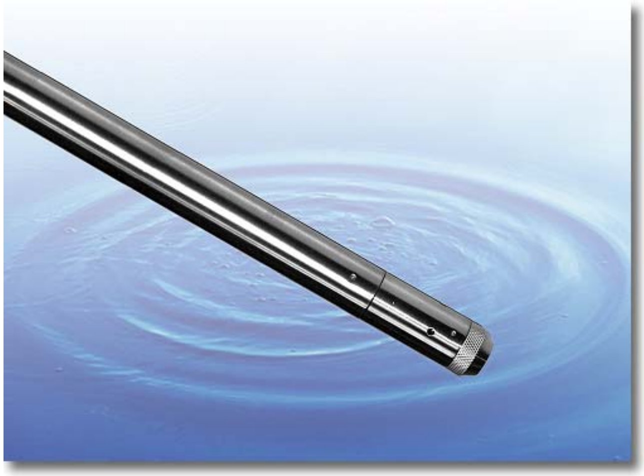
Pressure AND **Temperature**
with this easy-to-use
yet powerful and accurate
AquiStar® PT2X Smart Sensor!



Great almost anywhere you need to measure level and temperature – whether it be in a lake, in a tank, or in a well.

FEATURES

SENSOR

- Pressure, temperature, time
- Absolute, gauge, or sealed gauge
- Thermally compensated – *great where water temperatures vary, such as in streams or in industrial tank applications*
- ± 0.06% FSO typical accuracy
- Low power – *2 internal AA batteries*
- External power options (12 VDC) with AA's acting as backup
- 316 SS, Viton®, Teflon® construction (titanium optional)
- Small diameter – 0.75" (1.9 cm)
- Modbus® and SDI-12 interface for greater flexibility

DATALOGGER

- 130,000 record, 260,000 record, and 520,000 record versions
- Non-volatile memory – *data will not be lost in the event of a power failure*
- Flexible, multi-phase logging sequences – *save sequences to disk to reuse in the future*
- Pause logging feature – *temporarily pause the logging while repositioning or transporting sensor*
- Delayed start feature – *state a specific future start time, making it easy to set several sensors to start at the same time*

CABLING AND NETWORKING

- Wireless connectivity – radios *and/or cellular*
- RS485 network – *allows several sensors to be networked together and allows much longer cable leads than does RS232*
- Field serviceable connectors – *easily remove the connector, route cable through well seals, walls, or conduit, and then replace connector*
- Available cableless or with a variety of cable options – *polyethylene, polyurethane, or FEP Teflon®*

SOFTWARE - FREE, EASY-TO-USE

- Real time viewing
- Easy export to spreadsheets and databases
- Barometric compensation utility for use with absolute sensors
- Ability to update sensor via firmware while in the field – *great for future updates or custom development*

APPLICATIONS

- Pump and slug tests
- Stormwater runoff monitoring
- Well, tank, tidal levels
- River, stream, reservoir gauging
- Wetland monitoring
- Resource administration

Instrumentation Northwest, Inc.
1-800-776-9355
http://www.inwusa.com

PT2X SUBMERSIBLE PRESSURE/TEMPERATURE SMART SENSOR

DIMENSIONS, SPECIFICATIONS, and ORDERING INFORMATION

GENERAL

Length	11.875” (30.2 cm)
Diameter	0.75” (1.9 cm)
Weight	0.8lb. (0.4 kg)
Body Material	Delrin® & 316 Stainless Steel *or* Titanium
Wire Seal Materials	Viton® and Teflon®
Submersible Cable	Polyurethane, Polyethylene, FEP *or* Tefzel® available
Protection Rating	IP68, NEMA 6P
Desiccant	1-3mm indicating silica gel *(high or standard capacity)*
Terminating Connector	Available
Communication	RS485 Modbus RTU SDI-12 (ver.1.3)
Direct Modbus Read Output	32-bit IEEE Floating point
SDI-12 Output	ASCII
Internal Math	32 bit floating point
Operating Temp. Range[3]	-15°C to 55°C
Storage Temp. Range[1]	-40°C to 80°C

LOGGING

Memory	1MB - 130,000 records 2MB - 260,000 records 4MB - 520,000 records
Log Types	Variable, User-Defined, Logarithmic, Profiled
Programmable Baud Rate	9600, 19200, 38400
Logging Rate	8x/sec
Software	Complimentary Aqua4Plus or Aqua4Push
Networking	32 available addresses per junction w/ batching capabilities (up to 255)
File Formats	.xls/.csv/.a4d

POWER

Internal Battery	2x1.5V AA Alkaline[2]
Auxiliary Power	12VDC - Nominal 6-15 VDC - Range
Exp. Battery Life	18 months at 15m polling interval

TEMPERATURE

Element Type	Digital IC on board
Accuracy	±0.5°C
Resolution	0.06°C
Range	-40°C to 80°C
Units	Celsius, Fahrenheit, Kelvin

PRESSURE

Transducer Type	Silicon Strain Gauge
Transducer Material	316 Stainless *or* Titanium
Pressure Ranges	
Gauge	
PSIG[5]	1,2.5,5,15,30,50,100,300
mH_2O[5]	0.7,1.75,3.5,10.5,21,35,70,210
Absolute	
PSIA[5]	20,30,50,100,300
mH_2O[5]	14,21,35,70,210
Units	PSI, FtH_2O, inH_2O, cmH_2O, mmH_2O, mH_2O, inHg, cmHg, mmHg, Bars, mBars, kPa
Static Accuracy	±0.06% FSO *typical* ±0.1% FSO *maximum* *(B.F.S.L. 25°C)*
Maximum Zero Offset	±0.25% FSO *(@ 25°C)*
Maximum Operating Pressure	1.1 x FS
Burst Pressure[4]	3.0 x FS
Compensated Range	0°C to 40°C

---

[1] Storage without batteries
[2] Lithium available upon request
[3] Requires freeze protection kit if in water below freezing
[4] Burst reduced at PSI>300
[5] Higher Pressure ratings available upon request

Information in this document is subject to change without notice.

Instrumentation Northwest, Inc.
Sales and Service Locations
8902 122nd Avenue NE, Kirkland • Washington 98033 USA
(425) 822-4434 • (425) 822-8384 FAX • info@inwusa.com
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(916) 922-2900 • (916) 648-7766 FAX • inwsw@inwusa.com

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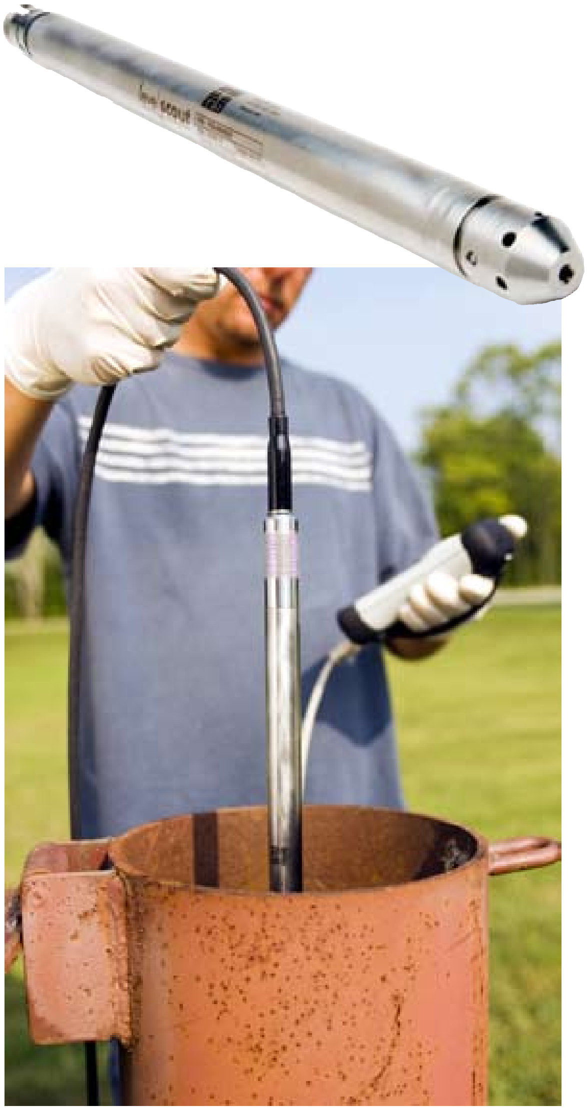
CE

YSI

level scout

LEVEL, TEMPERATURE, DATA LOGGING PRESSURE TRANSDUCERS



The YSI Level Scout is available as vented or absolute, stainless steel or titanium, and with 2 or 4 Mb of memory.

Applications include:

- Groundwater monitoring - long-term studies, resource management
- Well monitoring, aquifer testing - pump, slug, step, and recovery tests
- Soil Vapor Extraction Tests (SVE)
- Open channel monitoring
- Gaging stations - rivers, streams, lakes
- Tank level measurement
- Watershed management

Absolute Level Instrument

- Stainless Steel or Titanium
- 2 or 4 Mb

Vented Level Instrument

- Stainless Steel or Titanium
- 2 or 4 Mb

YSI's Level Scout™ contains a highly accurate pressure transducer in a field-rugged housing. Accurate measurements, low power consumption, and easy data management make the Level Scout ideal for your next level monitoring application.

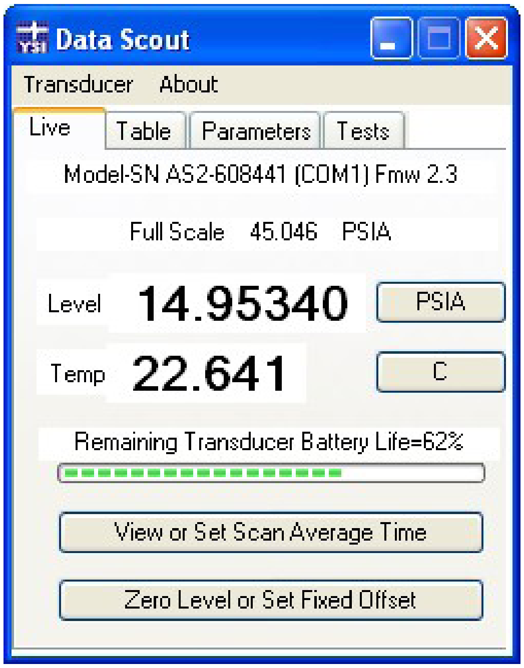
Features:

- Vented gauge or absolute pressure/level
- Maintenance-free vented field cables
- Fastest sample rate available (up to 15 readings/second)
- High accuracy, ± 0.05% FS (level ranges > 10 ft)
- Two year warranty on instrument and cable
- All software included with the instrument and free for download
- Baro Scout available for atmospheric pressure compensation
- Small diameter (.75 in) housing, stainless steel or titanium
- Built in sampling modes - linear, linear average, logarithmic, and event-based
- User-replaceable batteries, 3-year life at 15 minute sampling rates
- Field-upgradeable firmware

The Level Scout measures and logs pressure/level and temperature along with time stamp at user-selectable sampling modes and rates. Internal batteries and low power consumption provide years of data logging capabilities. Logging modes include linear, linear average, event triggered, and logarithmic sampling. The internal (2) AA batteries are user-replaceable with a quick-disconnect cable assembly.

Data Scout desktop software allows you to communicate with up to 16 Level Scouts at one time in order to set up tests, view live data, download logged data, and configure alarms. Logged files and be viewed in Excel® or DS Playback. DS Playback allows you to display tabular and graphical data, correlate barometric pressure data, and convert to other measurement units.

Data Scout Desktop and Mobile Software


Data Scout

Transducer About

Live | Table | Parameters | Tests

Model-SN AS2-608441 (COM1) Fmw 2.3

Full Scale 45.046 PSIA

Level 14.95340 PSIA

Temp 22.641 C

Remaining Transducer Battery Life=62%

View or Set Scan Average Time

Zero Level or Set Fixed Offset

View real time data from the Level Scout on Data Scout's home page. From the home page, you can re-zero the transducer, setup TOC measurements and navigate to the live data table or to the configure tests tab.

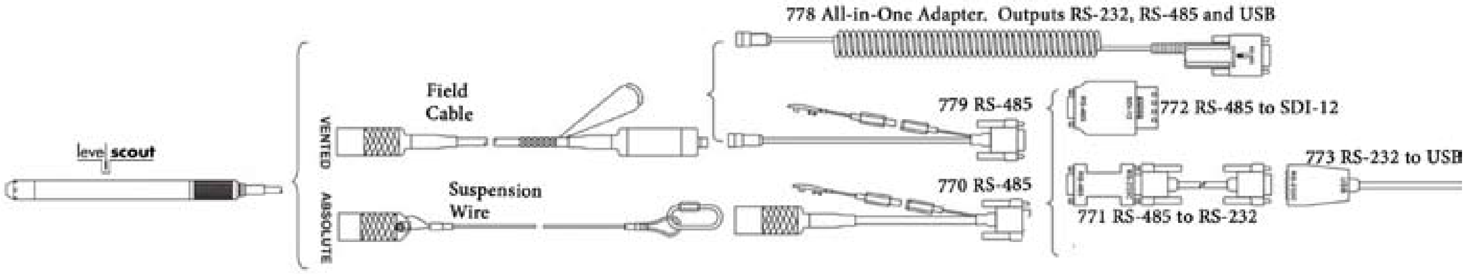
Easy-to-use desktop and mobile software makes operating the Level Scout simple and convenient. Data Scout Desktop and Mobile are included with the purchase of the Level Scout and available for free download. The software allows you to complete both simple and complex tasks. Data Scout runs on PCs with Windows® 98, ME, NT, 2000, or XP.

Capabilities

- Save and view real time data from the Level Scout
- Configure up to 16 independent logging tests
- Communicate with up to sixteen transducers at once, either over a serial interface or multi-drop network
- Change measurement units
- Configure alarms and broadcasts to DCPs
- Configure Top of Casing (TOC) measurements
- Download data from completed or active tests

Data Scout Playback allows you to view uploaded data in tabular or graphical formats, convert the measurement units and correlate data between an absolute Level Scout and data from a Baro Scout barometric pressure logger

Communications



Vented Level Scouts should be connected to field cable for use and deployment. An absolute Level Scout can be connected to a suspension wire or a field cable for use and deployment.

The field cable can provide continuous data readout for both vented and absolute Level Scouts. Its maintenance-free vent filter provides atmospheric pressure compensation to vented Level Scouts. The cable is available with a stainless steel or titanium connector, depending on which transducer you select. Additionally, the field cable is available as either polyurethane or ETFE jacketed. ETFE is a fluoropolymer material that is more chemically resistant then polyurethane. The cable includes a cable hanger and drain wire for cable shield grounding. The field cable connector works with YSI communications adapters.

To communicate and set up a Level Scout, connect the field cable to the 778 all-in-one adapter. The 778 provides signal outputs in RS-232, RS-485, and USB for communication to a PC, powerful pocket PC or RS-485 device. The 778 also has a DC power connector with detachable battery connection for use during data download.

For SDI-12 communication, connect the field cable to a 779 and then to a 772 in order to connect the Level Scout to a DCP. The 779 has a DC power connector with a detachable battery connection for use during data download.

The 770 is a Non-submersible RS-485 communication cable. Recommended if not purchasing a field cable assembly.

Level Scout Specifications

Level Ranges	*Full Scale Level Range*	10, 50, 75, 250, 692	ft H_2O (m H_2O)	for vented gauge reference
		(3, 15, 23, 76, 211)		
		10, 50, 70, 230, 692	ft H_2O (m H_2O)	for absolute reference
		(3, 15, 21, 70, 211)		
	Barometric Pressure Range	8 to 16 (55 to 110)	psia (kPa)	for barometer
	Proof Pressure	2.0	x FS	
	Burst Pressure	3.0	x FS	
Measurement Accuracy				Standard
	Level	±0.05	%FS TEB[1]	for level ranges >10 ft (3 m) H_2O
		±0.10	%FS TEB[1]	for level ranges <= 10 ft (3 m) H_2O
	Temperature	±1.0	°C	Models VS2, VT2, AS2, AT2
		±0.2	°C	Models VS4, VT4, AS4, AT4

Level Scout Data Logging Specifications

Modes of Sampling	Linear, Linear Average, Event, Logarithmic		user selectable
Pressure Units	psi, ft H_2O, mm H_2O, cm H_2O, m H_2O, kPa		user-specified or by slope and offset
Sampling Rate[2]	Programmable		15 readings per second max
Internal Non-Volatile Memory	2	Mbyte	Models VS2, VT2, AS2, AT2
	4	Mbyte	Models VS4, VT4, AT4, AS4
Maximum Pressure Scans	196,560	with time stamp	Models VS2, VT2, AS2, AT2
	393,120	with time stamp	Models VS4, VT4, AS4, AT4
Maximum Pressure and Temperature Scans	144,144	with time stamp	Models VS2, VT2, AS2, AT2
	288,288	with time stamp	Models VS4, VT4, AS4, AT4
Time Stamp Accuracy	±2	min/year	over compensated temp range
Data Upload Time	100	scans/sec	pressure and temp with time stamp per second @ 19200 baud rate

Level Scout General Specifications

Compensated Temperature Range	14 to 104 (-10 to 40)	°F (°C)	
Operating Temperature Range	-4 to 122 (-20 to 50)	°F (°C)	All level ranges with polyurethane cables and level ranges <=100 ft with ETFE cables
	32 to 122 (0 to 50)	°F (°C)	Level ranges >100 ft with ETFE cables
Storage Temperature Range	-40 to 176 (-40 to 80)	°F (°C)	without batteries
	-4 to 122 (-20 to 50)	°F (°C)	with batteries
Protection Rating and Certifications	IP-68, NEMA 6P, On-board surge protection, RoHS, CE		
Internal Battery	2 each 1.5 V	AA	alkaline recommended
Battery Life	3	years	15 minute sampling intervals w/alkaline
External Excitation	6 to 16	VDC	
External Input Current	13.0	mA	average current during measurement
	25.0	mA	15 mS peak current during page writes
	0.25	mA	quiescent
Communication Interface	RS-485, networkable		3 volt p-p differential w/ selectable baud rates from 1200 to 19200
Communication Protocol	SDI-12		ver 1.3 compliant
Approximate Weights	0.70 (318)	lb (g)	transducer with batteries
	0.15 (57)	lb (g)	cable assembly (less cable)
	0.05 (79)	lb/ft (g/m) cable	
	0.005 (8)	lb/ft (g/m) suspension wire	
Dimensions	0.75 (19.0)	in. (mm)	diameter
	12.44 (316.00)	in. (mm)	length

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1 Total Error Band (TEB) includes the combined errors due to non-linearity, hysteresis, non-repeatablility, and thermal effects over the compensated temperature range per ISA S51.1

2 For sampling rates greater than 3 Hz, the pressure/temperature averaging must be reduced as required

Accessories

NEW! Field Cable has in-line, life-time vent filter that allows for worry-free and maintenance-free deployments. Its waterproof patch keeps water out of the vent tube while internal desiccant absorbs any condensation. All of the vent tubing is internal to the cable so you'll never need to worry about accidently crimping it! The field cable is halogen free and allows for atmospheric compensation of vented Level Scouts and direct data readout and communication to any Level Scout while deployed in the field. Includes cable hanger for easy deployment and a drain wire grounding.

Suspension Wire
Model 750 (stainless steel) or Model 760 (titanium)

Used for suspension of absolute transducers. Includes stainless steel or titanium backshell, carabiner, and Teflon® coated stainless steel suspension wire.

Model 785

4-inch locking well cap. Includes carabiner for attaching equipment. Model 782 for 2-inch wells.

Ordering (Transducers, Cables, Communications Adapters Ordered Separately)

AS2-x[1]	Absolute Level Scout, Stainless Steel, 2 Mb memory
AS4-x[1]	Absolute Level Scout, Stainless Steel, 4 Mb memory
AT2-x[1]	Absolute Level Scout, Titanium, 2 Mb memory
AT4-x[1]	Absolute Level Scout, Titanium, 4 Mb memory
BS2	Atmospheric compensation Baro Scout, Stainless Steel, 2 Mb memory
BS4	Atmospheric compensation Baro Scout, Stainless Steel, 4 Mb memory
VS2-x[2]	Vented Level Scout, Stainless Steel, 2 Mb memory
VS4-x[2]	Vented Level Scout, Stainless Steel, 4 Mb memory
VT2-x[2]	Vented Level Scout, Titanium, 2 Mb memory
VT4-x[2]	Vented Level Scout, Titanium, 4 Mb memory
711-x[3]	Field cable with polyurethane jacket and stainless steel backshell
721-x[3]	Field cable with ETFE jacket and stainless steel backshell
731-x[3]	Field cable with polyurethane jacket and titanium backshell
741-x[3]	Field cable with ETFE jacket and titanium backshell
770	Non-submersible quick disconnect communication cable
750 or 760-x[3]	Suspension Wire Assembly, Stainless Steel or Titanium
778	All-in-one adapter, connects field cable to RS485, RS232 and USB
779	Technician cable, connects
771	Adapts 770 communication cable's RS-485 signal to RS-232 converter and 6 foot RS-232 cable
772	Adapts 778 RS-485 signal to SDI-12 converter

1 x = transducer rating available in depths of 10, 50, 75, 250, 692 feet (3, 15, 23, 76, 211 meters)
2 x = depth ranges available in 10, 50, 70, 230, 692 feet (3, 15, 21, 70, 211 meters)
3 Available in standard lengths of 25 ft increments up to 500 ft. and 50 ft increments up to 1000 ft; specials orders to the ft available.

To order, or for more information, contact YSI.

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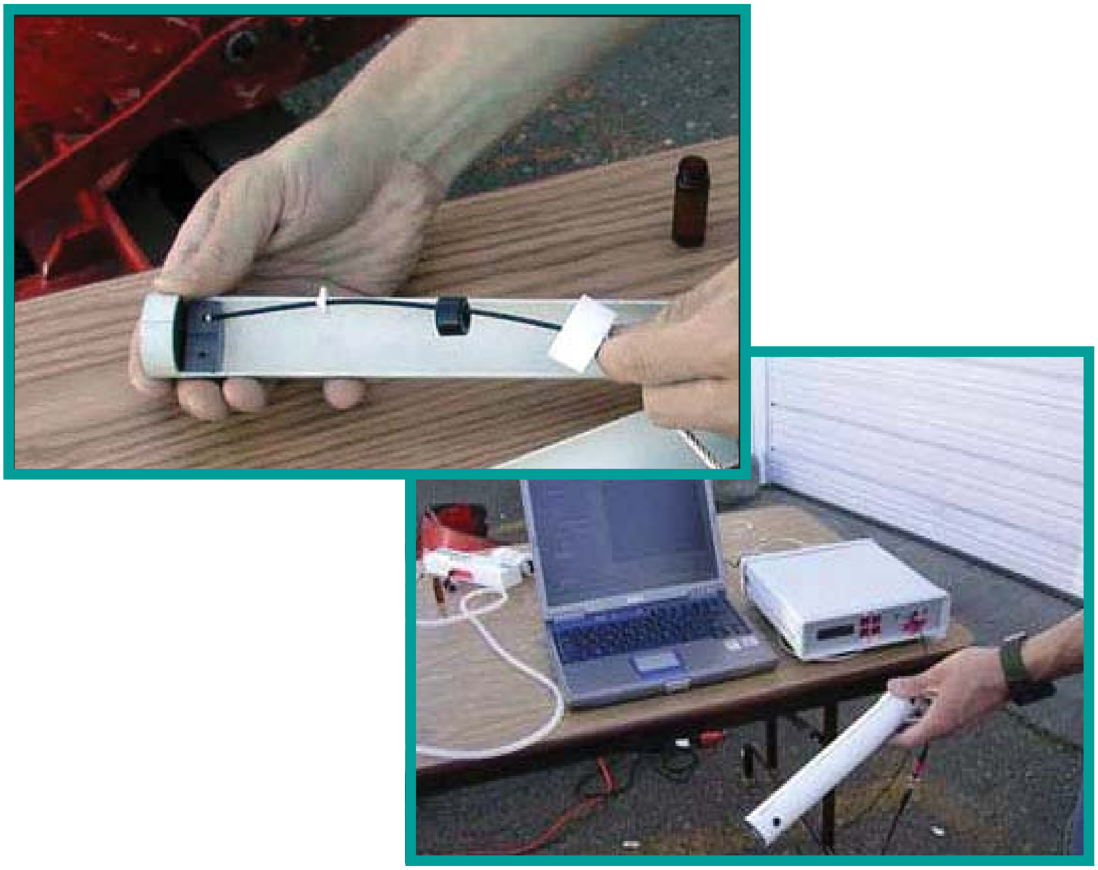
ISO 9001
ISO 14001
CE

Fiber Optic Biosensors

ESTCP
Cost and Performance Report

(ER-0115)



Fiber Optic Biosensors

December 2006

ENVIRONMENTAL SECURITY
TECHNOLOGY CERTIFICATION PROGRAM

U.S. Department of Defense

COST & PERFORMANCE REPORT
ESTCP Project: ER-0115

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ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
1,2-DCA	1,2-dichloroethane
A/D	analog to digital
bgs	below ground surface
BMS	buffered measurement solution
CDM	Camp Dresser & McKee Inc.
CSU	Colorado State University
DCA	dichloroethane
DO	dissolved oxygen
DoD	Department of Defense
EA	EA Engineering, Science, and Technology
EPA	Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
GC/MS	gas chromatography/mass spectroscopy
HCl	hydrochloric acid
LNAPL	light non-aqueous phase liquid
M	molar
mm	millimeter
mM	millimolar
nm	nanometer
ORP	oxidation/reduction potential
OU8	Operable Unit 8
PVA	polyvinyl alcohol
PWIA	Public Works Industrial Area
QA/QC	quality assurance/quality control
QC	quality control
Qva	Vashon advance outwash
Qvt	Vashon till
RPD	relative percent difference

ACRONYMS AND ABBREVIATIONS (continued)

SUBASE Bangor	Bangor Naval Submarine Base
UST	underground storage tank
VOA	volatile organic analyte
VOC	volatile organic compound

ACKNOWLEDGEMENTS

This report describes the demonstration of a novel analytical technology: fiber-optic-based biosensors for detecting groundwater contaminants in the field in near-real time. The report describes the demonstration of biosensors at a Department of Defense (DoD) site as well as supplemental development of additional biosensors.

Individuals who contributed to completion of this project and their affiliations: Ken Reardon, Ph. D., Colorado State University (CSU); Victor Acha, CSU; Brinson Willis, CSU; Cory Jenson, CSU; Roger Olsen, Ph.D. (PI), Camp Dresser & McKee Inc. (CDM); John Eisenbeis, Ph.D., CDM; Kristy Warren, CDM; Dan Adams, CDM; Michael Allen, Bangor Naval Submarine Base (SUBASE Bangor) (now with CDM); and Barb Chafin-Tissier, SUBASE Bangor.

1.0 EXECUTIVE SUMMARY

Significant costs are associated with laboratory analyses of groundwater samples collected at Department of Defense (DoD) sites. Most of these samples are needed to characterize the nature and extent of contamination at a site, evaluate remedial system performance, and track contaminant plume migration via regularly scheduled monitoring events. There is need to replace laboratory analyses with reliable, easy-to-use field methods that produce real-time results. Colorado State University (CSU) has developed fiber-optic biosensors that are ideally suited for field monitoring of groundwater contaminants. Generally, a biosensor is a device that utilizes a biological recognition element (typically enzymes or antibodies) to sense the presence of an analyte and create a response that is converted by a transducer to an electrical or optical signal.

The primary issue regarding the use of biosensors is reliability, i.e., are biosensor results comparable to laboratory analyses? The end user also needs to know whether there are conditions that affect the reliability of biosensor performance. Biosensors also need to be easy to use and calibrate so that reproducible results can be obtained from different users. The demonstration described in this document was designed to address these issues. The overall objective of the biosensor demonstration was to provide a basis to justify the use of biosensors to augment or replace conventional analytical methods for measuring selected compounds in groundwater. Specific objectives included:

- Demonstrating the accuracy, reliability, and cost of biosensors
- Demonstrating the effectiveness of on-site field measurements using biosensors
- Determining operational limits associated with using the biosensors
- Transferring the biosensor technology to end users.

Biosensors were used to analyze groundwater sampled from several monitoring wells at Operable Unit 8 (OU8) of the Bangor Naval Submarine Base (SUBASE Bangor) in Kipsap County, Washington, to evaluate biosensor performance under a range of conditions. The target analyte was 1,2-dichloroethane (1,2-DCA). Groundwater samples were collected from monitoring wells spaced throughout the plume to analyze a wide range of 1,2-DCA and cocontaminant concentrations. The samples were analyzed by biosensors and gas chromatography/mass spectroscopy (GC/MS). A flow-through cell was also set up to allow biosensor readings in flowing water similar to the setup typically used to collect pH, conductivity, and turbidity readings prior to monitoring well sampling. Biosensors were lowered into monitoring wells to record down-hole in situ readings.

Performance of the biosensors was evaluated based on the following criteria:

- Accuracy, as demonstrated by a one-to-one correlation between the two analytical techniques (conventional GC/MS and biosensors)
- Range, as demonstrated by a response from less than 5 micrograms per liter (µg/L) to greater than 500 µg/L 1,2-DCA
- Precision, as demonstrated by a low relative percent difference (RPD) between duplicate analyses

- Sample throughput, as demonstrated by short analysis time in the field
- Mechanical reliability, as demonstrated by a low incidence of failure
- Versatility, as demonstrated by acceptable performance under a variety of conditions.

Two performance levels were established with regard to the data that the biosensors might be used to collect:

Level 1: Semiquantitative screening concentration data
Moderate accuracy
Moderate quantitation limit
Moderate specificity and selectivity

Level 2: Quantitative concentration data
High accuracy
Low quantitation limit
High specificity and selectivity

The interference of parameters affecting the pH of the groundwater being measured impacted the biosensor's performance against several performance criteria, including accuracy, precision, sensitivity, and range. The biosensor measures small pH changes produced by the reaction of an enzyme with 1,2-DCA, and techniques are required to distinguish these pH changes from pH changes due to other processes. For vial measurements, this interference can be significantly reduced by proper calibration. However, for flow-through cell and down-hole measurements, calibration procedures have not been developed to reduce the pH interference. Because the biosensor measures small pH changes produced by the reaction of an enzyme with 1,2-DCA, methods are required to distinguish these pH changes from pH changes due to other processes. This can readily be accomplished by adding an optical fiber (bundled with the biosensor) and a second measurement channel to the hardware, thus providing optical pH measurement for correction of the pH changes. At the present level of development, the biosensors would most appropriately be used to provide semiquantitative data regarding 1,2-DCA concentrations in groundwater.

The biosensors can be used to collect Level 2 quantitative data when used in the vial measurement mode; however, further investigation into development and testing of the biosensors is required for them to be reliable field instruments for all the applications originally intended.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY DEVELOPMENT AND APPLICATION

The CSU biosensor is a two-layer detection element immobilized on the tip of an optical fiber (Figures 1 and 2). The outer layer of the detection element contains bacteria with an enzyme that catalyzes a reaction with the analyte resulting in protons being released. The inner detection layer contains a pH-sensitive fluorescent dye (fluoresceinamine). Thus, the presence of the contaminant leads to a pH change on the fiber tip, which can be measured as a change in fluorescence intensity (Figure 3). Since the change in fluorescence depends on the contaminant concentration, these optical, enzymatic biosensors provide quantitative output.

Many enzymes catalyze reactions that result in a pH change. CSU researchers have worked primarily with the class of enzymes known as hydrolytic dehalogenases, which catalyze the introduction of water into a halogenated organic compound with the production of a hydrohalide (e.g., hydrochloric acid [HCl]) (Figure 4). However, a biosensor based on organophosphorous hydrolase has also been developed to detect members of the organophosphorous family (which includes many nerve agents).

One of the advantages of fiber-optic sensors is their small size, typically about 1 millimeter (mm) in diameter (Figure 5). These optical sensors can be used at much longer distances than electronic sensors because signal loss in optical fibers is extremely low. In the field, the fiber-optic biosensors can be lowered into a small well (e.g., Geoprobe well) for measurement.

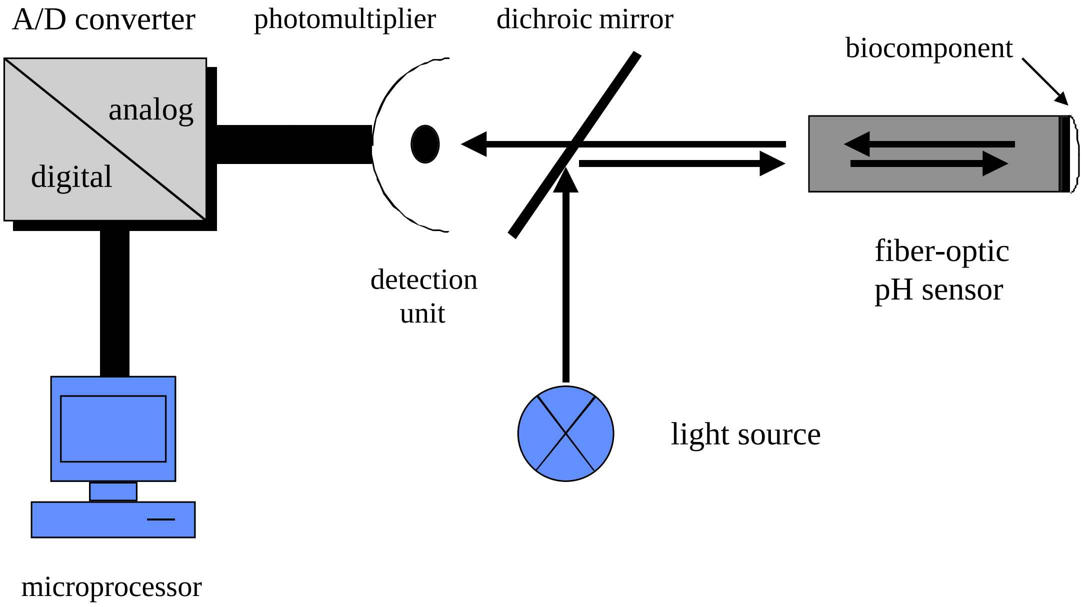

Figure 1. Schematic of the Fiber-Optic Biosensor System.

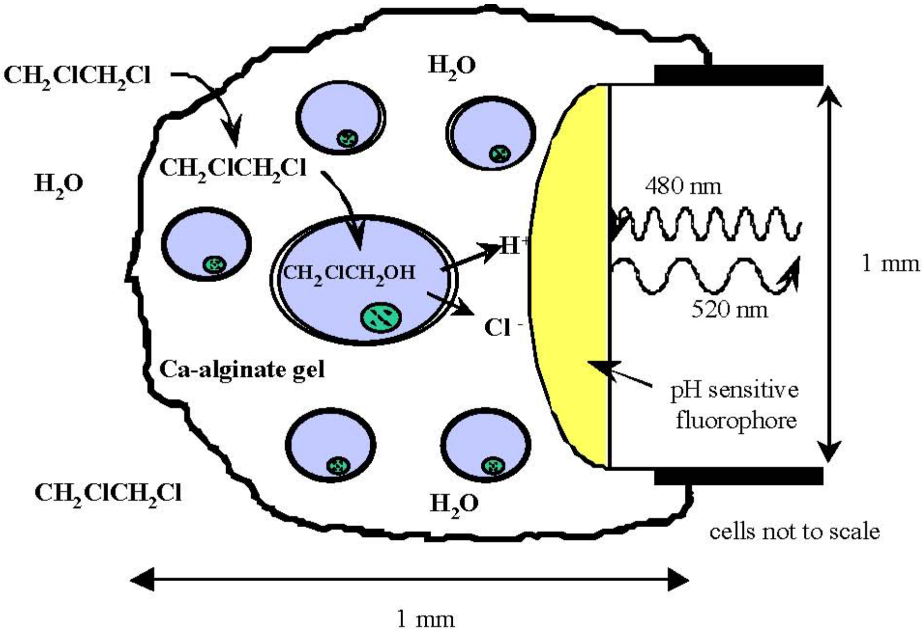

Figure 2. Schematic of the Two-Layer Detection Element of the CSU Biosensor, Illustrated for the Ethylene Dibromide Biosensor. (The pH-sensitive fluorophore is excited with 480-nanometer (nm) light and emits fluorescence at 520 nm, which is transmitted along the optical fiber to a photomultiplier.)

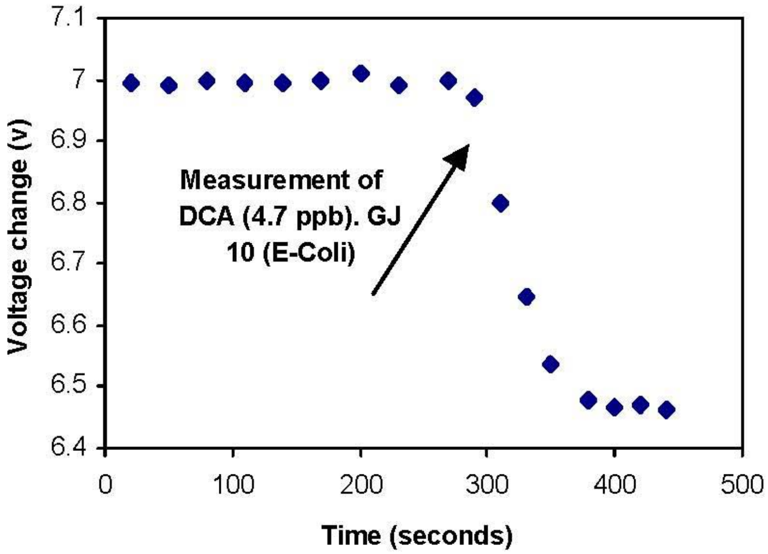

Figure 3. Biosensor Response as Photomultiplier Voltage Change Following a Change in Analyte Concentration.

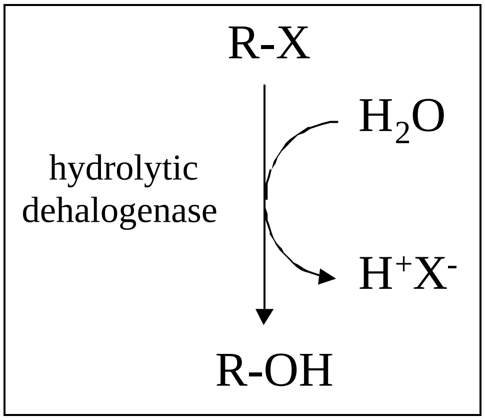

Figure 4. Reactions Catalyzed by Hydrolytic Dehalogenases Produce Protons, Which Change the pH of the Environment Near the Enzyme.

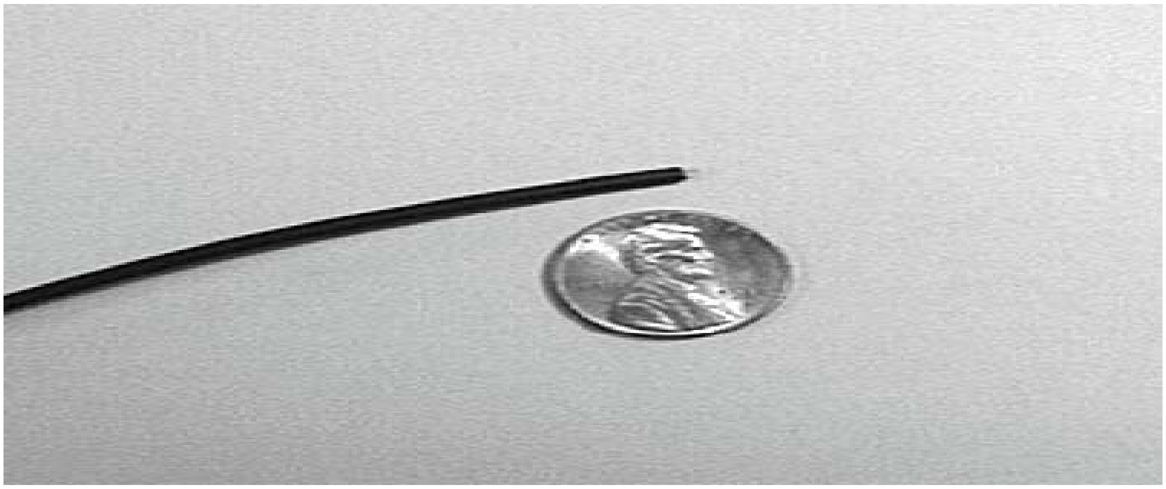

Figure 5. Comparison of Fiber-Optic Sensor to a Penny to Demonstrate Small Size.

2.2 PROCESS DESCRIPTION

Biosensor Construction Protocols

Biosensors consist of a layer of calcium-alginate-entrapped cells or purified enzymes in direct contact with a layer of a pH-sensitive fluorophore immobilized on one end of an optical fiber (Figure 6). Optical fibers coated only with fluorophore are termed pH optodes. To prepare these pH optodes, the cladding of fibers was removed from 1 mm of the distal end of the optical fiber, then polished with very fine grit paper. A pH-sensitive fluorophore was affixed to the distal end of the fiber-optic cable. The fluorophore, fluoresceinamine, was first coupled to polyvinyl alcohol (PVA) using cyanuric chloride, and the resulting product was cross-linked with glutaraldehyde in presence of HCl to form a hydrogel that was applied subsequently to the polished optical fiber tip by using a micropipette. After polymerization, the resulting pH optode was stored in 0.1 M Na_2HPO_4 at room temperature.

Figure 6. Fiber-Optic Biosensor. (One end of the optical fiber is coated by a pH-sensitive fluorophore, which in turn is covered by cells or enzymes entrapped in Ca-alginate.)

Whole cell biosensors were created by entrapping a small amount of concentrated resting cells in a calcium alginate hydrogel on the fluorophore end of a pH optode. Previously cultured cells were combined with a 4% sodium alginate solution to give a mixture at a desired ratio. Five microliters of this gel mixture were deposited on the end of a pH optode. The resulting biosensor was immediately immersed in ice-cold 0.47 molar (M) $CaCl_2$ for 30 min, placed into a buffered measurement solution (BMS) (1 millimolar (mM) $C_6H_{13}NO_4S$+ 25 mM $CaCl_2$ + 150 mM NaCl) and stored at 4°C.

Enzyme biosensors were created by entrapping pure enzymes in a calcium alginate hydrogel on the fluorophore end of a pH optode. Enzymes were previously isolated from cells by a special procedure consisting of disrupting fresh cells by sonication to get a cell-free extract that is purified on a Ni-nitrilotriacetic acid Sepharose column HR 16/10. The pure enzymes were combined with 4% sodium alginate solution to give a mixture at a desired ratio. The subsequent steps to create an enzyme biosensor are similar to those for preparation of whole cell biosensors.

Biosensors were treated with the cross-linking agent glutaraldehyde to improve their physical stability. Biosensors were suspended in 6 M glutaraldehyde for 30 min at room temperature with stirring. The treated biosensors were washed with deionized water and stored at 4°C in measurement solution until used.

The treatment improved the stability of biosensors but lowered the diffusion of substrate and product in and out of the gel matrix, resulting in a slight decrease in the sensitivity of the biosensors.

2.3 PREVIOUS TESTING OF THE TECHNOLOGY

No significant field testing of the biosensors was performed prior to the Environmental Security Technology Certification Program (ESTCP) demonstrations.

2.4 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

In situ measurements by fiber-optic biosensors could be used to reduce costs at DoD sites in at least four scenarios. First, biosensors could be used to monitor groundwater contaminant concentrations in existing plumes, either by permanent installation of wells for monitoring over time or by analyses of wells at discrete time points. Second, biosensors could be placed in sentinel wells between a plume and a receptor to detect offsite contaminant migration. Third, biosensors could be used to continuously monitor treatment system effluent to determine treatment efficiency and provide evidence as to whether regulatory limits for discharge are met. Finally, they could be used for site characterization—as soon as a Geoprobe or well is placed, a biosensor could determine the contaminant concentration and the results could direct the placement of subsequent Geoprobes or wells.

Relative to traditional, discrete sampling approaches, biosensors have the following advantages:

- The capability of providing low-cost, simultaneous measurements at different depths in a well (i.e., spatial resolution). Currently, average values over a screened interval are obtained because discrete interval monitoring, although more informative, is too expensive and complicated.

- The capability of providing low-cost, continuous monitoring (i.e., temporal resolution). Current methods rely on single periodic measurements that may not be representative.

To achieve the full potential of this biosensor technology, it will be necessary to develop biosensors that are stable over long (> 2 months) periods. For many applications, such as on-site vial sampling, the requirement is that the rate of sensitivity loss be low enough to allow recalibration to occur only once per day, as would be typical of any sensor. For down-hole monitoring, the rate of sensitivity loss should be lower; if this cannot be achieved, then the down-hole monitoring mode will be limited to qualitative rather than quantitative measurements.

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3.0 DEMONSTRATION DESIGN

3.1 PERFORMANCE OBJECTIVES

Performance of the biosensors was compared to the GC/MS method for groundwater analysis. Performance was evaluated based on the following objectives identified in the Demonstration Plan:

- Accuracy, as demonstrated by a one-to-one correlation between the two analytical techniques
- Range, as demonstrated by a response from less than 5 µg/L to greater than 500 µg/L 1,2-DCA
- Precision, as demonstrated by a low relative percent deviation between duplicate analyses
- Sample throughput, as demonstrated by low analysis time in the field
- Mechanical reliability, as demonstrated by a low incidence of failure
- Versatility, as demonstrated by acceptable performance under various conditions.

Table 1 presents a summary of the performance objectives and indicates which objectives were met during the demonstration.

Table 1. Performance Objectives.

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)	Actual Performance Objective Met?
Qualitative	Sample processing rate	>6 samples/day	Yes
	Mechanical reliability	Low breakdown incidence	Yes
	Versatility	Applicability to all conditions	No
	Ease of use	Typical operator training and labor required	No
Quantitative	Accuracy	Relative percent difference (RPD) <25% (RPD for GC/MS method); correlation coefficient (r2) >0.9	No
	Precision	RPD for biosensor equal to or less than 25% (RPD for GC/MS method)	No
	Sensitivity	<5 µg/L	Yes (if no interference)
	Range	> 500 µg/L	Yes (if no interference)

This section describes the criteria used to select a demonstration site. These criteria included:

- Presence of a contaminant detectable by biosensors
- Existence of an ongoing groundwater monitoring program with which data can be coordinated and shared
- Preference for many monitoring points and monitoring wells with long screen intervals to facilitate discrete depth measurements
- Preference for nonhomogeneous aquifer concentrations to demonstrate the importance of discrete depth monitoring.

The demonstration site selected was SUBASE Bangor since it met all the above criteria, including having a groundwater plume with 1,2-DCA as a major component. 1,2-DCA is one of the compounds for which a biosensor had already been developed and lab-tested.

3.2 TEST SITE/FACILITY HISTORY/CHARACTERISTICS

SUBASE Bangor

The study area is OU8 in the Public Works Industrial Area (PWIA) of SUBASE Bangor, which is located near the town of Silverdale, Washington. An on-site underground storage tank (UST) is believed to be the source of a release of unleaded gasoline into the surrounding media between 1982 and 1986. In 1986, soil vapor extraction/air system and product recovery were implemented to clean up the site. To date, liquid petroleum hydrocarbons remain in several monitoring wells at the PWIA. Chlorinated volatile organic compounds (VOC) are also present in site groundwater. EA Engineering, Science, and Technology (EA) conducted an investigation to assess natural attenuation processes at OU8.

OU8 geological conditions have been highly characterized by drilling and monitoring well installation. The area consists of four stratigraphic units: construction fill, Vashon till (Qvt), Vashon advance outwash (Qva), and Lawton clay. The construction fill can be found 2 to 3 feet below ground surface (bgs) and consists of a sandy material. Underlying the construction fill and ranging to a depth of about 45 ft bgs is the Qvt, which consists of silt, sand, gravel, and cobbles. This unit is 20 to 40 ft thick. The Qva (location of the shallow aquifer) is beneath the Qvt and consists of sand, silt, and gravel. The thickness of the Qva is about 100 to 130 ft. Beneath the Qva is the Lawton clay aquitard. A silty transition zone in the bottom of the Qva separates the shallow aquifer from the lower aquitard.

There are approximately 100 monitoring wells at OU8. The wells were installed at three different depth intervals: shallow, intermediate, and deep. The depth to groundwater is about 20 ft bgs, and the general flow direction is southeast. The Qva lies beneath the Qvt at OU8 and is the location of the shallow unconfined aquifer. The shallow aquifer contained in the Qva is about 125 ft thick. The shallow wells are screened within 30 ft of the water table; intermediate wells are screened within the middle 40 ft of the aquifer thickness; and the deeper wells are screened within 30 ft of the Lawton clay aquitard. The plume contains dissolved petroleum contaminants (including benzene) and dichloroethane (DCA). Most of the contaminants are in the shallow and intermediate zones of the Qva. Site characterization data for SUBASE Bangor can be found in Appendix A of the Final Report (Olsen and Reardon, 2005).

3.3 PHYSICAL SETUP OPERATION

All equipment and supplies necessary for measurements were mobilized to and around the demonstration site in a van. No site utilities were required. Power was obtained from either a vehicle battery or a portable generator. Biosensors were transported to the site from CSU on ice. The tips were stored in a 0.01 M buffer solution at pH 7.0 with no contaminant present and were maintained in that solution on ice until shortly before their use.

3.4 SAMPLING/MONITORING PROCEDURES

The fiber-optic biosensor demonstrations used the following sampling methods.

- **VOA Vial Measurements.** A biosensor was inserted into a vial containing a sample of the groundwater from a monitoring well. A split sample was sent to an off-site laboratory for analysis by GC/MS.
- **Flow-Through Cell Measurements.** A biosensor was inserted into an aboveground, flow-through cell (with continuous flow of groundwater from the monitoring well) in conjunction with recording routine measurements of the field parameters pH, dissolved oxygen (DO), oxidation/reduction potential (ORP), temperature, and specific conductance.
- **Down-Well Measurements.** A biosensor was lowered down-hole in an unpumped monitoring well. Measurements were taken at several depth intervals to define contaminant gradients.
- **Sampling of "Sentinel" Wells.** A biosensor was installed down-hole in a selected monitoring well. The fiber-optic cable and analyte probe were left in the hole and monitored on a routine basis over the period of a day. Results from this type of sampling provided a basis to determine if the biosensors could be left in a well for longer periods and what calibration needs are necessary for such sampling.

The above procedures allowed for comparison of biosensor readings with analytical results from GC/MS laboratory analysis. The results were also used to compare sampling methods and concentration profiles with depth. The results and details concerning measurement methods used at each monitoring well are provided in Section 4.

Field QC Samples

The following types of quality control (QC) samples were collected and analyzed:

- **Duplicate samples**. Two of the VOA vials filled with groundwater were analyzed on site using the bsiosensor. The second sample was analyzed immediately after the first sample and was identified as a duplicate sample. A third sample was retained for potential later analysis.
- **Colocated samples**. As previously described, concentrations of 1,2-DCA were measured down-hole in selected wells. At one of these locations, the biosensor was removed and cleaned. The down-hole analyses were then repeated at the same depths in the same well.
- **Additional QC samples**. Additional quality assurance/quality control (QA/QC) samples are discussed in the following paragraphs that would typically be used only in an off-site

laboratory. However, because the biosensor is being evaluated for use as a replacement for off-site analyses, additional samples were analyzed.

3.5 ANALYTICAL PROCEDURES

Groundwater samples collected from monitoring wells during the demonstrations at SUBASE Bangor were analyzed for VOCs using Environmental Protection Agency (EPA) Method 8260B for GC/MS.

4.0 PERFORMANCE ASSESSMENT

4.1 PERFORMANCE DATA

Volatile Organic Analyte (VOA) Vial Analysis. The objective of this type of analysis was to compare the biosensor readings to off-site laboratory results (GC/MS) for 1,2-DCA. After field parameters indicated that stable groundwater conditions had been reached during pumping, two VOA vials were filled. Three additional VOA vials were filled for analysis by the biosensors. Filling alternated between vials for biosensor and off-site analyses. The cap of one of the biosensor vials was removed briefly and immediately replaced with a cap fitted with a biosensor. A biosensor reading was recorded after sufficient time had elapsed to obtain a stable reading. This procedure was then repeated for the second vial (duplicate).

Flow-Through Cell Analysis. While groundwater from the sample pump was being measured for field parameters (pH, DO, etc.) in a flow-through cell, a second flow-through cell (connected in series and attached to the effluent port of the first cell) was utilized to take biosensor readings of the groundwater flowing from the well. Before placement in the cell, a biosensor was inserted into a field standard of 1,2-DCA at a concentration that was similar to the anticipated concentration from the well being sampled (based on the last lab results for that well). This helped to minimize the time needed for a stable reading when the biosensor was put into the flow-through cell. Readings were recorded from the biosensor at regular intervals until field parameter readings stabilized. In addition to individual biosensor readings, notes were taken as to the range in fluctuation of readings and the approximate average reading.

Down-Well Measurements. A biosensor was lowered down-hole in an unpumped monitoring well. Measurements were taken at several depth intervals to define contaminant gradients.

Sampling of "Sentinel" Wells. A biosensor was installed down-hole in a selected monitoring well. The fiber-optic cable and analyte probe were left in the hole and monitored on a routine basis over the period of a day. Results from this type of sampling provided a basis to determine if the biosensors could be left in a well for longer periods and what calibration needs are necessary for such sampling.

4.2 PERFORMANCE CRITERIA

The performance of the biosensor was assessed at two levels: Level 1 is the ability to provide qualitative, screening data with definitive compound identification. Level 2 is the ability to provide definitive compound identification and quantitative concentrations.

Level 1: Semiquantitative screening concentration data
Moderate accuracy
Moderate quantitation limit
Moderate specificity and selectivity

Level 2: Quantitative concentration data
High accuracy
Low quantitation limit
High specificity and selectivity

Table 2 provides the data quality objectives and evaluation criteria. Evaluation criteria for 1,2-DCA were selected to be consistent with those standard procedures used by the off-site laboratory (GC/MS methods equivalent to EPA method 8260B).

Table 2. Expected Performance and Performance Confirmation Methods.

Performance Criteria	Expected Performance Metric (pre-demonstration)	Performance Confirmation Method	Actual (post-demonstration)
PRIMARY CRITERIA (Performance Objectives) (Qualitative)			
Sample throughput	> 6 samples per day	Experience from demonstration operation	For vial measurements, >6 samples per day
Mechanical reliability	Low breakdown incidence	Experience from demonstration operation	Further development needed to improve mechanical reliability of biosensor tips. Hardware reliability was high.
Versatility	Applicability to all conditions tested	Comparison of results from different wells and laboratory testing	Further development needed for the biosensors to address interference of pH on measurements.
Ease of use	Operator training and labor required similar to other field equipment	Comparison to operator requirements for other commonly used field instruments	Ease of operation similar to other field instruments, although calibration could be simplified.
PRIMARY CRITERIA (Performance Objectives) (Quantitative)			
Accuracy	RPD <25% (the RPD for EPA Method 8060B) r2 >0.9	Correlation with GC/MS reference method	Accuracy was dependent on ability to correct for non-analyte-related pH changes. For vial measurements, r2 = 0.934 and average RPD = 45.6%
Precision	RPD for biosensor equal to or less than RPD for reference method	RPD between replicates, taking into account best RPD attained with the GC/MS reference method	Average RPD for vial measurements = 45.6% Overall, RPDs higher than reference method.
Sensitivity	Detection limit for 1,2-DCA <5 µg/L	Detection of 1,2-DCA concentrations less than 5 µg/L as determined by GC/MS reference method	Detection limit for 1,2-DCA <5 µg/L
Range	> 500 µg/L 1,2-DCA	Ability to quantify 1,2-DCA concentrations greater than 500 µg/L as determined by GC/MS reference method	> 500 µg/L 1,2-DCA
SECONDARY PERFORMANCE CRITERIA (Qualitative)			
Hazardous materials	No hazardous materials produced	Evaluate materials needed for operation	No hazardous materials produced
Process waste	No process waste produced	Observation	No process waste produced

Table 2. Expected Performance and Performance Confirmation Methods (continued).

Performance Criteria	Expected Performance Metric (pre-demonstration)	Performance Confirmation Method	Actual (post-demonstration)
Factors affecting performance • Throughput groundwater quality	• Analysis rate >6 samples/day • No interferences under typical groundwater conditions	• Time/sample analysis Performance not affected by groundwater characteristics	• Analysis rate >6 samples/day • In some cases, pH changes interfered with biosensor analysis • Biosensor tips need to be stabilized for long-term immersion
Maintenance	Maintenance requirements similar to other field instruments	Comparison of field records to operator requirements for other commonly used field instruments	Biosensor tips need refrigeration and have a finite shelf life. Durability of tip could be improved. Hardware maintenance not dissimilar to other field instruments.
Scale-up constraints	No commercialization constraints	Investigate ability to easily produce commercially	Likely no commercialization constraints; however, depends on further development results.

4.3 DATA ASSESSMENT

This section presents the results for the various types of biosensor measurements taken during the second demonstration at SUBASE Bangor. The first demonstration was ineffective due to damage to the biosensor hardware during shipping to the site. The hardware was repaired on site; however, few usable measurements were collected. Valuable experience was obtained during the first demonstration (logistics, sampling methods, field calibration, etc.) The following sections describe results from the second demonstration.

4.3.1 Vial Measurements

Results of the biosensor and the off-site laboratory measurements (GC/MS) are summarized in Tables 3 and 4. The biosensor results for these measurements are plotted against results of the laboratory method (GC/MS) in Figures 7a and 7b. The correlation coefficient (r2 value) for the two methods was 0.934. This indicates good agreement between biosensor readings and the laboratory results under the conditions of the vial measurements.

Figure 7b shows the biosensor results for vial measurements plotted against the laboratory GC/MS results. The one-to-one correlation line is shown as the dashed line. The 50% and 100% error lines represent the areas of the graph where points must fall to be within 50 and 100% of the one-to-one correlation.

Table 3 also presents the RPD values for the biosensor and laboratory analyses. The average RPD for nine vial samples was 45.6 %, with a range of 16.2 to 80.0%. This is greater than the RPD for the reference method (EPA Method 8260B for GC/MS) of 25%.

Table 3. Comparison of Biosensor and Laboratory (GC/MS) Measurements of 1,2-DCA Concentrations Along with Laboratory Data on Co-Contaminants in Each Well.

Well	Laboratory DCA (µg/L)	Biosensor DCA (µg/L)	RPD (%)	Aromatic VOCs (µg/L)	Chlorinated VOCs (µg/L)
8MW35	17	10	51.8	ND	18.4
8MW33	18	38	71.4	ND	55
8MW33	19	15	23.5	78	51
8MW33	18	36	66.7	77	52
MW-05	900	475	61.8	14,090	1,520
8MW49	730	610	17.9	40,460	730
8MW06	990	842	16.2	4,548	1,031
8MW25	<1	<27*	--	ND	ND
8MW03	6	14	80.0	ND	6
8MW47	600	483	21.6	38,100	600
8MW08	<20	<107*	--	9,780	58
Average			45.6		

* Unreliable delta V/pH (pho)

Table 4. Comparison of Biosensor and Laboratory (GC/MS) Measurements of 1,2-DCA Concentrations Along with Field Parameter Results for Sampled Groundwater.

Well	Laboratory DCA (µg/L)	Biosensor DCA (µg/L)	pH (S.U.)	ORP (mV)	DO (mg/L)	Specific Conductance (µS/cm)
8MW35	17	10	6.7	132	0.07	128
8MW33	18,19, 18	38, 15, 36	7.1	92	0.11	346
MW-05	900	475	6.5	-46	0.13	457
8MW25	<1	<27	6.6	22	1.11	131
8MW03	6	14	6.7	46	1.63	140
8MW47	600	483	6.7	-59	0.09	704
8MW08	<20	13	6.6	6	1.18	764

Table 3 data show that samples with high 1,2-DCA concentrations had high concentrations of aromatic VOCs (e.g., benzene). No correlation between aromatic VOC concentrations or chlorinated VOC concentrations and the RPD of laboratory and biosensor measurements was observed. This indicates that the biosensors were not affected by the presence of relatively high concentrations of these co-contaminants.

The vial measurement results indicate that at their current state of development, the biosensors would be appropriately used as a Level 1 instrument, providing semiquantitative screening concentration data.

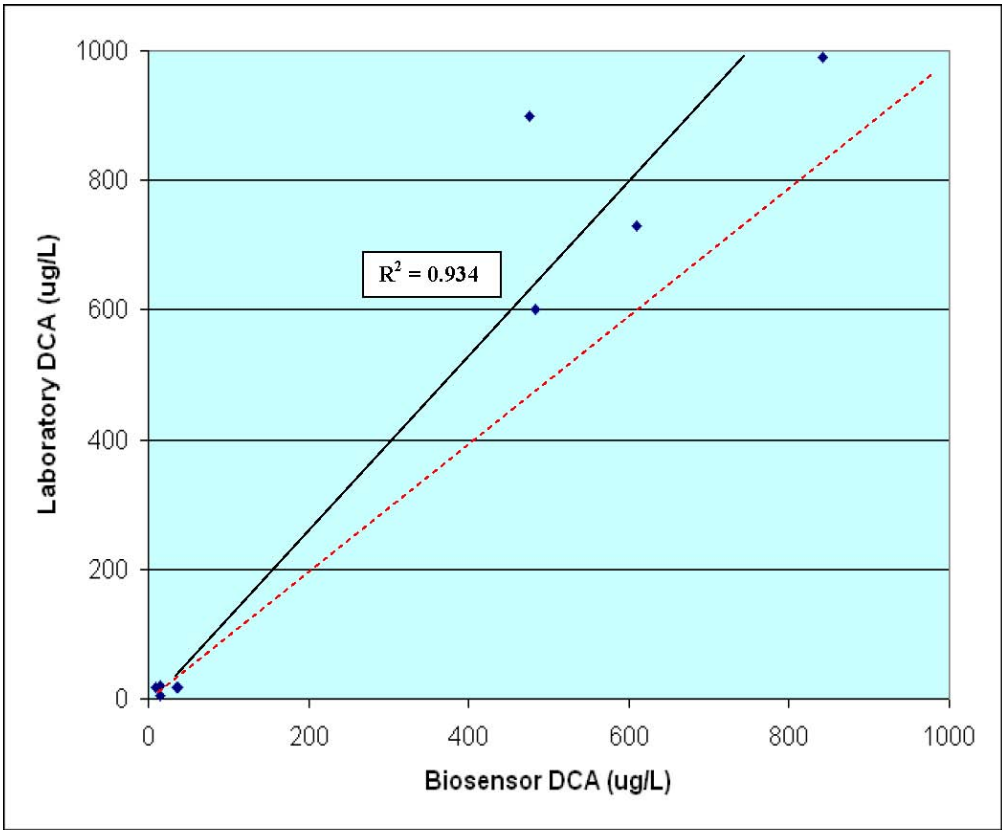

Figure 7a. Correlation Between Biosensor and Laboratory Results.
(Dashed line is the one-to-one correlation line.)

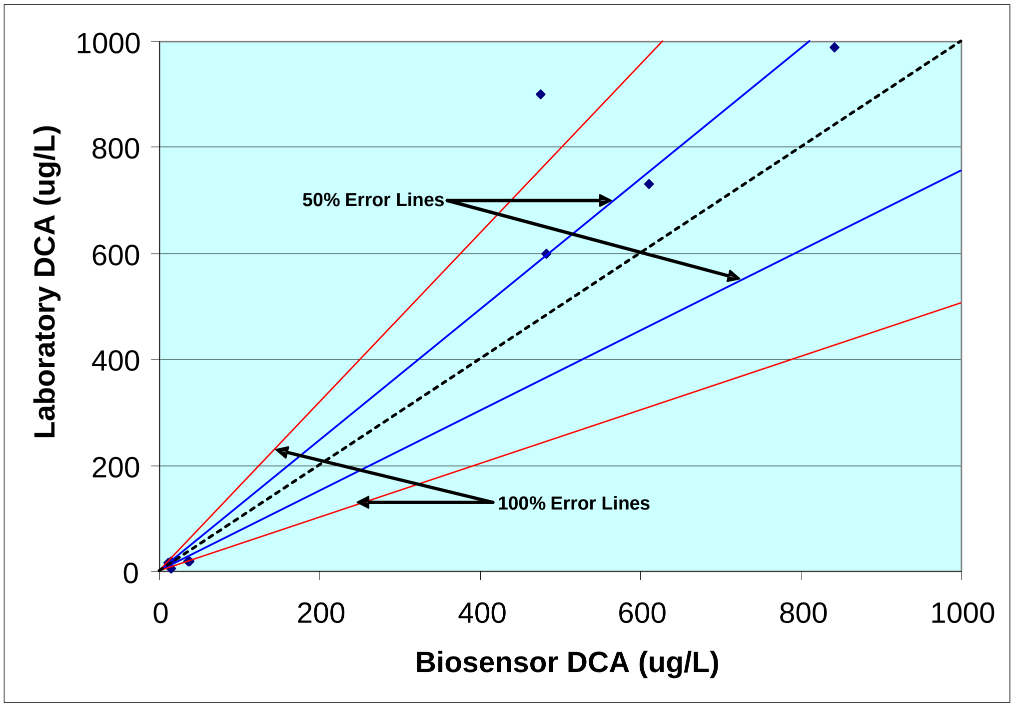

Figure 7b. Biosensor and Laboratory Results for Vial Samples Shown with Percent Error Lines.

4.3.2 Flow-Through Cell Measurements

Flow-through cell measurements were taken with the biosensors at two monitoring wells—8MW47 and 8MW33. Figure 8 shows the setup for taking biosensor readings in a flow-through cell. As biosensor readings were taken in the flow-through cell, measurements of pH, specific conductivity, temperature, ORP, and DO were also recorded.

8MW47

Figure 9 shows the flow-through cell setup at 8MW47. Figures 10, 11, and 12 show the flow-through cell biosensor readings plotted along with pH, ORP, and DO readings, respectively. Since flow-through cell measurements are frequently used to indicate when a well has been pumped sufficiently to allow for sampling of groundwater, it is of interest to note that the biosensor measurements were steady before ORP and at about the same time as DO and pH. The data in these three figures do not indicate a strong correlation between ORP or DO with the biosensor response (and none is expected). Since the biosensor signal is composed of a response to the analyte concentration as well as a response to the environmental pH, some correlation of the biosensor response with pH signal might be expected. This was not the case in the first 15 min of the test, suggesting that changes in analyte concentration were dominant during this period (recall that lower biosensor signal indicates increased analyte concentration). These two effects could be resolved by including a second optical fiber on the instrument for measurement of pH.

Figure 8. Flow-Through Cell Setup.

Figure 9. Flow-Through Cell Setup at 8MW47.

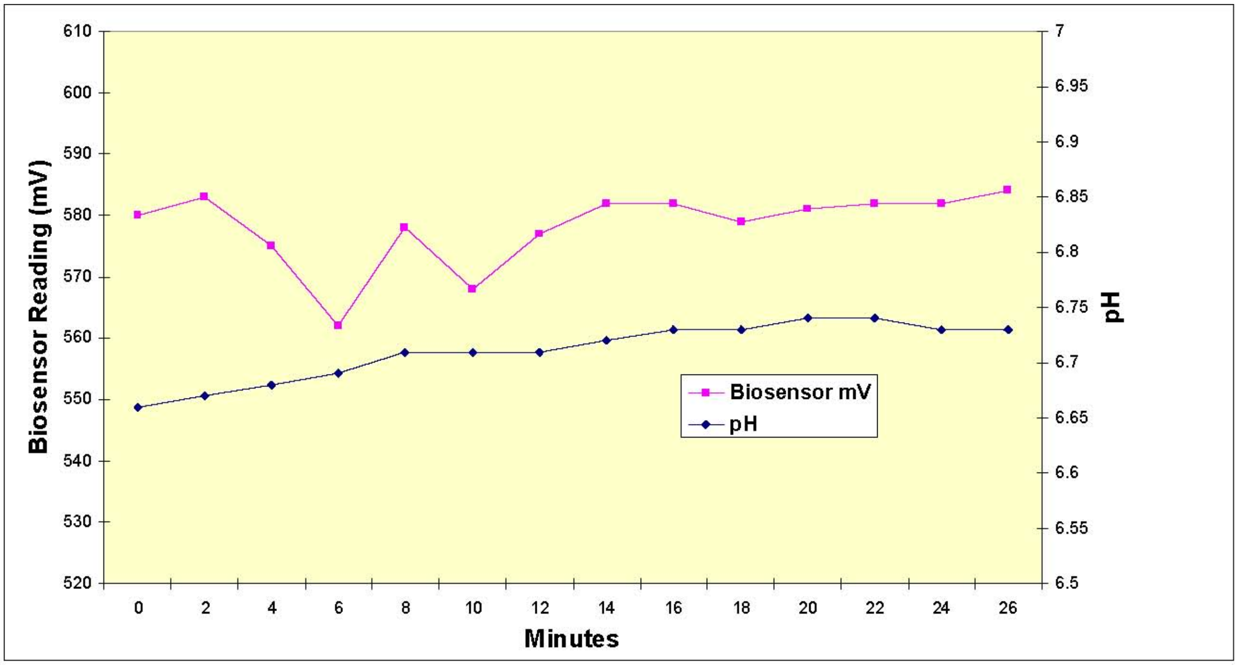

Figure 10. Flow-Through Cell Results at 8MW47—pH Versus Biosensor Readings.

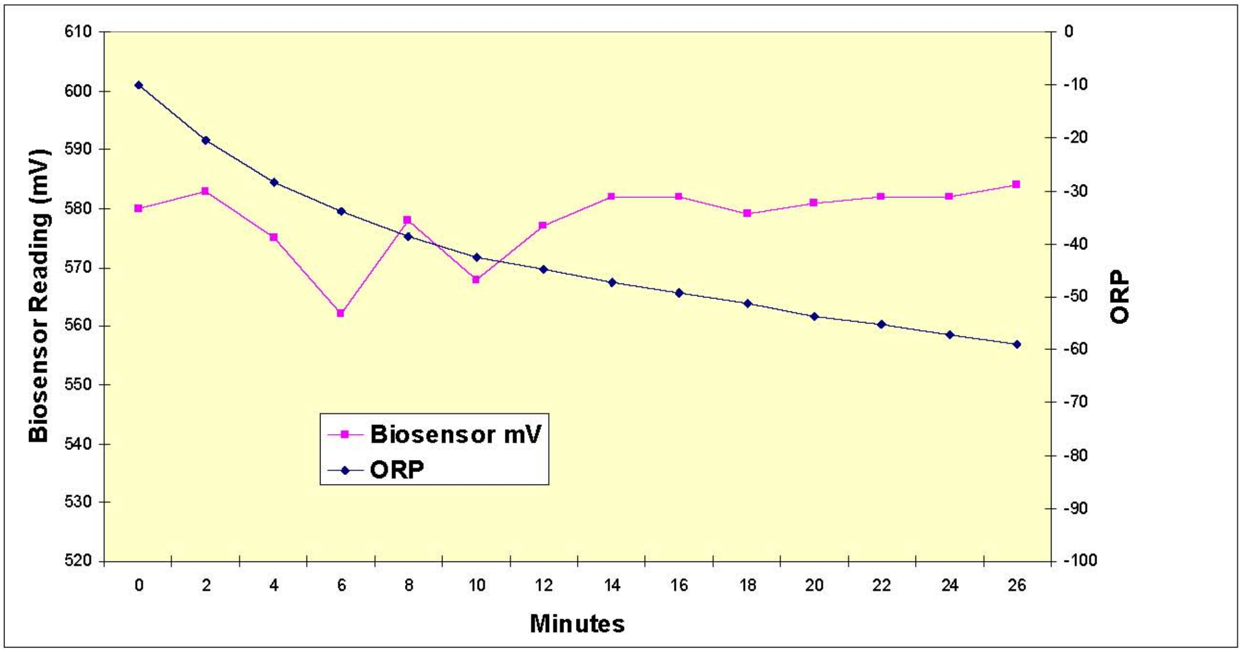

Figure 11. Flow-Through Cell Results at 8MW47—ORP Versus Biosensor Readings.

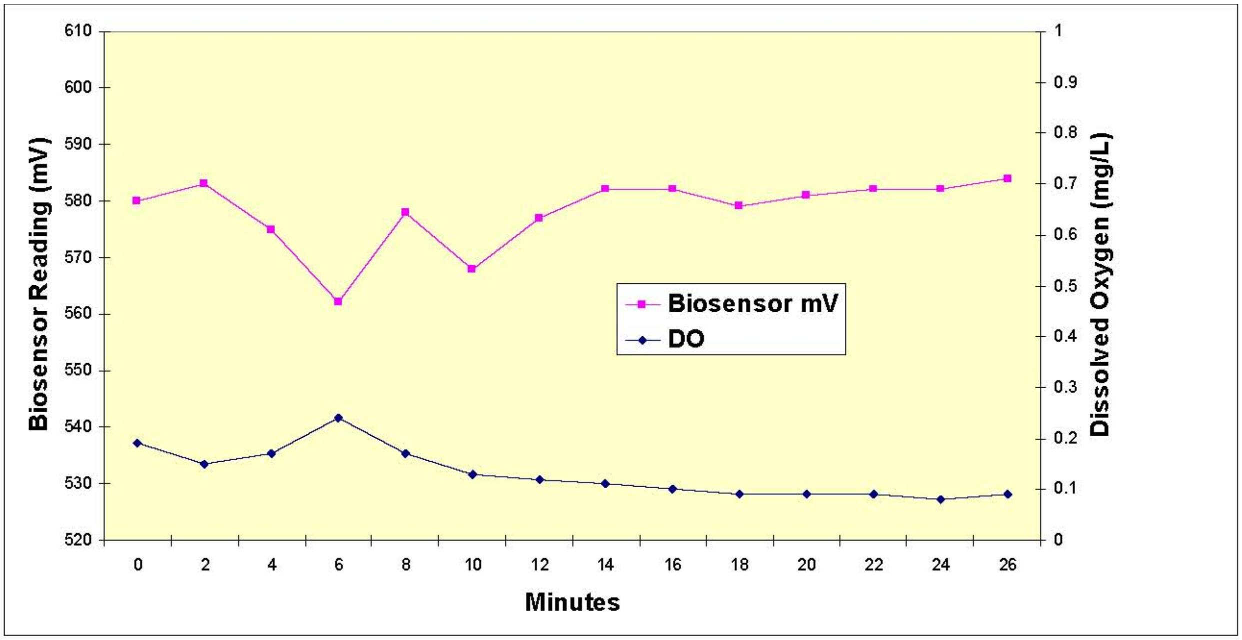

Figure 12. Flow-Through Cell Results at 8MW47—DO Versus Biosensor Readings.

8MW33

Figures 13 and 14 show the flow-through cell setup at 8MW33. Figures 15, 16, and 17 show the flow-through cell biosensor readings plotted along with pH, ORP, and DO readings, respectively. The results were similar to those obtained from 8MW47 in that the biosensor measurements did not correlate with ORP or DO. The influence of pH on the biosensor measurements can be noted when the two data sets are parallel (after approximately 15 min of pumping). However, in the initial phase of the experiment, the biosensor and pH measurements change at different rates, indicating that the biosensor measurements reached a steady value earlier. Inclusion of an optical pH measurement as a second channel on the biosensor instrument would allow analyte measurements to be separated from these environmental pH changes (not related directly to the analyte).

Overall, the results indicate that the biosensors can be used to determine when water quality during pumping and sampling has reached stable conditions. At these wells (at least 8MW33), the water could have been sampled earlier based on the stable biosensor readings. The results are classified as Level 1.

4.3.3 Down-Hole Profiling

A biosensor was placed in a protective sheath (Figure 18) to take measurements down hole for the purpose of defining the 1,2-DCA vertical profile within a monitoring well. This setup was lowered into well 8MW47 and readings were recorded at 2-ft intervals from the water table to the bottom of the screened zone. Measurements were also made at the same 2-ft intervals as the biosensor was raised from the bottom of the screen zone. The results were identical to those observed as the biosensor was lowered into the well. The results are shown in Figure 19, which shows measurements in millivolts because calibration procedures for a flow-through setup have not yet been developed to effectively translate millivolts readings to 1,2-DCA concentrations. Although a firm assessment of 1,2-DCA concentrations cannot be made without having an optical pH measurement at the same location as the biosensor, a preliminary evaluation of the data in Figure 19 suggests that the concentration of 1,2-DCA was highest at the surface, decreased over the next 5 ft until a layer of higher concentration was reached, then decreased again (recall from Figure 3 that higher 1,2-DCA concentrations lead to lower fluorescence measurements). Small amounts of light non-aqueous phase liquid (LNAPL) were encountered in this well, and thus it is possible that the high surface concentrations were caused by 1,2-DCA that was partitioned into the LNAPL. However, multidepth groundwater sampling would be needed to confirm these conclusions (i.e., determine the extent to which an increase in biosensor response was due to an increase in DCA concentration).

These biosensor readings may be among the first near-real-time readings to allow detection of varying low 1,2-DCA concentrations in groundwater with varying hydraulic conductivity in a vertical profile. The results clearly show that stratification within the screened interval occurs. Therefore, the typical pumped samples will depend on placement of the pump and the mixing of stratification that occurs. Development of a tool to measure stratification in situ is a significant advancement. The results are classified as Level 1 (no quantitative data were obtained). However, estimates of the changes in concentrations between the depths were made and the changes were significant.

Figure 13. Flow-Through Setup at 8MW33.

Figure 14. Flow-Through Cell Readout Setup.

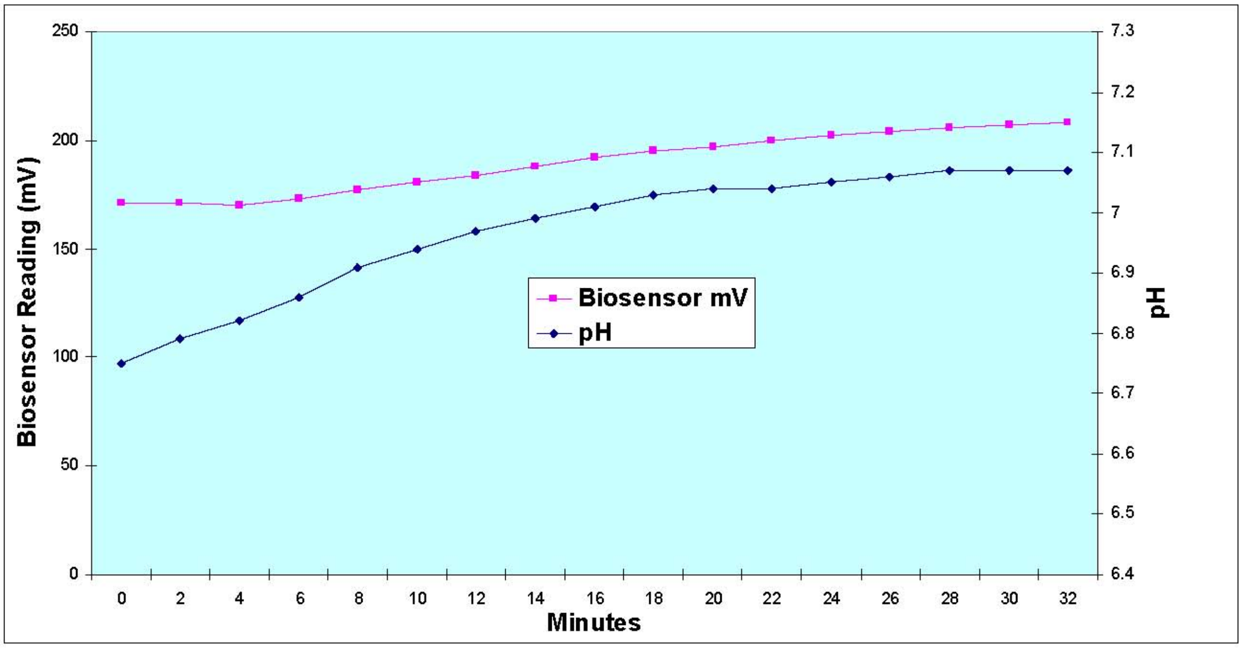

Figure 15. Flow-Through Cell Results at 8MW33—pH Versus Biosensor Readings.

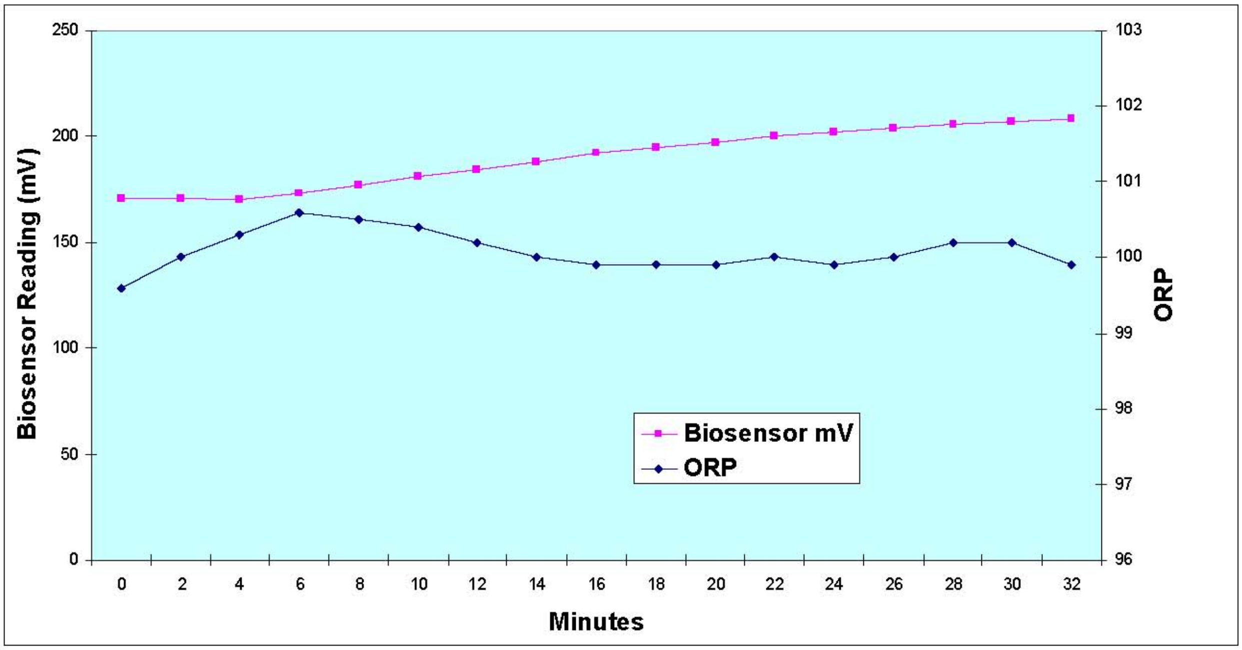

Figure 16. Flow-Through Cell Results at 8MW33—ORP Versus Biosensor Readings.

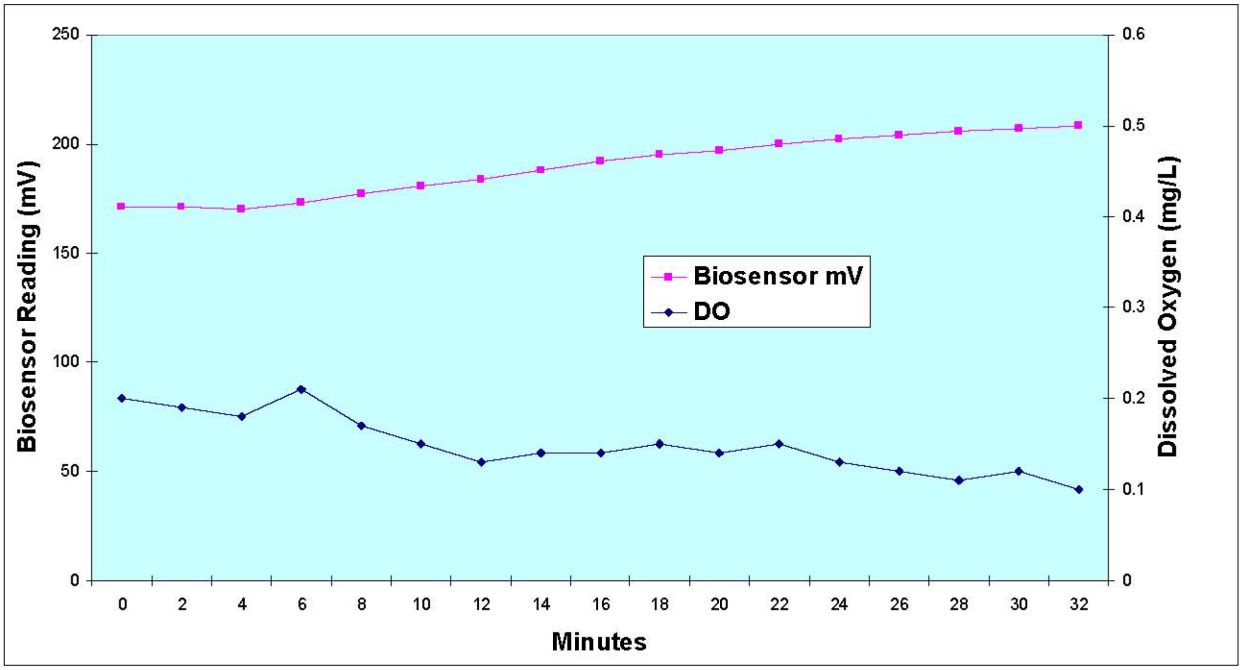

Figure 17. Flow-Through Cell Results at 8MW33—DO Versus Biosensor Readings.

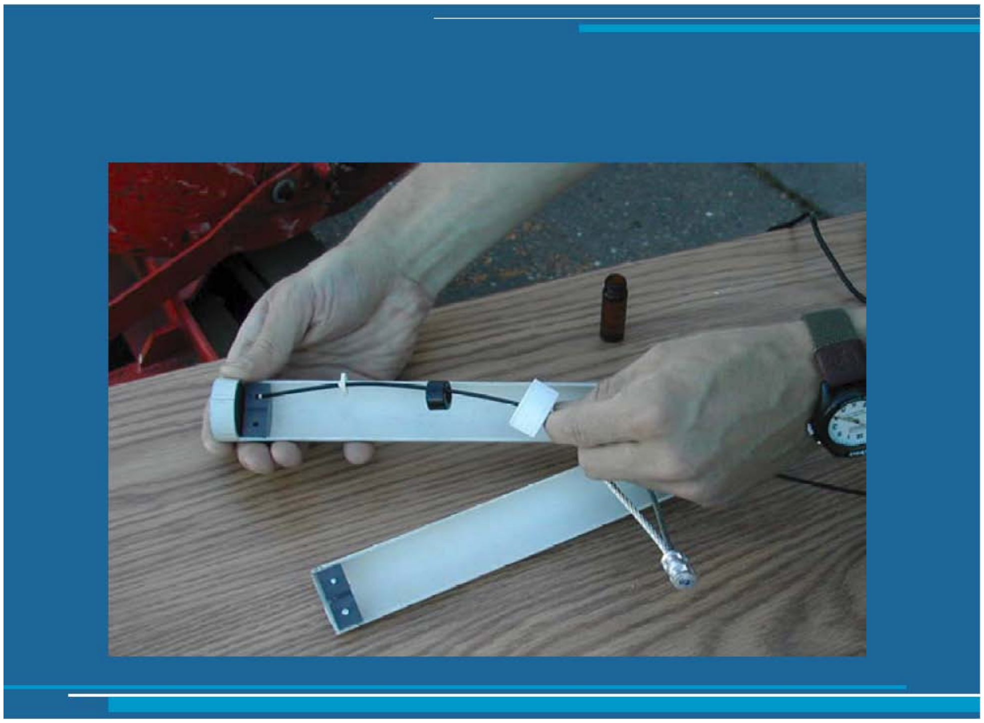

Figure 18. Down-Hole Profiling Setup.

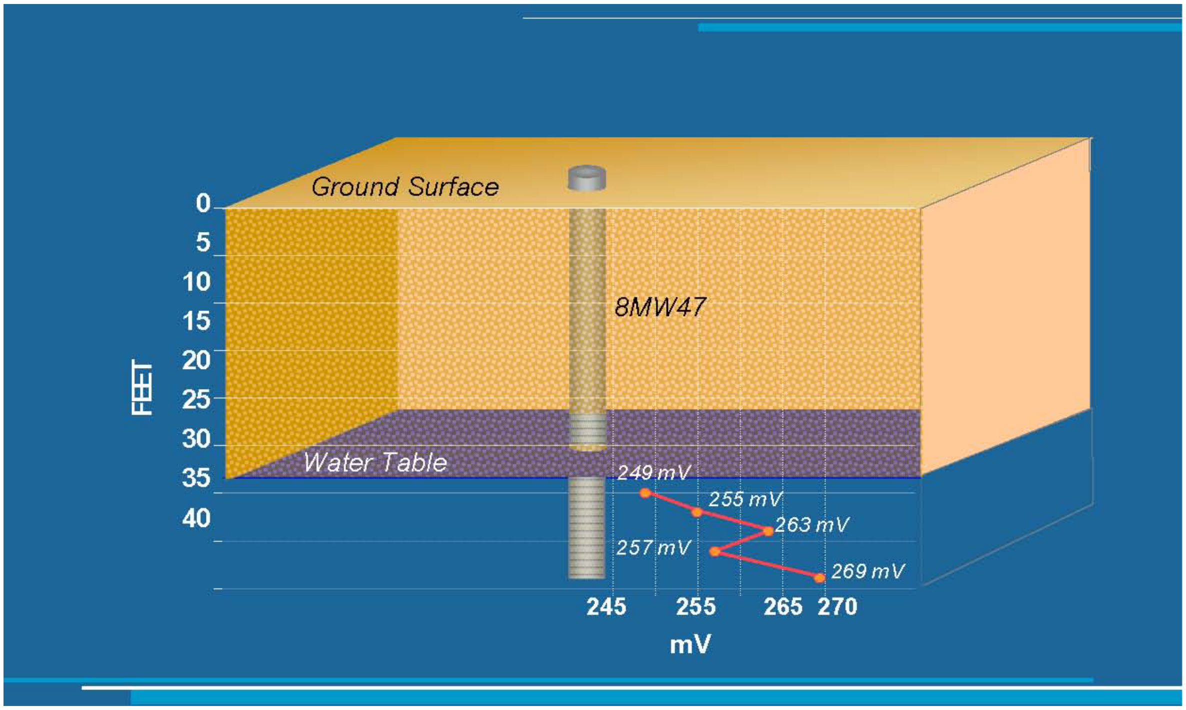

Figure 19. Down-Hole Profiling Results (biosensor readings versus depth).

4.3.4 Sentinel Well Measurements

A biosensor was placed down hole in the protective sheath used for down-hole profiling in monitoring well 8MW47 and was left in place for 24 hours. Periodically, readings were recorded by connecting the hardware to the biosensor. The results are shown in Figure 20. The biosensor signal decreased about 20% over the first 18 hours, and the signal was essentially constant from 15 to 18 hours. However, the biosensor output then dropped another 65% in the next 6 hours. Since the biosensors were shown to have significantly longer lifetimes in laboratory studies, the observed decline was expected to be caused by a factor other than loss of enzyme activity. Visual inspection of the tip of the biosensor after 24 hours down hole indicated the alginate layer containing the bacteria (and enzyme) had become detached from the tip. If the biosensors are to be used in a down-hole mode, then the biosensor tips need to be stabilized to allow for long-term immersion in groundwater. This can be accomplished by cross-linking the alginate polymer or by choosing a different immobilization matrix.

4.4 TECHNOLOGY COMPARISON

In general, the biosensors functioned as Level 1 measurement devices and provided measurements that were not impacted by the presence of other groundwater contaminants. When used in flow-through cells and for vertical profiling, the biosensors produced significant data that were not readily available by other means. Three factors that limit the performance and utility of this measurement technology must be addressed:

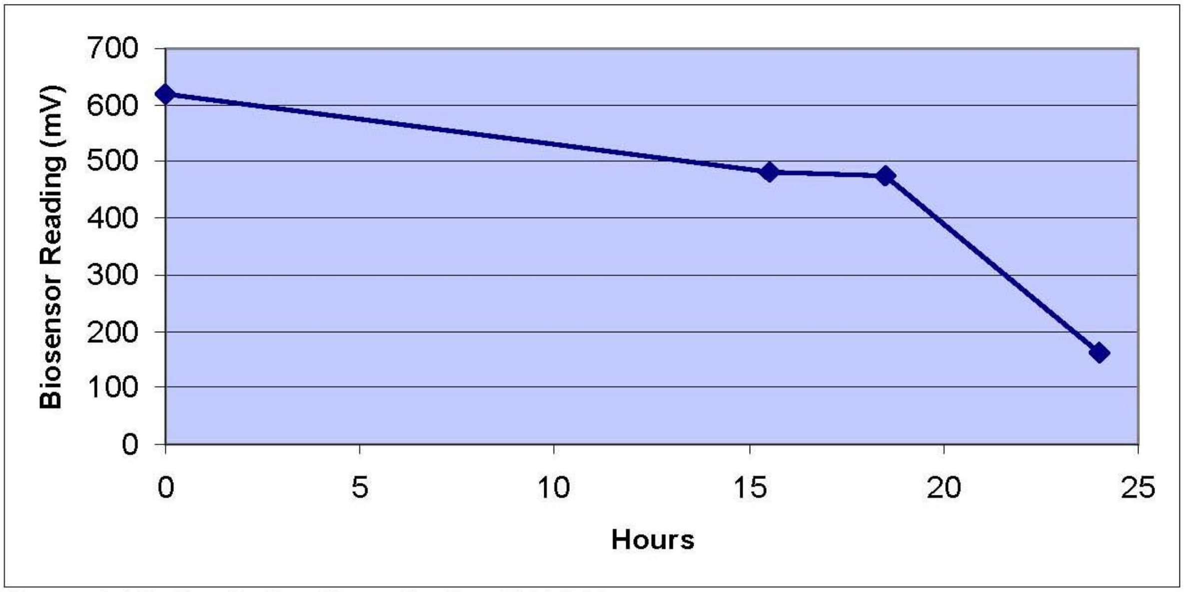

Figure 20. Sentinel Well Results for 8MW47.

1. **The influence of pH on the biosensor measurement**. Because the biosensor measures small pH changes produced by the reaction of an enzyme with 1,2-DCA, methods are required to distinguish these pH changes from pH changes due to other processes. This can readily be accomplished by adding an optical fiber (bundled with the biosensor) and a second measurement channel to the hardware, thus providing optical pH measurement for correction of the pH changes.
2. **Calibration procedures**. An adequate calibration procedure has been developed for vial measurements; however, calibration procedures must still be developed for flow-through cell and down-hole measurements.
3. **Robustness**. The biosensor tips should be designed to be more durable. Methods to do this (e.g., cross-linking the alginate layer) have been tested in the laboratory and appear to be feasible.

The biosensors can be used to collect Level 2 data when used in the vial measurement mode; however, further investigation into development and testing of the biosensors is required for them to be reliable field instruments for all the applications originally intended.

5.0 COST ASSESSMENT

5.1 COST REPORTING

Given the developmental requirements of the biosensors before they can be commercialized and being at ESTCP's direction, no costs for their use have been developed at this time.

After further development, the potential benefits of using biosensors in groundwater monitoring can be assessed by comparing costs associated with biosensor use with conventional monitoring methods (i.e., laboratory methods similar to EPA Method 8260B) on a per well basis as well as on a sampling event basis.

The primary cost driver for the biosensor technology is the capital cost of the optical-electronic system that includes the light source and detection units. Although the cost of this unit is currently approximately $5,000, the figure is for custom construction. If manufactured commercially, the price would be substantially lower.

One cost issue with biosensors is the length of time a biosensor tip will last during regular use. To date, biosensor tips have been prepared with very good activity retention over 10 days, and further improvements are anticipated. However, the biosensor tips themselves are inexpensive to prepare and thus should not be costly to purchase. Installation of new tips and disposal of old ones is not labor-intensive. Recalibration must be done periodically, regardless of whether a new tip has been installed or an old tip is being used in a new location.

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6.0 IMPLEMENTATION ISSUES

6.1 COST OBSERVATIONS

As noted above, no costs for the biosensors' use have been developed at this time.

6.2 PERFORMANCE OBSERVATIONS

These demonstrations showed that, while the biosensors are not yet ready for commercialization, with further development they can be valuable tools for providing accurate field analyses.

6.3 SCALE-UP

Scale-up is not an issue for the biosensors.

6.4 OTHER SIGNIFICANT OBSERVATIONS

There are no other significant observations regarding the biosensors at this time.

6.5 LESSONS LEARNED

This demonstration showed that, while the biosensors are not yet ready for commercialization, with further development they can be a valuable tool for providing accurate field analyses of several groundwater contaminants. This further development needs to focus on:

- Improving calibration methods to increase accuracy and precision
- Improving field usability
- Adding multichannel capability to hardware to facilitate calibration and analyze multiple compounds.

6.6 END-USER ISSUES

Potential end-user issues that exist for the use of biosensors for groundwater monitoring include:

- Is the instrument easy to use?
- Is calibration an easy process?
- Are the results accurate and repeatable for conditions at the site?
- What is the detection limit and does it change with changing conditions?
- Can biosensors detect other and/or multiple compounds?

The demonstration was designed to address each of these issues. Ease of use and calibration procedures were documented. The evaluation criteria that have been presented for comparing biosensor and conventional laboratory method results address accuracy, interference, and detection limit issues.

After the required additional development, procurement of the biosensor technology is expected to be straightforward. Although CSU is pursuing patent protection for this technology being done for the purpose of providing incentive for an equipment manufacturer that would require intellectual property protection to commercialize the device (Patent application, Reardon, and Das, 2001). The goal is to license the patent to such a company, which would then manufacture the biosensors commercially with no restrictions; i.e., the biosensors would be available to DoD and remediation professionals similar to oxygen and pH sensors.

Also, the long-term performance of this sensor technology is an important factor for its commercialization. Although this performance characteristic was not within the scope of this demonstration, we have evidence from laboratory tests that storage lifetimes of at least 50 days are possible with less than 10% loss in sensitivity. If sensitivity loss is limited to the same low rate when the biosensors are in frequent or continual use, this would mean that recalibration would need to occur only weekly in the vial or depth profiling measurement modes. For down-hole monitoring, that rate of sensitivity loss would mean that the biosensors would need to be recalibrated every 50 days to retain accuracy within 10%. However, if only semiquantitative or presence/absence signals are required, recalibration could occur much less frequently. Future research could target this aspect of the biosensor performance. Once the causes of sensitivity loss (e.g., enzyme leakage from the biosensor tip, enzyme degradation, fluorophore bleaching) are evaluated, the appropriate redesign could take place.

6.7 APPROACH TO REGULATORY COMPLIANCE AND ACCEPTANCE

Comparison of the biosensor results to conventional results will be necessary to obtain regulatory approval of biosensor use. With respect to execution of the demonstration, minimal regulatory involvement was needed since this was a demonstration of analytical technology and not of a remediation technology.

7.0 REFERENCES

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Reardon, K.F., and N. Das. 2001. Optical Biosensor with Enhanced Activity Retention for Detection of Halogenated Organic Compounds. Provisional patent application.

Reardon, K.F., D.W. Campbell, and C. Müller. Biosensor for Halogenated Hydrocarbons. Provisional patent application 60/099,890. 1998.

Environmental Security Technology Certification Program
(ESTCP)

Final Report
Fiber Optic Biosensors for Contaminant Monitoring
ESTCP Project Number ER-0115

December 2005

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Acronyms

μg/L	microgram per liter
1,1,2-TCA	1,1,2-trichloroethane
1,2-DCA	1,2-dichloroethane
bgs	below ground surface
CDM	Camp Dresser & McKee Inc.
CSU	Colorado State University
DCM	dichloromethane
DoD	Department of Defense
EDB	ethylene dibromide
EPA	U.S. Environmental Protection Agency
ESTCP	Environmental Security Technology Certification Program
LNAPL	light non-aqueous phase liquid
M	molar
mL	milliliter
mm	millimeter
mM	micromolar
nm	nanomolar
OU 8	Operable Unit 8
PWIA	Public Works Industrial Area
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
Qva	Vashon Advance Outwash
Qvt	Vashon Till
RPD	relative percent difference
SUBASE Bangor	Bangor Naval Submarine Base, Washington
TCE	trichloroethene
UST	underground storage tank
VOA	volatile organic analyte
VOC	volatile organic compound

Preface

This report describes the demonstration of a novel analytical technology: fiber optic-based biosensors for detecting groundwater contaminants in the field in near-real time. The report describes the demonstration of biosensors at a Department of Defense (DoD) site as well as supplemental development of additional biosensors.

Several individuals and organizations contributed to completion of this project and are listed below:

Ken Reardon, Ph. D.	Colorado State University (CSU)
Victor Acha	CSU
Brinson Willis	CSU
Cory Jenson	CSU
Roger Olsen, Ph.D. (PI)	Camp Dresser & McKee Inc. (CDM)
John Eisenbeis, Ph.D.	CDM
Kristy Warren	CDM
Dan Adams	CDM
Michael Allen	SUBASE Bangor (now with CDM)
Barb Chafin-Tissier	SUBASE Bangor

Fiber Optic Biosensor Demonstration
(ESTCP Project Number CU-0115)

Executive Summary

Significant costs are associated with laboratory analyses of groundwater samples collected at Department of Defense (DoD) sites. The majority of these samples are needed to characterize the nature and extent of contamination at a site, evaluate remedial system performance and track contaminant plume migration via regularly scheduled monitoring events. A need exists to replace laboratory analyses with reliable, easy-to-use field methods that produce real time results. Colorado State University (CSU) has developed fiber optic biosensors that are ideally suited for field monitoring of groundwater contaminants. Generally, a biosensor is a device that utilizes a biological recognition element (typically enzymes or antibodies) to sense the presence of an analyte and create a response that is converted by a transducer to an electrical or optical signal.

The primary issue regarding the use of biosensors is reliability (i.e., are biosensor results comparable to laboratory analyses?). The end-user also needs to know whether there are conditions that affect the reliability of biosensor performance. Lastly, biosensors need to be easy to use and calibrate so that reproducible results can be obtained from different users. The demonstration described in this document was designed to address these issues. The overall objective of the biosensor demonstration was to provide a basis to justify the use of biosensors to augment or replace conventional analytical methods for measuring selected compounds in groundwater. Specific objectives included:

- Demonstrate the accuracy, reliability and cost of biosensors
- Demonstrate the effectiveness of on-site field measurements using biosensors
- Determine operational limits associated with using the biosensors
- Transfer the biosensor technology to end-users

Biosensors were used to analyze groundwater sampled from several monitoring wells at Operable Unit 8 (OU 8) of the Naval Submarine Base in Kipsap County, Washington (SUBASE Bangor) to evaluate biosensor performance under a range of conditions. The target analyte was 1, 2-dichloroethane (1,2-DCA). Groundwater samples were collected from monitoring wells spaced throughout the plume to analyze a wide range of 1,2-DCA and co-contaminant concentrations. Groundwater samples were analyzed by biosensors and gas chromatography/ mass spectroscopy (GC/MS). A flow-through cell was also set up to allow biosensor readings in flowing water similar to the setup typically used to collect pH, conductivity and turbidity readings prior to monitoring well sampling. Lastly, biosensors were lowered into monitoring wells to record down hole *in situ* readings.

Performance of the biosensors was evaluated based on the following criteria:

- **Accuracy** as demonstrated by a one-to-one correlation between the two analytical techniques (conventional GC/MS and biosensors).
- **Range** as demonstrated by a response from less than 5 µg/L to greater than 500 µg /L 1,2-DCA.
- **Precision** as demonstrated by a low relative percent difference (RPD) between duplicate analyses.
- **Sample throughput** as demonstrated by short analysis time in the field
- **Mechanical reliability** as demonstrated by a low incidence of failure.
- **Versatility** as demonstrated by acceptable performance under a variety of conditions.

Two performance levels were established with regard to the data that the biosensors might be used to collect:

Level 1: Semi-quantitative screening concentration data
Moderate accuracy
Moderate quantitation limit
Moderate specificity and selectivity

Level 2: Quantitative concentration data
High accuracy
Low quantitation limit
High specificity and selectivity

The interference of parameters affecting the pH of the groundwater being measured impacted how the biosensor performed against several performance criteria, including accuracy, precision, sensitivity, and range. This is because the biosensor measures small pH changes produced by the reaction of an enzyme with 1,2-DCA and techniques are required to distinguish these pH changes from pH changes due to other processes. For vial measurements, this interference can be significantly reduced by proper calibration. However, for flow-through cell and down-hole measurements, calibration procedures have not been developed to reduce the pH interference. At the present level of development, the biosensors would most appropriately be used to provide semi-quantitative data regarding 1,2-DCA concentrations in groundwater.

The biosensors can be used to collect Level 2, quantitative data when used in the vial measurement mode; however, further investigation into development and testing of the biosensors is required for them to be reliable field instruments for all of the applications originally intended.

1.0 Introduction

1.1 Background

Significant costs are associated with laboratory analyses of groundwater samples collected at Department of Defense (DoD) sites. The majority of these samples are needed to characterize the nature and extent of contamination at a site, evaluate remedial system performance and track contaminant plume migration via regularly scheduled monitoring events. A need exists to replace laboratory analyses with reliable, easy-to-use field methods that produce real time results. Colorado State University (CSU) has developed fiber optic biosensors that are ideally suited for field monitoring of groundwater contaminants. Generally, a biosensor is a device that utilizes a biological recognition element (typically enzymes or antibodies) to sense the presence of an analyte and create a response that is converted by a transducer to an electrical or optical signal.

Use of biosensors at DoD sites would provide a cost effective user-friendly approach for providing accurate contaminant analyses at low microgram per liter (µg/L) levels. In addition, biosensors would allow for *in situ* vertical profiling of contaminant concentrations within a monitoring well. This information would be valuable for identifying depth intervals that are primary migration pathways for contaminants.

1.2 Objectives of the Demonstration

The overall objective of the demonstration was to provide a basis to justify the use of biosensors to augment, or in some cases replace, the use of conventional analytical methods for measuring some compounds in groundwater.

Specific objectives of the field demonstration included:

- Demonstrate the accuracy, reliability and cost of biosensor
- Demonstrate the effectiveness of on-site field measurements using biosensors
- Determine operational limits associated with using the biosensors
- Transfer the biosensor technology to end-users

1.3 Regulatory Drivers

At most DoD sites a regulatory requirement exists to monitor groundwater quality before, during and after implementation of a remedial system. This requirement coupled with the number and average size of DoD sites results in a significant number of groundwater samples that are collected for laboratory analyses. A significant cost savings could be realized if a field method of analysis that provides real time results could be used in place of some of these analyses.

1.4 Stakeholder/End-User Issues

The primary issue regarding the use of biosensors is reliability (i.e., are biosensor results comparable to laboratory analyses?) The end-user also needs to know whether there are conditions that affect the reliability of biosensor performance. Lastly, biosensors need to be easy to use and calibrate so that reproducible results can be obtained from different users. The demonstration discussed in this document was designed to address these issues.

2.0 Technology Description

2.1 Technology Development and Application

2.1.1 Description of Biosensor

The CSU biosensor is a two-layer detection element immobilized on the tip of an optical fiber (Figures 2-1 and 2-2). The outer layer of the detection element contains bacteria with an enzyme that catalyzes a reaction with the analyte resulting in protons being released. The inner detection layer contains a pH-sensitive fluorescent dye (fluoresceinamine). Thus, the presence of the contaminant leads to a pH change on the fiber tip, which can be measured as a change in fluorescence intensity (Figure 2-3). Since the change in fluorescence depends on the contaminant concentration, these optical, enzymatic biosensors provide quantitative output.

Many enzymes catalyze reactions that result in a pH change. CSU researchers have worked primarily with the class of enzymes known as hydrolytic dehalogenases, which catalyze the introduction of water into a halogenated organic compound with the production of a hydrohalide (e.g., hydrochloric acid) (Figure 2-4). However, a biosensor based on organophosphorous hydrolase has also been developed to detect members of the organophosphorous family (which includes many nerve agents).

One of the advantages of fiber optic sensors is their small size, typically about 1 millimeter (mm) in diameter (Figure 2-5). These optical sensors can be used at much longer distances than electronic sensors because signal loss in optical fibers is extremely low. In the field, the fiber optic biosensors can be lowered into a small well (e.g., Geoprobe well) for measurement.

Research on this biosensor concept began at CSU in 1995 and the viability of the sensor concept was first demonstrated in 1996 with development of a biosensor for 1,2-DCA. Research from 1996 to 1998 focused on a biosensor for EDB and characterization of the detection limits, stability, and effects of interfering chemicals for that biosensor. From 1998-2000, research was directed at the development of a biosensor for atrazine and the extension of the usable lifetime of the biosensor. During this period, the first soil column tests were also performed. Since 2000, a focus of the development work has been the refinement of the optical hardware and improving aspects of the system that will lead to increased sensitivity and robustness of the biosensor technology.

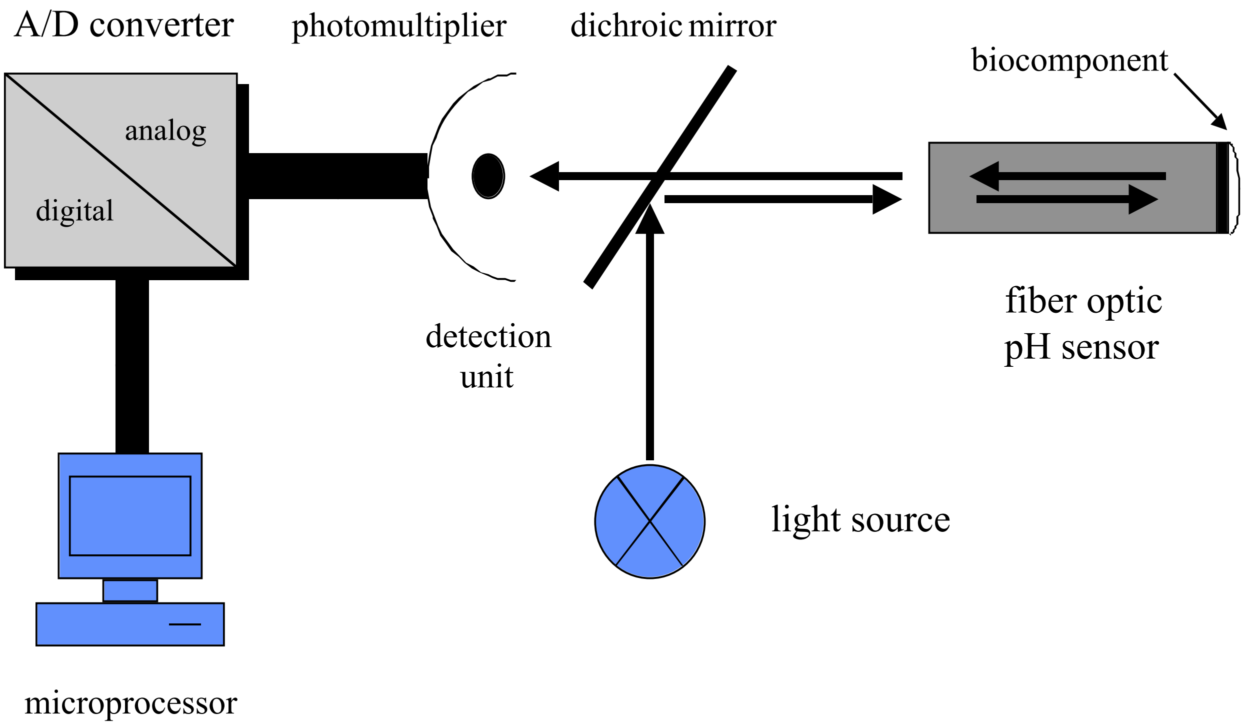


Figure 2-1. Schematic of the fiber optic biosensor system.

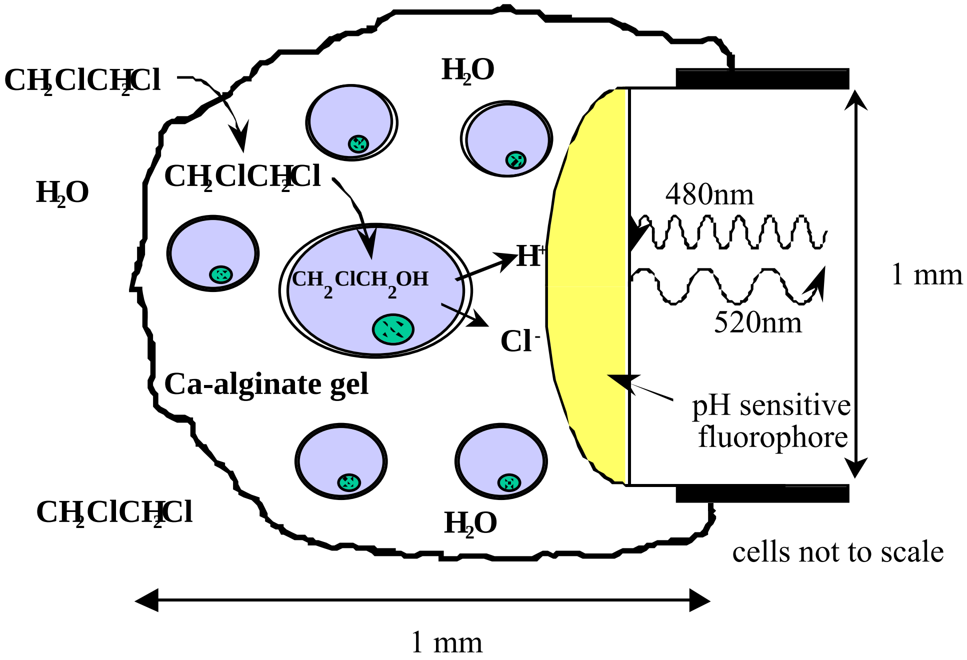


Figure 2-2. Schematic of the 2-layer detection element of the CSU biosensor, illustrated for the ethylene dibromide biosensor. The pH-sensitive fluorophore is excited with 480-nm light and emits fluorescence at 520 nm, which is transmitted along the optical fiber to a photomultiplier.

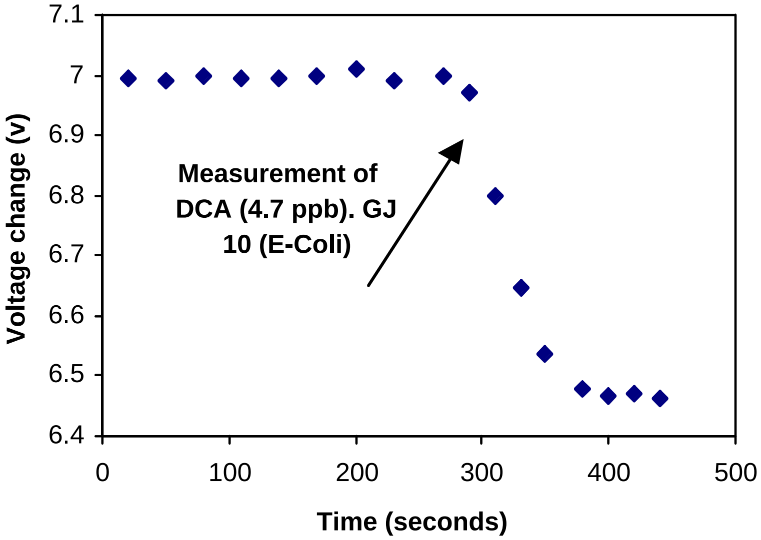


Figure 2-3. Biosensor response (as photomultiplier voltage change) following a change in analyte concentration.

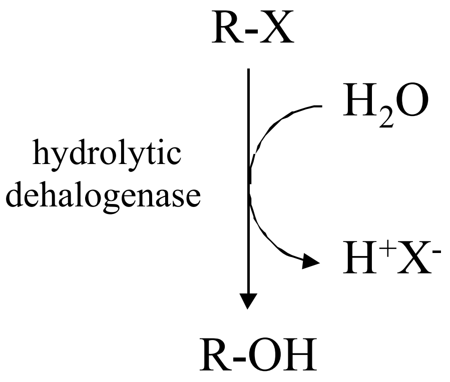


Figure 2-4. Reactions catalyzed by hydrolytic dehalogenases produce protons which change the pH of the environment near the enzyme.

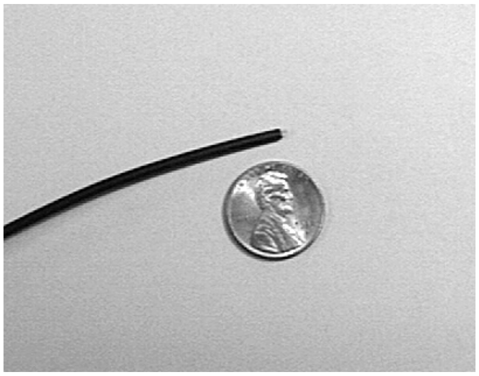


Figure 2-5. Photograph of a fiber optic biosensor; the functional tip with immobilized pH indicator and cells is directly over the coin.

2.1.2 Technology Development

2.1.2.1 Biosensor Construction Protocols

Standard method

Biosensors consist of a layer of calcium-alginate-entrapped cells or purified enzymes, in direct contact with a layer of a pH-sensitive fluorophore immobilized on one end of an optical fiber (Figure 2-6). Optical fibers coated only with fluorophore are termed pH optodes. To prepare these pH optodes, the cladding of fibers was removed from 1 mm of the distal end of the optical fiber, and then polished with very fine grit paper. A pH-sensitive fluorophore was affixed to the distal end of the fiber optic cable. The fluorophore, fluoresceinamine, was first coupled to polyvinyl alcohol (PVA) using cyanuric chloride, and the resulting product was cross-linked with glutaraldehyde in presence of HCl to form a hydrogel that was applied subsequently to the polished optical fiber tip by using a micropipette. After polymerization, the resulting pH optode was stored in 0.1 M Na_2HPO_4 at room temperature.

Figure 2-6. Fiber optic biosensor. One end of the optical fiber is coated by a pH-sensitive fluorophore which in turn is covered by cells or enzymes entrapped in Ca-alginate.

Two types of biosensors were developed and tested. The large majority of tests, including all field tests, were performed with biosensors in which the dehalogenase enzymes (the biocomponent) were immobilized within intact cells, taken directly from a cultivation. To prepare the second type of biosensor, these cells were disrupted and the dehalogenase enzyme removed and purified; only pure enzyme was immobilized on the tip of the biosensor. This purified enzyme biosensor was constructed to determine whether it would have advantages in terms of sensitivity, response time, and specificity.

Whole cell biosensors were created by entrapping a small amount of concentrated cells in a calcium alginate hydrogel on the fluorophore end of a pH optode. Previously cultured cells were combined with a 4% sodium alginate solution to give a mixture at a desired ratio. Five microliters of this gel mixture were deposited on the end of a pH optode. The resulting biosensor was immediately immersed in ice-cold 0.47 M $CaCl_2$ for 30 minutes, placed into a buffered measurement solution (BMS) [1mM beta-morpholino-ethansulfonic acid monohydrate (MES) + 25 Mm $CaCl_2$ + 150 mM NaCl] and stored at 4°C.

Enzyme biosensors were created by entrapping pure enzymes in a calcium alginate hydrogel on the fluorophore end of a pH optode. Enzymes were previously isolated from cells by a special procedure consisting of disrupting fresh cells by sonication to get a cell-free extract that is purified on a Ni-nitrilotriacetic acid Sepharose column HR 16/10. The pure enzymes were combined with 4% sodium alginate solution to give a mixture at a desired ratio. The subsequent steps to create an enzyme biosensor are similar to those for preparation of whole cell biosensors.

Glutaraldehyde cross-linking

Biosensors were treated with the cross-linking agent glutaraldehyde to improve their physical stability. Biosensors were suspended in 6 M glutaraldehyde for 30 min at room temperature with stirring. The treated biosensors were washed with deionized water and stored at 4^{o}C in measurement solution until used.

The treatment improved the stability of biosensors, but lowered the diffusion of analyte and product in and out of the gel matrix, resulting in a slight decrease in the sensitivity of the biosensors.

Fluorophore performance

The performance of the pH-sensitive fluorophore was studied by depositing different amounts of cross-linked fluorophore on the tip of optical fibers (Figure 2-7). The response of the pH optode ($\Delta V/\Delta pH$) increased linearly with amounts of PVA-immobilized fluorophore less than 37.5 mg but was constant at higher amounts (Figure 2-7). Depositing large amounts of fluorophore (and polymer) on pH optode tips was found to decrease the sensor response time. Therefore, pH optodes with 37.5 mg of fluorophore were used subsequently for optimal biosensor response. The sensitivity of pH optodes was expressed per pH unit change as determined by testing in 1 mM MES solutions at pH values of 6.8 and pH 6.7 ($\Delta pH = 0.1$).

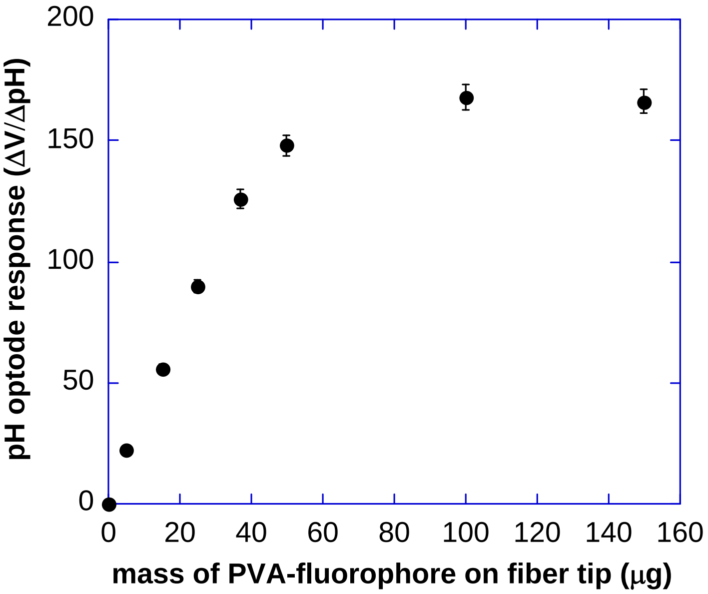


Figure 2-7. Response of pH optodes with different masses of immobilized polymer-fluorophore preparation. Each point is the average of three measurements; error bars represent one standard deviation.

Cells on the biosensor

The effect of the cell concentration in the Ca-alginate layer of the biosensors was also investigated. As a test case, *E. coli* cells expressing atrazine chlorohydrolase (AtzA) were combined with Ca-alginate hydrogel in different ratios. Figure 2-8 shows the biosensor response to atrazine (15.5 μg/L) as a function of the percent of cells in the Ca-alginate layer at the optical fiber tip. As the biocomponent concentration was increased from 10 to 85% – decreasing the Ca-alginate concentration from 90 to 15%, respectively – the biosensor response (DV) increased proportionally. Cells at 90% in Ca-alginate or at higher percent did not remain affixed to the fiber tip. Cells at 67% in Ca-alginate were used subsequently to ensure a good attachment of cells to the tip of the pH optode as well as high sensitivities.

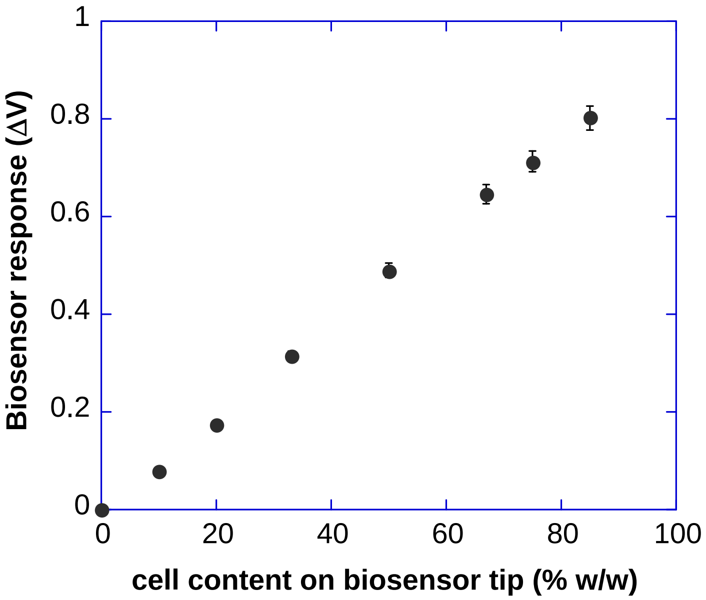


Figure 2-8. Biosensor response to atrazine (15.5 ppb) at different levels of *E. coli* DH5a pMD4 cells immobilized in Ca-alginate. Cells prepared at different percents in Ca-alginate were affixed to the tip of a pH optode that had a sensitivity of 25 V/pH. Each point is the average of three measurements; error bars represent one standard deviation.

2.1.2.2. Biosensor measurement protocols

Standard vial measurements

Biosensor experiments were performed in a 4.85-mL vial containing BMS at pH 7. The vial was covered with black tape to prevent interference by external light. To obtain a desired concentration of analyte in the vial, a known volume of analyte standard solution prepared in BMS at pH 7 was added to the vial using a syringe. The increase in analyte concentration resulted in a pH decrease at the biosensor tip and therefore a decrease in fluorescence intensity, recorded as a voltage decrease from the instrument photomultiplier tube (PMT). This response (voltage change, DV) could be related to the analyte concentration change in the vial. Continuous stirring in the vial ensured complete mixing. Control tests were conducted using a biosensor containing only Ca-alginate (no cells), using biosensors made with *E. coli* TG1 cells that cannot transform the tested analytes, and injecting analyte-free BMS into the vial.

pH correction

Since the biosensor measurements are based on pH changes, it is necessary to make sure that the measurement is based on the interaction of enzymes with the analyte and not by other effects (such as pH variation between the pH of the matrix and that of the analyte standard or the sample injected in the vial).

For a biosensor measurement in an aqueous matrix of unknown pH, an observed response (fluorescence intensity change recorded as PMT voltage change) can be expressed as:

$$R_{EB,obs} = R_{EB}^{*} + R_{EB,pH}$$

where $R_{EB,obs}$ is the observed response of the biosensor; R_{EB}^{*} is the response of a biosensor that is directly due to the dehalogenation of the analyte; and $R_{EB,pH}$ is the response of the biosensor that is due to a pH change in the measurement solution caused by the addition of a standard or analyte at a different pH.

$R_{EB,pH}$ was determined using information from a pH optode measurement in the same matrix. Since the pH optode does not measure analyte concentrations, the observed signal is:

$$R_{opt,obs} = R_{opt,pH}$$

Where $R_{opt,obs}$ is the observed response of the pH optode and $R_{opt,pH}$ is the response due to any solution pH change. The sensitivities of pH optodes and biosensors are not the same and must be calibrated by measuring their responses to identical pH changes (e.g., HCl in BMS). From this, the pH response ratio K_{pH} is determined as:

$$K_{pH} = R_{opt,pH} / R_{EB,pH}$$

Thus, the procedure for making pH corrections using a biosensor/pH optode pair for which K_{pH} is known is to use the biosensor to measure a set of standards and unknowns, then to use the pH optode to measure the identical set of samples. The corrected biosensor response for each measurement is calculated as:

$$R_{EB}^{*} = R_{EB,obs} - R_{opt,obs}/K_{pH}$$

Mass correction

For biosensor measurements of volatile analytes, the measurement vial was kept full to eliminate volatilization to the headspace. Before any injection in the vial, the same volume that was to be injected was first removed. This meant that some analyte mass was removed, and a simple mass balance calculation was performed to correct for this removal.

2.1.2.3. Development of biosensors for different analytes

Biosensors based on different strains of bacteria were developed to measure a wide range of analytes (Table 2-1, Figures 2-9 through 2-16).

Table 2-1. Biosensors developed in this project. Limit of detection (LOD) was estimated from the response curve for that biosensor

Analyte	Bacterial strain	Enzyme	Estimated LOD	Concentration range tested
1,2-dichloroethane (DCA)	*E. coli* BL21 (DE3) pGELAF	DhlA dehalogenase	< 4 ppt (ng/L)	(0.1 - 1000) ppt
	E. coli HB101 pAQN	LinB dehalogenase	< 1 ppb (µg/L)	(0.035 – 35) ppb
1,2- dibromoethane (ethylene dibromide, EDB)	*E. coli* HB101 pAQN	LinB dehalogenase	< 5 ppt	(0.1– 1000) ppt
trichloroethene (TCE)	*E. coli* HB101 pAQN	LinB dehalogenase	< 0.5 ppb	(0.25 – 35) ppb
Tetrachloroethene (perchloroethene, PCE)	*E. coli* HB101 pAQN	LinB dehalogenase	< 0.5 ppb	(0.1 – 1000) ppt
cis-1,2-dichloroethene (DCE)	*E. coli* HB101 pAQN	LinB dehalogenase	< 0.5 ppb	(0.1 – 1000) ppt
1-chlorohexane	*E. coli* HB101 pAQN	LinB dehalogenase	< 1 ppb	(0.025 – 75) ppb
lindane	*E. coli* HB101 pAQN	LinB dehalogenase	< 1 ppb	(0.025 – 75) ppb
dichloromethane (DCM)	*E. coli* BL21 (DE3) pAQN	DhlA dehalogenase	< 25 ppb	(1 – 1000) ppb
	E. coli DH5a pME1983	DcmA dehalogenase	< 10 ppb	(1 – 750) ppb
paraoxon	*E. coli* XL1-Blue pPNCO33	Oph Organophosphorous hydrolase	< 1 ppt	(0.015 – 500) ppt

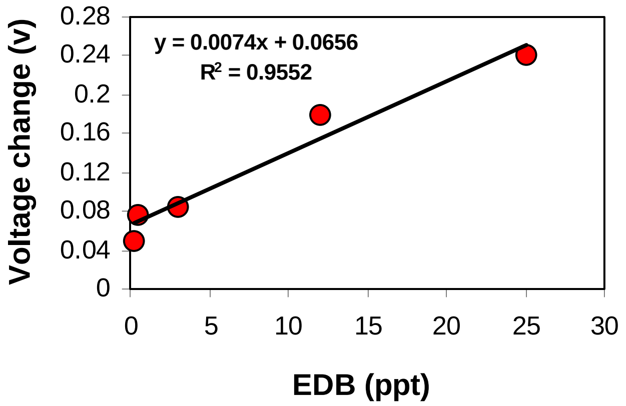


Figure 2-9. Calibration curve for an EDB biosensor [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase]

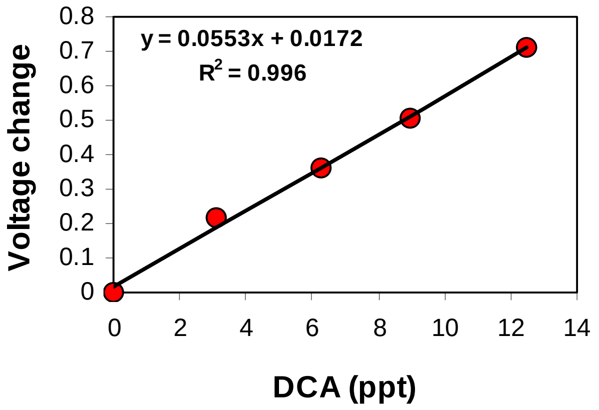


Figure 2-10a. Calibration curve for a DCA biosensor [*E. coli* strain BL21 (DE3) pGELAF

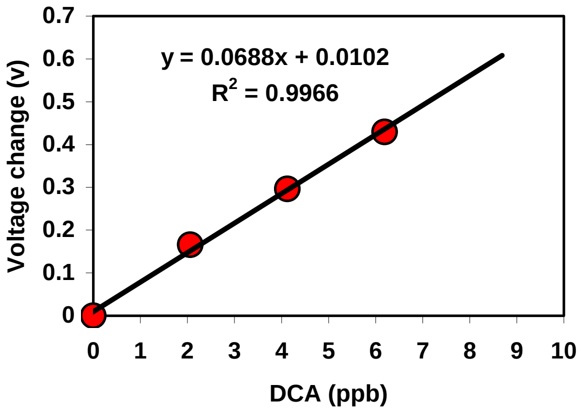


Figure 2-10b. Calibration curve for a DCA biosensor [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase].

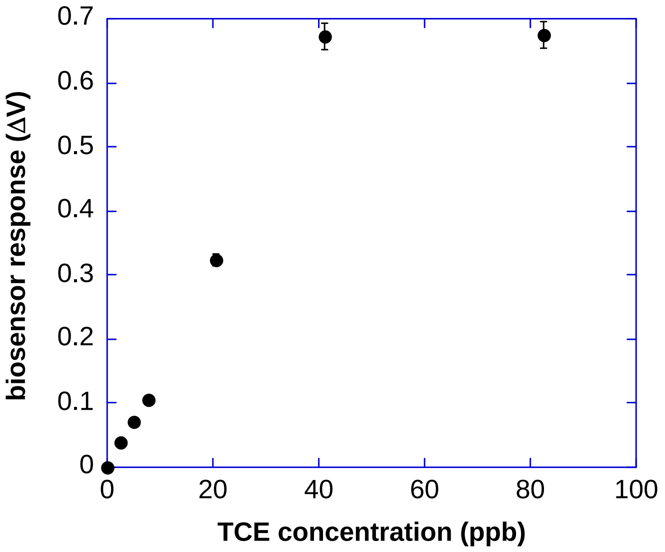


Figure 2-11. Calibration curve for a TCE biosensor [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase]. Error bars represent one standard deviation of triplicate measurements.

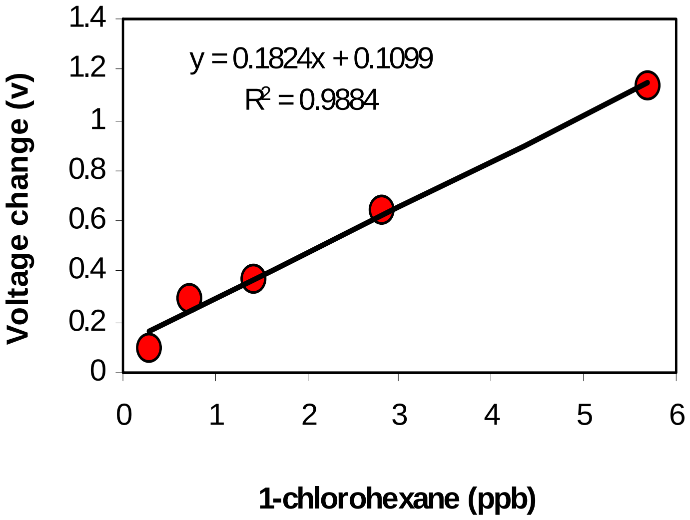


Figure 2-12. Calibration curve for a 1-chlorohexane biosensor [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase]

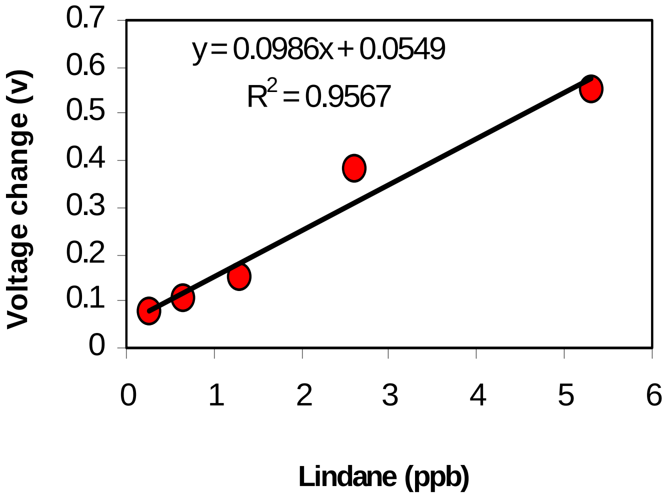


Figure 2-13. Calibration curve for a Lindane biosensor [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase]

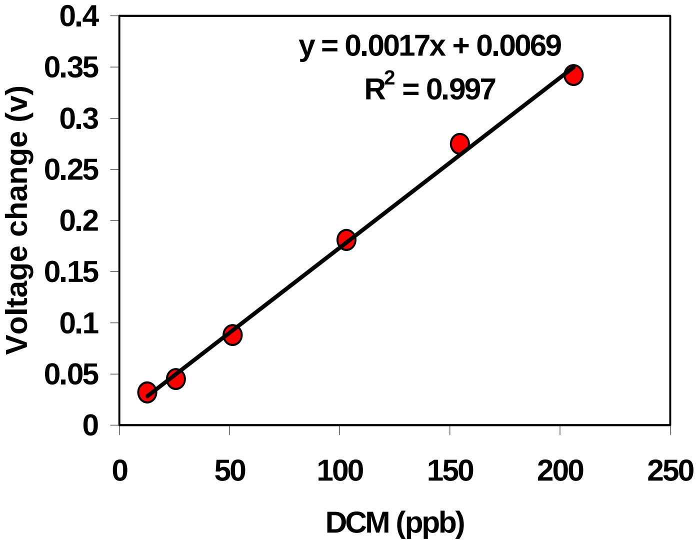


Figure 2-14. Calibration curve for a DCM (dichloromethane) biosensor [*E. coli* strain DH5a (pME1983) expressing DcmA dehalogenase]

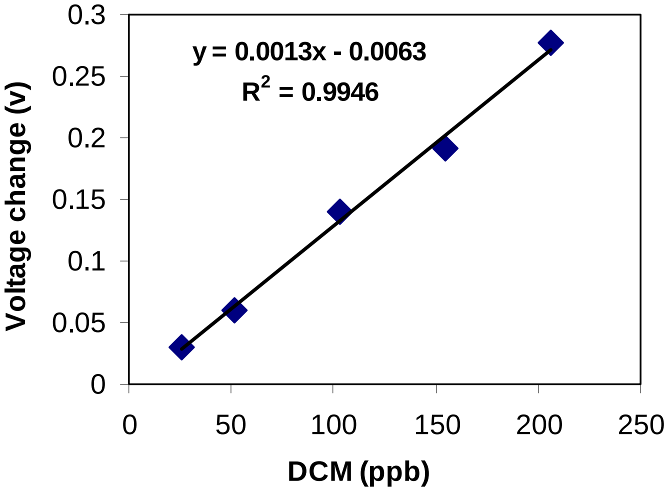


Figure 2-15. Calibration curve for a DCM biosensor [*E. coli* strain BL21 (DE3) expressing DhlA dehalogenase]

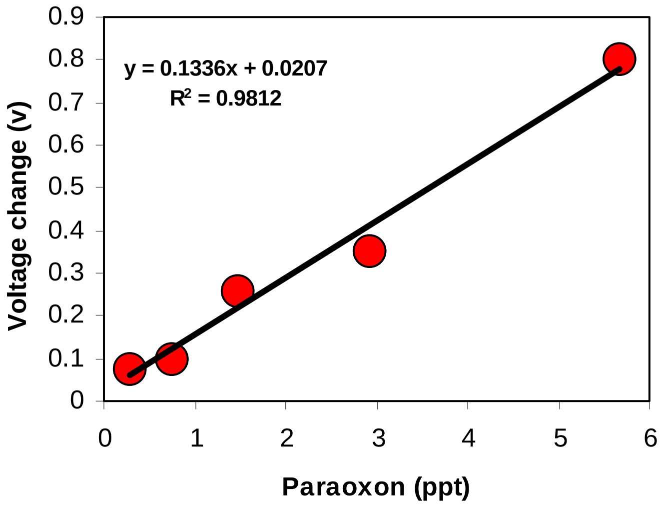


Figure 2-16. Calibration curve for Paraoxon biosensor [*E. coli* strain XL1-Blue (pPNCO33) expressing organophosphorous hydrolase (OPH)]

2.1.2.4. Influence of Environmental Parameters

pH

The effect of pH on the biosensor response is shown in Figure 2-17. The biosensor response increased up to pH 7 and then decreased as the sample became more basic. The maximum response was in the range of pH values 6.5-7.5. Since dehalogenases have maximum activity at pH 8 - 8.5, the cause of the decrease in sensitivity is the fluorophore. In fact, the pH optimum range of 3.5 - 7 was reported for the fluoresceinamine fluorescence response. Fort this reason, laboratory tests were performed at a pH value of 7.0 unless otherwise noted. Higher pH ranges could readily be achieved by using a different fluorophore.

Temperature

The biosensor response was temperature sensitive (Figure 2-18) increasing from 15 to 35^{o}C but declining rapidly with further temperature increase. This temperature effect on biosensor response could be attributed to the increase of both the enzyme reaction and mass transfer rates. At higher temperatures (> 45^{o}C), enzyme denaturation occurs. Standard laboratory biosensor experiments were done at room temperature.

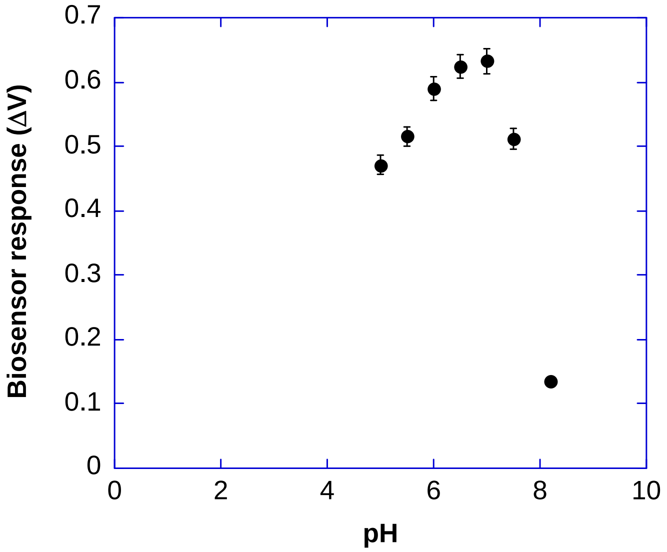


Figure 2-17. Effect of pH on biosensor response to 20.6 ppb DCA (in 1mM HEPES + 25 mM NaCl + 150mM $CaCl_2$). Error bars represent one standard deviation from triplicate measurements.

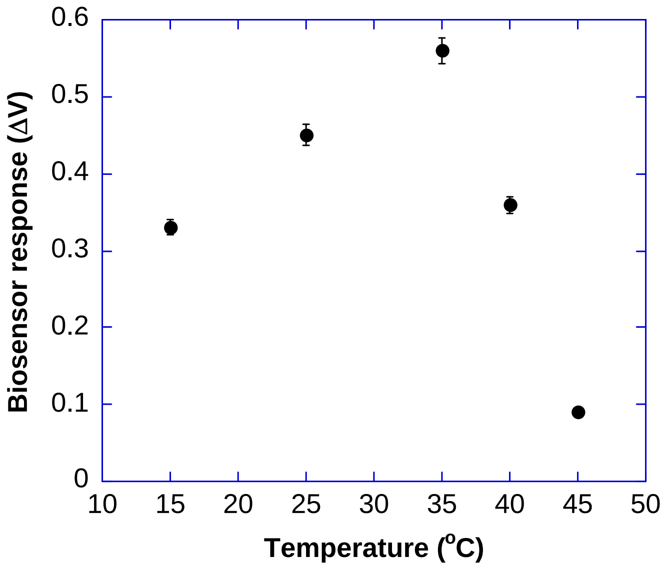


Figure 2-18. Effect of temperature on biosensor response to 3 ppb atrazine [*E. coli* strain DH5a (pMD4) expressing AtzA chlorohydrolase]. Error bars represent one standard deviation from triplicate measurements.

Ionic strength

The effect of the sample's ionic strength on biosensor response was studied at both high (brine) and low (groundwater) ranges.

Low ionic strength

The response of biosensors to DCA in different dilutions of the standard BMS was studied to provide information on the effect of low ionic strength, which is important for determining whether the biosensors can be effective in typical ground waters. Figure 2-19 shows the biosensor measurements of DCA in the different solutions. The response of the DhlA-based biosensors to DCA was not affected by ionic strength over the range evaluated. The measurement solution used had a TDS concentration of 11.6 g/L and thus the 1% solution contained 116 mg/L. Groundwater TDS generally ranges from 100 to 1,000 mg/L.

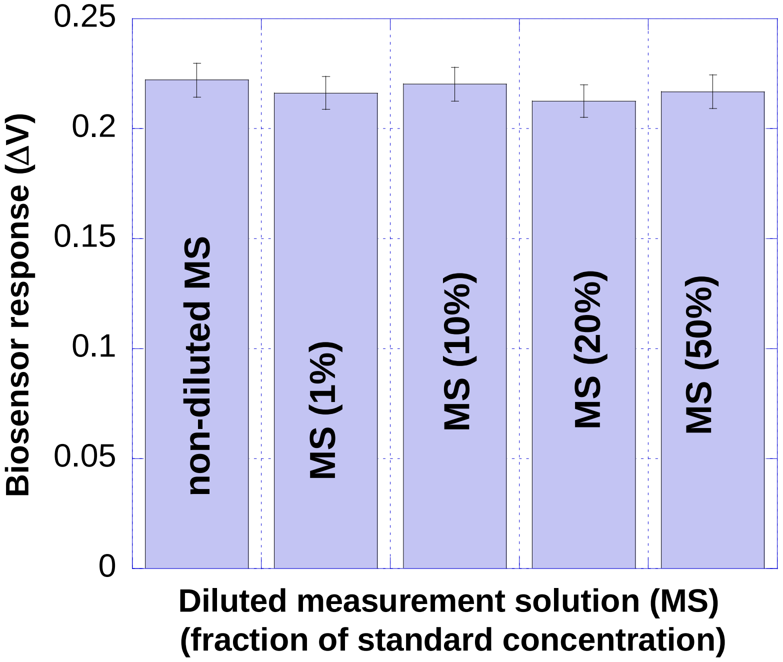


Figure 2-19. Effect of dilution measurement solution (MS) (9 g/L NaCl + 2.7 g/L $CaCl_2$) on biosensor response to DCA at 20.6 ppb [*E. coli* strain BL21 (DE3) expressing DhlA dehalogenase]. All the MS dilutions were prepared with deionized water. The BMS was prepared by combining each of the diluted MS with 1 mM MES buffer. Error bars represent one standard deviation of triplicate measurements.

High salt (NaCl) content

The response of biosensors in different measurement solutions containing high concentrations of NaCl was also studied (Figure 2-20). No effect was noted up to 20 g/L (for comparison, sea water has total dissolved solids of approximately 30 g/L).

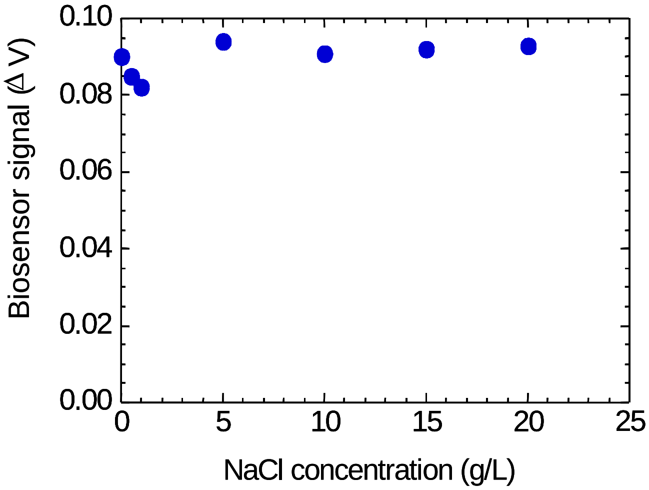


Figure 2-20. Effect of NaCl on biosensor response to atrazine at 13 ppb. [*E. coli* strain DH5a (pMD4) expressing AtzA chlorohydrolase]

Oxygen

To determine the effect of oxygen on biosensor measurements, oxygen levels in the measurement solution were changed by sparging with air or N_2. Figure 2-21 shows the biosensor responses to DCA in unsparged BMS, BMS sparged with air, and BMS sparged with N_2. The pH was constant after sparging the measurement solutions with air or N_2. The response of DhlA-based biosensors to DCA was not affected by the concentration of dissolved oxygen.

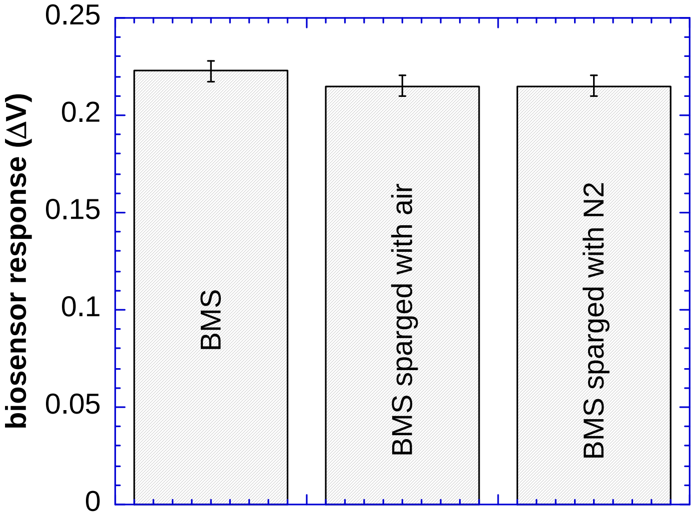


Figure 2-21. Effect of sparging the measurement solution with air or N_2 (1 mM MES+25 mM $CaCl_2$ + 150 mM NaCl) on biosensor response to DCA at 20.6 ppb [*E. coli* strain BL21 (DE3) expressing DhlA dehalogenase]. Error bars represent one standard deviation from triplicate measurement.

Buffer capacity

The biosensor response was studied in buffered measurement solutions representing different buffer capacities. When a buffering agent is present, the basic buffer ions neutralize part of the enzymatically-generated protons. Thus, little free acid is produced resulting in a smaller biosensor response. However, biosensors retained good sensitivity even at the buffer capacities normally present in ground water.

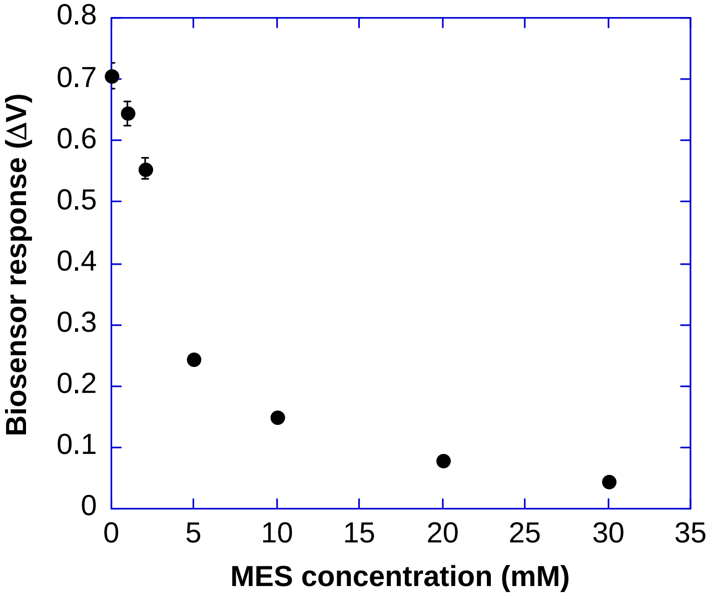


Figure 2-22. Effect of buffer capacity on biosensor response to atrazine at 15.5 ppb [*E. coli* strain DH5a (pMD4) expressing AtzA chlorohydrolase]. Tests were done in measurement solution with the indicated concentration of MES buffer at pH 7 and room temperature. Error bars represent one standard deviation from triplicate measurements.

2.1.2.5. Selectivity and Specificity

The goal of these studies was to determine whether certain co-contaminants would affect the measurement of the target analyte. Co-contaminants of two types were tested: those that are chemically dissimilar and not expected to be transformed by the dehalogenase enzyme (but which might alter the enzyme activity) and those that were potential or known dehalogenase substrates.

Results for dissimilar co-contaminants are shown in Figures 2-23 and 2-24. No effect of metals (Cd and Cr), aromatic hydrocarbons (benzene and toluene), or naturally occurring organic compounds (acetate and amino acids) was observed.

Some biosensors responded to several analytes. The LinB dehalogenase was found to be relatively nonspecific, producing biosensors for DCA (Figure 2-10b), EDB (Figure 2-9), Lindane

(Figure 2-13), 1-chlorohexane (Figure 2-12), and TCE,/PCE/*cis*-1,2-DCE (Figure 2-25). In the latter case, the response to PCE was about 50% greater than to TCE or *cis*-1,2-DCE.

DhlA dehalogenase-based biosensors responded to both DCM (Figure 2-15) and DCA (Figure 2-26), but they showed no response to the structurally similar EDB (Figure 2-27).

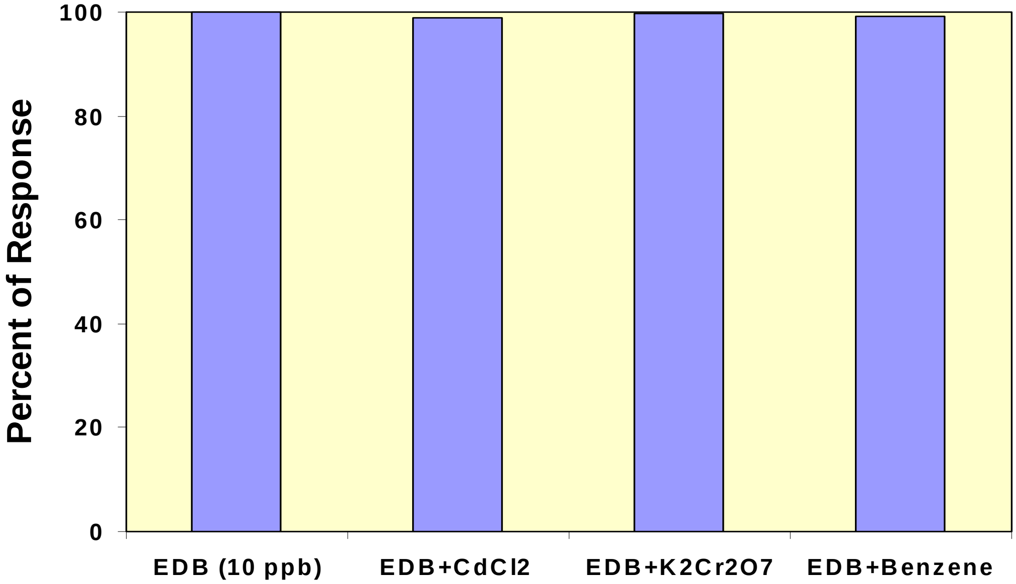


Figure 2-23. Selectivity of biosensor response to EDB at 10 ppb in measurement solutions containing different metals (1 ppm) and benzene (100 ppm) [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase].

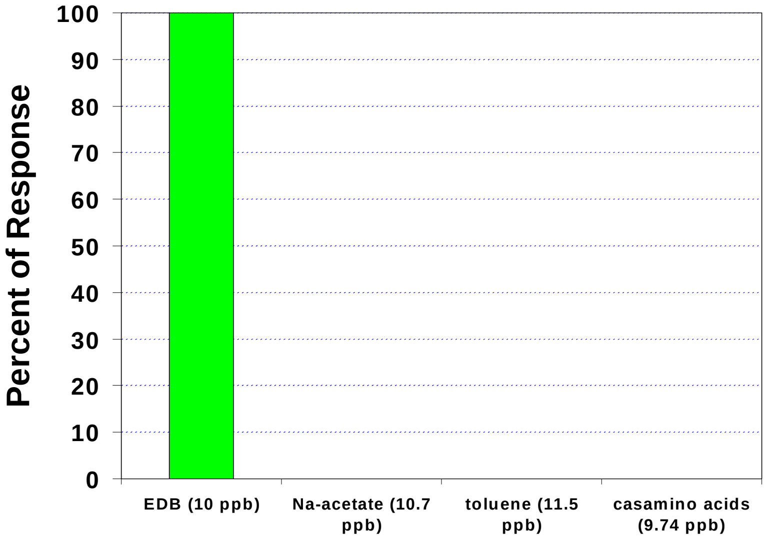


Figure 2-24. Specificity of biosensor response to EDB at 10 ppb in measurement solutions containing different contaminants [*E. coli* strain HB101 (pAQN) expressing LinB dehalogenase].

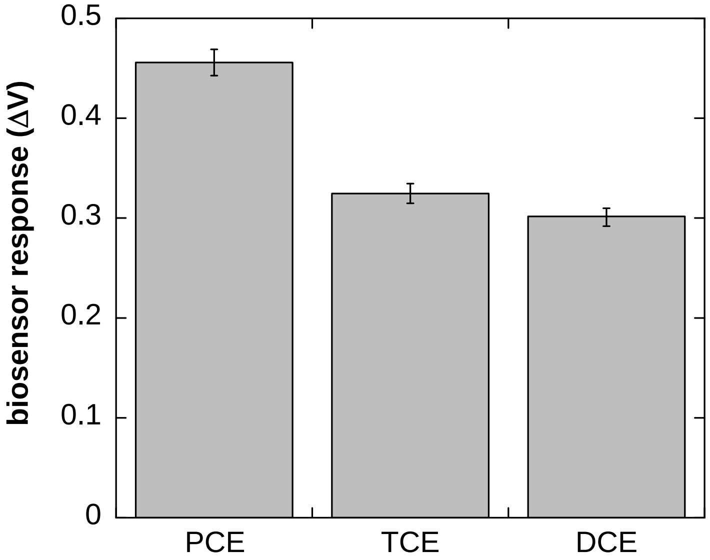


Figure 2-25. Relative biosensor response to different chlorinated compounds each at 20.6 ppb. Biosensors were based on *E. coli* strain HB101 (pAQN) expressing LinB dehalogenase. Error bars represent one standard deviation of triplicate measurements.

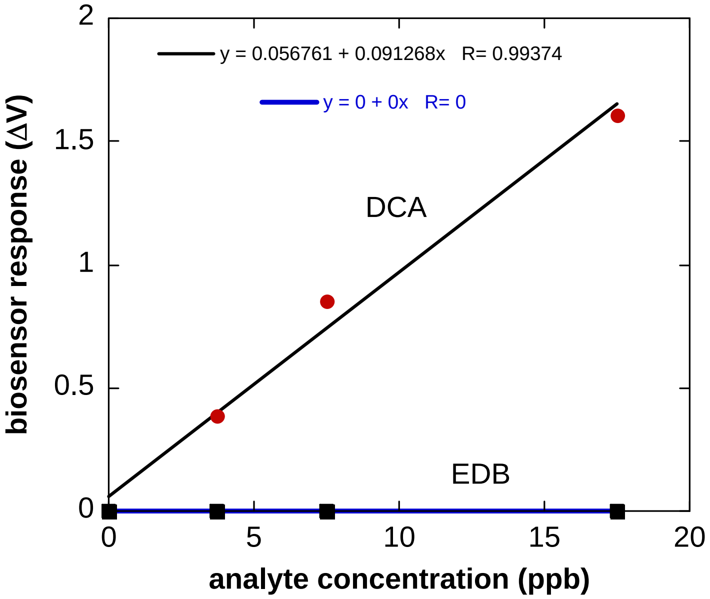


Figure 2-26. Calibration curve for a biosensor toward DCA [*E. coli* strain BL21 (DE3) expressing DhlA dehalogenase]. The same DhlA biosensor showed no response to EDB.

2.1.2.6. Purified Enzyme Biosensors

Biosensors based on purified enzymes were developed by immobilizing the enzymes in Ca-alginate hydrogel. The mass ratio of enzyme to Ca-alginate was 1 to 10. Although the detection limits achieved with this biosensor were not as low as for the whole-cell case, this result is significant because further development of purified enzyme biosensors could reduce certain non-specific responses and allow for further miniaturization of the sensors.

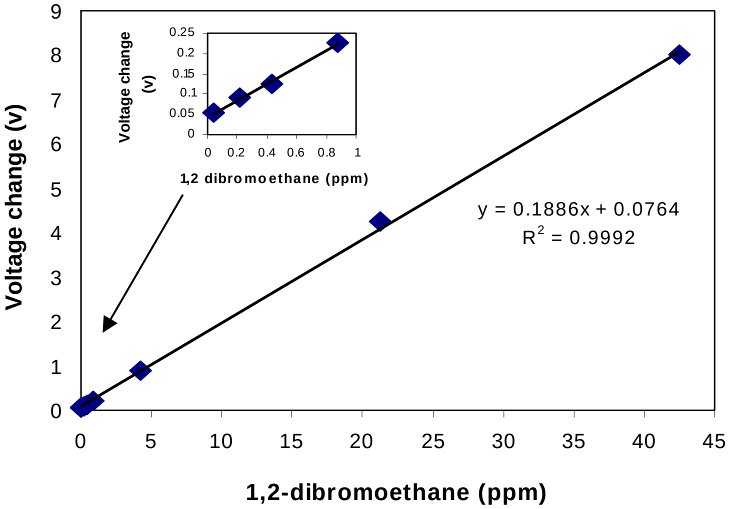


Figure 2-27. Response of biosensors based on purified LinB dehalogenase to 1,2-dibromoethane.

2.1.2.7. Stability

Since the biosensor technology is based on biological activity, the stability of the sensor output (activity retention of the enzyme) is a valid concern. However, since this biosensor concept does not require the cells to be alive (no cofactor such as NADH is required for the detection reaction), practical biosensor lifetimes should be achievable. Furthermore, for some applications (e.g., sentry wells), accurate concentration determination is less important than the capability to provide a yes/no response. Several laboratory tests indicate that multi-month lifetimes are possible (Figures 2-28 and 2-29).

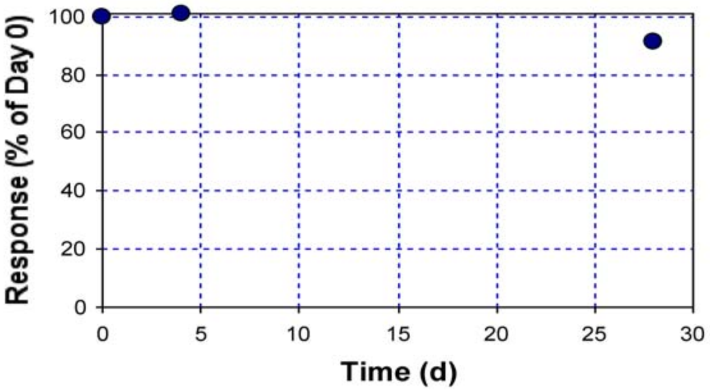


Figure 2-28. Activity retention by a Paraoxon biosensor in a laboratory test (response to 0.8 ppt Paraoxon). The biosensor was stored at 4°C between measurements.

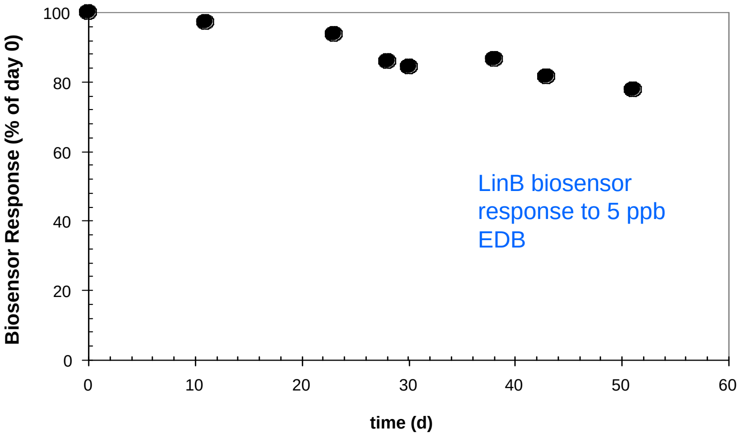


Figure 2-29. Activity retention by an EDB biosensor in a laboratory test. The biosensor was stored at 4°C between measurements.

2.1.2.8 Laboratory Samples Analyzed by Biosensors and Gas Chromatography

Samples for biosensor and GC analysis were prepared by dilution of pure chemical. GC samples were sent to Pace Analytical (Lenexa, KS) and analyzed for VOCs by EPA Method 8260b. Biosensor samples were analyzed as described above after preparation of a calibration curve using separate standards. Table 2-2 presents the results of the analysis of these samples for both methods.

Table 2-2. Results of Analysis of Laboratory Samples Using Biosensors and Gas Chromatography

Compound	GC Result (µg/L)	Biosensor Result (µg/L)
1,2-DCA	1.6	1.2
1,2-DCA	11	10.4
1,chlorohexane	<0.36	0.83
cis-1,2-dichlorethene	<0.36	0.86
trichloroethene	11	10.5
tetrachloroethene	3.2	2.3
ethylene dibromide	18	16.7

2.2 Previous Testing of the Technology

No significant field testing of the biosensors was performed prior to the ESTCP demonstrations.

2.3 Factors Affecting Cost and Performance

Issues that may arise when this technology is transferred to the field include sensor stability, and sensor durability. Strategies to address each of these problems are described below:

- Sensor Stability: Laboratory test results suggest that active lifetimes of the biosensors can exceed one month. This period could be extended by overcoming the causes of activity loss, and might include strategies such as heat treatment and expression of enzymes on the cell surface (to minimize protease attack), engineering or selecting more stable enzymes and loading the tip with a higher cell concentration. Ultimately, the most promising approach is to express the enzyme on the surface of the cells. However, the biosensor tips can easily be replaced with new tips which cost approximately $0.25 to produce.

- Sensor Durability: To date calcium alginate gel has been used to coat the biosensors. One strategy for increasing biosensor durability is to coat the outside of the alginate with a second, more durable polymer such as polyethyleneimine. This coating may lengthen the response time slightly but may also increase activity retention in addition to making the sensor more suitable for field use.

The primary performance issues that were validated in these field demonstrations were the ability of the biosensors to: function accurately as a repeat analytical device (to replace or supplement traditional field sampling and offsite lab analysis), and provide discrete-depth measurements instead of the well-averaged values obtained with traditional methods.

2.4 Advantages and Limitations of the Technology

In situ measurements by fiber optic biosensors could be used to reduce costs at DoD sites in at least three scenarios. First, biosensors could be used to monitor groundwater contaminant concentrations in existing plumes, either by permanent installation of wells for monitoring over time or by analyses of wells at discrete time points. Second, biosensors could be placed in sentinel wells between a plume and a receptor to detect offsite contaminant migration. Finally, they could be used for site characterization -- as soon as a Geoprobe or well is placed, a biosensor could be used to determine the contaminant concentration and the results used to direct the placement of subsequent wells.

Relative to traditional, discrete sampling approaches, biosensors have the following advantages:

- The capability of providing low cost, simultaneous measurements at different depths in a well (i.e., spatial resolution); currently, average values over a screened interval are obtained because discrete interval monitoring, although more informative, is too expensive and complicated.

- The capability of providing low cost, continuous monitoring (i.e., temporal resolution); current methods rely on single periodic measurements that may not be representative

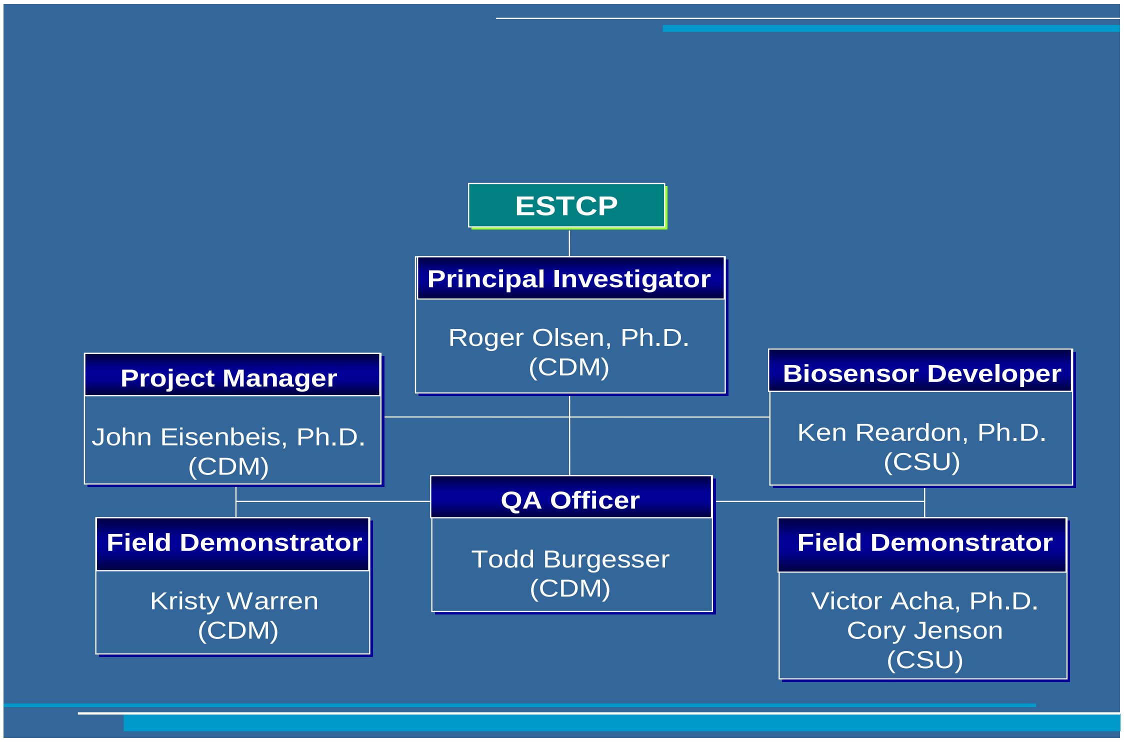
To achieve the full potential of this biosensor technology, it will be necessary to develop biosensors that are stable over long (> 2 months) periods. For many applications, such as on-site vial sampling, the requirement is that the rate of sensitivity loss be low enough to allow recalibration to occur only once per day, as would be typical of any sensor. For down-hole monitoring, the rate of sensitivity loss should be lower; if this cannot be achieved, then the down-hole monitoring mode will be limited to qualitative rather than quantitative measurements.

3.0 Demonstration Design

The demonstration described in this section was performed by CDM and CSU in accordance with the *Technology Demonstration Plan* (CDM and CSU, 2001) with the exceptions noted in Section 3.1.1. Points of contact involved in the demonstration are listed in Section 8. A project organization chart is shown in Figure 3-1.

This section describes the performance objectives, gives a summary of site conditions for the demonstration site, and describes the experimental design and methods that were used to implement this design.

Figure 3-1. Organizational chart for biosensor demonstration.



3.1 Performance Objectives

3.1.1 Deviations from Demonstration Plan

This section describes deviations from the methods and approach described in the Demonstration Plan.

It was originally intended to demonstrate the use of biosensors at three sites, the first of which was to be Operable Unit 8 (OU 8) of the Naval Submarine Base in Kipsap County, Washington (SUBASE Bangor). The Demonstration Plan stated that:

> "It is anticipated that at Sites 2 and 3 we will demonstrate multi-analyte measurement capability using bundled fiber optic sensors. These sites will be selected using the above criteria and other criteria that may be appropriate as the demonstration proceeds. Site 2 will be selected following completion of the field measurements at Site 1. Site 3 will be selected during the second set of field measurements at Site 2."

Due to difficulties encountered in calibrating the biosensors to compensate for pH changes in groundwater samples (see Section 4), the demonstration was instead limited to two events at SUBASE Bangor. The multi-analyte measurement capability using bundled biosensors was not developed or demonstrated as part of this project.

Over the course of the demonstration, the biosensor calibration procedures were modified and improved. As described in Section 3.5.7, the calibration procedures used were different from those described in the Demonstration Plan.

The schedule and period of performance were different from what was anticipated in the Demonstration Plan. The actual periods of biosensor field measurements were as follows:

- SUBASE Bangor (first demonstration): February 25 to March 2, 2002
- SUBASE Bangor (second demonstration): September 20 to September 24, 2004

3.1.2 Meeting Performance Objectives

Performance of the biosensors was compared to the conventional GC/MS method for groundwater analysis. Performance was evaluated based on the following objectives identified in the Demonstration Plan:

- **Accuracy** as demonstrated by a one-to-one correlation between the two analytical techniques (biosensor and GC/MS).
- **Rang**e as demonstrated by a response from less than 5 µg/L to greater than 500 µg/L 1,2-DCA
- **Precision** as demonstrated by a low relative percent difference (RPD) between duplicate analyses
- **Sample throughput** as demonstrated by short analysis time in the field
- **Mechanical reliability** as demonstrated by a low incidence of failure
- **Versatility** as demonstrated by acceptable performance under variety of conditions

A summary of the performance objectives is presented in Table 3-1 along with whether each objective was met during the demonstration.

Table 3-1. Performance Objectives

Type of Performance Objective	Primary Performance Criteria	Expected Performance (Metric)	Actual Performance Objective Met?
Qualitative	1. Sample Processing Rate	> 6 samples/day	Yes
	2. Mechanical Reliability	Low breakdown incidence	Yes
	3. Versatility	Applicability to all conditions	No
	4. Ease of use	Typical operator training and labor required	No
Quantitative	1. Accuracy	Relative Percent Difference (RPD) < 25 percent (RPD for GC/MS method); correlation coefficient (r^2) > 0.9	No (r^2) > 0.9, but RPD > 25%
	2. Precision	RPD for biosensor equal to or less than 25% (RPD for GC/MS method)	No
	3. Sensitivity	< 5 µg/L	Yes (if no interference)
	4. Range	> 500 µg/L	Yes (if no interference)

3.2 Selection of Test Site(s)

This section describes the criteria used to select demonstration site. These criteria included:

- Presence of a contaminant detectable by biosensors
- Existence of an ongoing groundwater monitoring program with which data can be coordinate and shared
- Preference for many monitoring points and monitoring wells with long screen intervals to facilitate discrete depth measurements
- Preference for non-homogeneous aquifer concentrations to demonstrate the importance of discrete depth monitoring

The demonstration site selected was SUBASE Bangor since it met all of the above criteria, including having a groundwater plume with 1,2-DCA as a major component. 1,2-DCA is one of the compounds for which a biosensor had already been developed and lab-tested.

3.3 Test Site Description

This section provides a brief summary of the history and site characteristics of SUBASE Bangor that are pertinent to the field demonstration of the biosensors. This information has been taken from the Final Technical Memoranda titled *Preliminary Evaluation of the Natural Attenuation Process Phase II* (EA Engineering, Science and Technology, 2000) and *First Quarter 2000 Sampling* (Foster Wheeler, 2000). Site characterization details are presented in Appendix A.

Two demonstrations were performed at Operable Unit 8 (OU8), which is located in the Public Works Industrial Area (PWIA) of Bangor. Bangor is located near the town of Silverdale, Washington. An onsite underground storage tank (UST) is believed to be the source of a release of unleaded gasoline into the surrounding media between 1982 and 1986. Chlorinated volatile organic compounds (VOC) and LNAPLs are also present in site groundwater (EA 2000).

OU8 geological conditions have been highly characterized by drilling and monitoring well installation. The area consists of four stratigraphic units: construction fill, Vashon till (Qvt), Vashon Advance Outwash (Qva), and Lawton Clay. The construction fill can be found 2 to 3 feet below ground surface (bgs) and consists of a sandy material. Underlying the construction fill and ranging to a depth of about 45 feet bgs is the Vashon till, which consists of silt, sand, gravel, and cobbles. This unit is 20 to 40 feet thick. The Vashon Advance Outwash (location of the shallow aquifer) is beneath the Vashon till and consists of sand, silt, and gravel. The thickness of the Vashon Advance Outwash is about 100 to 130 feet. Beneath the Vashon Advance Outwash is the Lawton Clay aquitard. A silty transition zone in the bottom of the Vashon Advance Outwash separates the shallow aquifer from the lower aquitard.

There are about 100 monitoring wells at OU8. The wells were installed at three different depth intervals: shallow, intermediate, and deep. The depth to groundwater is about 20 feet bgs and the general flow direction is southeast. The Vashon Advance Outwash lies beneath the Vashon till at OU8 and is the location of the shallow unconfined aquifer. The shallow aquifer contained in the Vashon Advance Outwash is about 125 feet thick. The shallow wells are screened within 30 feet of the water table, intermediate wells are screened within the middle 40 feet of the aquifer thickness, and the deeper wells are screened within 30 feet of the Lawton Clay aquitard. The plume contains dissolved petroleum contaminants (including benzene) and DCA. Some wells also contain LNAPLs. The majority of the contaminants are located in the shallow and intermediate zones of the Vashon Advance Outwash.

3.4 Pre-Demonstration Testing and Analysis

Prior to the first demonstration, the CDM/CSU team visited SUBASE Bangor and began to coordinate with the site's quarterly monitoring crew. Arrangements were made with site staff to work with the monitoring crew during their fall monitoring event (October 2001) to obtain co-located samples and to use the biosensors in wells that were to be sampled for this event. However, delays in laboratory preparation of the biosensors and associated hardware occurred prior to mobilizing to the field, and the first demonstration was postponed until February 2002.

Laboratory development and testing of the biosensors prior to the demonstrations is described in Section 2.1.2.

3.5 Testing and Evaluation Plans

3.5.1 Demonstration Installation and Start-Up

All equipment and supplies necessary for measurements were mobilized to and around the demonstration site in a van. No site utilities were required. Power was obtained either from a vehicle battery or from a portable generator. Biosensors were transported to the site from CSU on ice. The tips were stored in a 0.01 molar (M) buffer solution at pH 7.0 with no contaminant present, and were maintained in that solution on ice until shortly before their use.

3.5.2 Period of Operation

The periods of biosensor field measurements were as follows:

- SUBASE Bangor (first demonstration): February 25 to March 2, 2002
- SUBASE Bangor (second demonstration): September 20 to September 24, 2004

3.5.3 Amount/Treatment Rate of Material to Be Treated

Since this demonstration involved a site characterization method, this subsection is not applicable.

3.5.4 Residuals Handling

Use of the biosensors did not generate residuals that required special handling. Groundwater used in calibration of the sensors along with decontamination and rinse water was added to the waste generated during the quarterly monitoring sampling.

3.5.5 Operating Parameters for the Technology

Several modes of sampling were used during the demonstrations to evaluate the performance of the biosensors under different conditions. These sample modes are described in detail in the next subsection.

3.5.6 Experimental Design

The fiber optic biosensor demonstrations used a variety of sampling methods.

1. **Vial Measurements:** A biosensor was inserted into a vial containing a sample of the groundwater from a monitoring well. A split sample was sent to an off-site laboratory for analysis by GC/MS.

2. **Flow-Through Cell Measurements:** A biosensor was inserted into an aboveground, flow-through cell (with continuous flow of groundwater from the monitoring well) in conjunction with recording routine measurements of the field parameters pH, DO, ORP temperature, and specific conductance.

3. **Down Well Measurements:** A biosensor was lowered down hole in an un-pumped monitoring well. Measurements were taken at several depth intervals to define contaminant gradients.

4. **Sampling of "Sentinel" Wells:** A biosensor was installed down hole in a selected monitoring well. The fiber optic cable and analyte probe were left in the hole and monitored on a routine basis over a period of a day. Results from this type of sampling provided a basis to determine if the biosensors could be left in a well for longer periods and what calibration needs are necessary for such sampling.

The above procedures allowed for comparison of biosensor readings with analytical results from GC/MS laboratory analysis. The results were also used to compare sampling methods and concentration profiles with depth. The results and details concerning measurement methods used at each monitoring well are provided in Section 4.

Field QC Samples

The following types of QC samples were collected and analyzed.

Duplicate Samples **–** Three vials were filled with groundwater minimizing volatilization**.** Two of the vials filled with groundwater were analyzed onsite using the biosensor. The second sample was analyzed immediately after the first sample and was identified as a duplicate sample. A third sample was retained for potential later analysis.

Co-Located Samples **-** As previously described, concentrations of 1,2-DCA were measured downhole in selected wells. At one of these locations, the biosensor was removed and cleaned. The downhole analyses were then repeated at the same depths in the same well.

Additional QC Samples **-** Additional quality assurance/quality control (QA/QC) samples are discussed in the following paragraphs that would typically be used only in an offsite laboratory. However, because the biosensor is being evaluating for use as a replacement for offsite analyses, additional samples were analyzed.

Calibration Standards

Calibration procedures are described in Section 3.5.7.2 and will not be repeated in this section. The biosensors were calibrated once per day. As part of the calibration procedure, a laboratory control standard was analyzed after completion of the calibration.

Evaluation Methods

Onsite Duplicate Samples Precision of the onsite biosensor can be assessed by comparing the analytical results of the onsite duplicate samples. Precision is most often expressed in terms of relative percent difference (RPD). The RPD can be calculated for each pair of duplicate analyses using the following equation:

$$\text{RPD (\%)} = [S-D]/[(S+D)/2] \times 100$$

Where:

S = first sample value
D = second sample value

Comparison of Onsite and Offsite Samples Comparison of the onsite and offsite (GC/MS) analytical results was performed by calculating the RPD between samples. A RPD was calculated for each of the onsite duplicate samples described previously (i.e., an average value of the two onsite samples was not used).

Evaluation Criteria

The performance of the biosensor was assessed at two levels: Level 1 is the ability to provide qualitative, screening data with definitive compound identification. Level 2 is the ability to provide definitive compound identification and quantitative concentrations.

Level 1: Semi-quantitative screening concentration data
Moderate accuracy
Moderate quantitation limit
Moderate specificity and selectivity

Level 2: Quantitative concentration data
High accuracy (RPD $\leq$ 25%)
Low quantitation limit
High specificity and selectivity

The two corresponding sets of data quality objectives and evaluation criteria are provided in Table 4-2. Level 2 evaluation criteria for 1,2-DCA were selected to be consistent with those standard procedures used by the offsite laboratory (GC/MS methods equivalent to EPA method 8260B).

3.5.7 Sampling Plan

Section 3.5.7.1 provides the sampling plan description for the first demonstration and Section 3.5.7.2 provides the description of the sampling plan for the second demonstration.

3.5.7.1 First Demonstration

The biosensor demonstration largely depended on comparing results from the offsite laboratory with the biosensor results collected onsite. Samples for laboratory analysis were collected using methods described in the SUBASE Bangor long-term monitoring Quality Assurance Project Plan (QAPP) (EA 2000). Sampling and analysis procedures not associated with the site monitoring activities are described in this section.

Biosensor Calibration Procedure.

Individual biosensors vary in their response characteristics. Furthermore, biosensor measurements are influenced by groundwater characteristics such as pH and buffer capacity (alkalinity). Thus, calibration was performed using water from the well or representative water with similar characteristics from a nearby well. The following calibration procedure was used during the first demonstration. Measurements were only recorded when the instrument signal was steady (+/- 0.02 V) for three minutes. Measurements were made in standard 40 milliliter (mL) VOA vials with zero headspace, and the biosensor was fitted with a special VOA vial-compatible cap. Additions of standard solutions were made rapidly to avoid volatilization losses. The calibration steps used were:

- Obtain a steady reading of the biosensor in the standard buffer solution used for storage (2 mM Tris HCl). Adjust the output of the system using the offset control until a steady reading of 10.0 is obtained.
- Submerge the biosensor in the groundwater sample. Obtain a steady reading (R1).
- Rinse the biosensor with the standard buffer solution. Spike the groundwater sample with 10 µL of a concentrated solution (known value) of the analyte to bring the concentration in the groundwater sample to a value of C0 + x, where C0 is the unknown concentration of the analyte in the original groundwater sample and x is the concentration added by spiking. Mix the spiked solution using a magnetic stirrer (inert, clean stir bar previously inserted into vial) or by shaking (with inert solids previously added to the vial to facilitate mixing). Submerge the biosensor in the groundwater sample. Obtain a steady reading (R2).
- Rinse the biosensor with the standard buffer solution. Again spike the groundwater sample with 10 µL of the concentrated solution of the analyte to bring the concentration in the groundwater sample to a value of C0 + 2x. Submerge the biosensor in the groundwater sample. Obtain a steady reading (R3).
- Rinse the biosensor with the standard buffer solution and replace it in a vial of storage solution until use.

To obtain the calibration parameters, compute the change in readings from the baseline as $\Delta R = 10 - R_i$. Since the calibration curve ΔR versus concentration (C) is known to be linear, the equation of this curve is

$$\Delta R = mC + b \qquad \text{(m is slope and b is intercept)}$$

Thus, for each of the three measurements, the following equations can be written:

$$\Delta R_1 = mC_0 + b$$
$$\Delta R_2 = m(C_0 + x) + b$$
$$\Delta R_3 = m(C_0 + 2x) + b$$

Since the values of ΔR_1, ΔR_2, ΔR_3, and x are known, this provides three equations that can be solved for the three unknowns: m, C_0, and b. Once m and b are obtained, the equation of the calibration curve ($\Delta R = mC + b$) can be rearranged as

$$C = (\Delta R - b)/m$$

This equation can be used to convert instrument readings to concentrations.

These calibration procedures were used for two types of analysis that were performed with the biosensors during the first demonstration, as described below.

Split VOA Analysis

The objective of this type of analysis was to compare the biosensor readings to offsite laboratory results (GS/MS) for 1,2-DCA. After field parameters indicated that stable groundwater conditions had been reached during pumping, two VOA vials were filled. Three additional VOA vials were filled for analysis by the biosensors. Filling alternated between vials for biosensor and offsite analyses. The cap of one of the biosensor vials was removed briefly and was immediately replaced with a cap fitted with a biosensor. A biosensor reading was recorded after sufficient time had elapsed to obtain a stable reading. This procedure was then repeated for the second vial (duplicate).

Flow-Through Cell Analysis

While groundwater from the sample pump was being measured for field parameters (pH, DO, etc) in a flow-through cell, a second flow-through cell (connected in series and attached to the effluent port of the first cell) was utilized to take biosensor readings of the groundwater flowing from the well. Before placement in the cell, a biosensor was inserted into a field standard of 1,2-DCA at a concentration that was similar to the anticipated concentration from the well being sampled (based on the last lab results for that well). This helped to minimize the time needed for a stable reading when the biosensor was put into the flow-through cell. Readings were recorded from the biosensor at regular intervals until field parameter readings stabilized. In addition to individual biosensor readings, notes were taken as to the range in fluctuation of readings and the approximate average reading.

Analysis Locations Table 3-2 presents the monitoring wells that were used for each analysis type described above during the first demonstration. The wells were selected based on the latest

1,2-DCA concentration measured, as well as the diameter and construction (e.g., depth) of the well.

Table 3-2. Monitoring Wells Used in the First Demonstration

Analysis Type	Monitoring Well ID	1,2-DCA (µg/L)	Screened Interval (feet bgs)
Split VOA/Flow-Through Cell	8MW06	1,200	37.8 - 47.8
	8MW03	56	72 - 82
	8MW33	16	68.3 - 78.3
	8MW35	3.0	72.6 - 82.6
Vertical Profiling	8MW48	320*	23 - 38
	MW05	340*	20 - 40
	25MW05	62*	12.8 - 22.8
Multi-Day	8MW03	56	72 - 82

* Collected June 2000

3.5.7.2 Second Demonstration

Based on lessons learned from the first demonstration, some of the methods used in the second demonstration were modified from those used during the first. Prior to beginning the second demonstration, calibration tests were performed at CSU using SUBASE Bangor groundwater to reduce the chance that unforeseen problems would occur during the second field demonstration. The 1,2-DCA biosensors were refined based on results of these calibration efforts, and then biosensors were produced in sufficient quantity for field use.

Calibration Methods This section describes the steps that were used during the second demonstration to calibrate and take sample measurements with the biosensors for three types of measurements: 1) Measurements in vials; 2) Measurements in a flow-through cell; and 3) *in situ* measurements in a monitoring well.

Vial Measurements

The vial method calibration procedures used during the second demonstration were based on those described in Section 2.1.2.2. Specifically, a pH optode was used to separate the response of the biosensor to the analyte (R_{EB}^*) from the biosensor's response to bulk solution pH changes ($R_{EB,pH}$), since both contribute to the observed response of the biosensor ($R_{EB,obs}$). A set of measurements is performed first with a biosensor and then with a pH optode, and the two sets of data used to calculate R_{EB}^*.

Measurements

1. Collect a groundwater sample from the well (about 50 mL) and record the pH. Completely fill several small vials (e.g., 4.85 mL) with this sample and close with septum caps.

2. In a separate 4.85-mL vial, place a small magnetic stir bar. Fill the vial completely with buffered measurement solution (BMS; 150 mM NaCl, 25 mM CaCl2, and 10 mM MES at pH 7.0). Close the vial with a septum cap through which a biosensor tip has been inserted.

3. Connect the biosensor tip to the fiber optic lead (and the optoelectronic instrument) and place the vial in a darkened measurement chamber on top of a magnetic stirring plate.

4. When a steady signal (PMT voltage) has been obtained, remove 100 µL of solution using a syringe inserted through the vial septum. Then add 100 µL of groundwater sample.

5. When a new steady signal has been obtained, calculate the voltage change (ΔV) between the initial and the final values. This is REB,obs.

6. Perform at least three additions of a standard solution of the analyte, each time removing the same volume that will subsequently be added. Record the ΔV resulting from each addition. The volume of standard added should be varied to obtain ΔV values that are both larger and smaller than REB,obs. In the case of the second demonstration, the standard solution was 100 µg/L of 1,2-DCA, and the volumes added were typically 25, 50, and 100 µL.

7. Perform a series of injections of a 1 mM HCl solution in water, adding 25, 50, and then 75 µL of solution, withdrawing the same amount before each addition, and measuring the resulting ΔV. These values will be used to calculate the relative pH response of the biosensor vs. the pH optode.

8. Fill a new 4.85-mL vial with BMS and close the vial with a septum cap through which a pH optode tip has been inserted.

9. Connect the pH optode tip to the fiber optic lead (and the optoelectronic instrument) and place the vial in a darkened measurement chamber on top of a magnetic stirring plate.

10. Repeat exactly the measurements described in steps 4-7 above.

Calculations

1. Calculate the pH response ratio KpH, defined by

$$K_{pH} = R_{opt,pH} / R_{EB,pH}$$

   from the sets of ΔV values obtained from the HCl additions as measured by the pH optode and the biosensor.

2. Use this value of KpH to convert the ΔV values measured by the pH optode (Ropt,obs) to equivalent biosensor values, and from this obtain the pH-corrected biosensor response for each measurement according to:

$$R_{EB}^{*} = R_{EB,obs} - R_{opt,obs}/K_{pH}$$

3. For biosensor measurements of volatile analytes such as 1,2-DCA, the same volume that was to be injected was first removed. This meant that some analyte mass was removed, and a simple mass balance calculation must be performed to correct for this removal.

A sample spreadsheet is provided in Appendix D to illustrate these calculations.

Flow-Through Cell Measurements

The calibration procedure for the flow cell was similar to that in the vials except that the volumes involved were larger and that the primary solution was the groundwater.

1. Collect a groundwater sample from the well (about 50 mL). Completely fill several small vials (e.g., 4.85 mL) with this sample and close with septum caps.

2. In a separate 4.85-mL vial, place a small magnetic stir bar. Fill completely with buffered measurement solution (BMS; 150 mM NaCl, 25 mM CaCl2, and 10 mM MES at pH 7.0). Close the vial with a septum cap through which a biosensor tip has been inserted.

3. Collect a sample from the well (about 50 mL). Record the pH.

4. Create a closed-loop flow system with the flow cell by connecting the outlet and inlet tubing and having the peristaltic pump in-line. Fill this closed-loop system with the groundwater sample, minimizing the headspace. Insert a biosensor in the flow cell and get a steady voltage signal.

5. Spike the flow cell with known volumes of a standard 100 µg/L DCA solution.

6. When each new steady signal has been obtained, calculate the voltage change (ΔV) between the initial and the final values.

7. Remove the biosensor from the flow cell and insert a pH optode in its place. Fill the closed-loop flow-cell system with fresh groundwater sample.

8. Repeat steps 3 and 4 using the same volumes of standard 1,2-DCA solution.

9. Correct the biosensor ΔV readings with their corresponding ΔV values obtained using the pH optode sensor and the KpH (determined separately).

10. Plot the corrected ΔV values against the 1,2-DCA concentrations after each additions to obtain the calibration equation.

11. Convert the flow cell back to the open (flow-through) configuration and begin pumping groundwater through the flow cell.

12. Determine ΔV when a new steady response has been obtained.
13. Determine the concentration of 1,2-DCA in the groundwater from the calibration equation.

Down-Hole Direct Measurement

The strategy for calibrating the biosensors for downhole measurement was slightly different than for the other two methods because standards could not be added directly to the measurement environment (the well). Instead, biosensors to be used in a well were first calibrated in a groundwater-filled vial and then used down-hole.

1. Collect a groundwater sample from the well (about 50 mL) and record the pH. Completely fill several small vials (e.g., 4.85 mL) with this sample and close with septum caps.

2. Open one of these vials, place a small magnetic stir bar inside, and close the vial with a septum cap through which a biosensor tip has been inserted.

3. Connect the biosensor tip to the fiber optic lead (and the optoelectronic instrument) and place the vial in a darkened measurement chamber on top of a magnetic stirring plate.

4. Follow steps 4-7 of the vial measurement calibration procedure.

5. Open a second vial, place a small magnetic stir bar inside, and close the vial with a septum cap through which a pH optode has been inserted.

6. Follow steps 9-10 of the vial measurement calibration procedure.

7. Use the calculations described for the vial measurement calibration procedure to determine REB* for each addition of 1,2-DCA, and make a calibration curve that relates this REB* to the 1,2-DCA concentration.

8. To start the down-hole measurement procedure, place the calibrated biosensor in a new groundwater-filled vial and record the steady signal from the optoelectronic instrument.

9. Remove the biosensor from the vial and lower it into the well. Record the signal at each depth of interest.

10. Changes in signal (ΔV) are calculated between the signal obtained with the biosensor in the vial and those signals measured down-hole. Using the calibration curve produced in step 7, these signal changes can be converted to changes in 1,2-DCA concentration relative to the concentration in the vial. To obtain actual concentration data, the concentration of 1,2-DCA in the vial can be measured in a separate vial test.

Measurement Locations

For the second demonstration of the biosensors, specific monitoring wells were selected based primarily upon:

- The latest 1,2-DCA concentration
- The depth of the screened interval
- The accessibility of the well

Table 3-3 shows the wells that were sampled, the 1,2-DCA concentration detected in samples collected in July 2004 (offsite analyses by GC/MS), and the groundwater zone in which the well is screened.

Table 3-3. Second Demonstration Monitoring Wells for Biosensor Measurements

Monitoring Well	July 2004 1,2-DCA (µg/L)	Groundwater Zone
8MW-06	1,100	Shallow
MW-5	500[1]	Shallow
8MW-33	35	Intermediate
8MW-47	25	Shallow
8MW-35	20	Intermediate
8MW-03	11	Intermediate
8MW-28	<0.12	Intermediate
8MW-25	<0.12	Deep

[1] Sample collected 6/15/04

3.5.8 Demobilization

No major demobilization activities were needed for demonstration of the biosensors. At each monitoring well where the biosensors were used the following was done:

- Monitoring wells were recapped and locked
- The biosensor and optical cable were rinsed with clean water
- All waste solutions were placed in containers and
- Instrument electronics turned off
- Equipment packed and moved to next well

3.6 Selection of Analytical/Testing Methods

Groundwater samples collected from monitoring wells for analytical laboratory analysis were analyzed for VOCs using U.S. Environmental Protection Agency (EPA) Method 8260B, a GC/MS method.

3.7 Selection of Analytical/Testing Laboratory

Laboratory analysis was done by Columbia Analytical (Kelso, Washington) for the first demonstration and by Pace Analytical (Lenexa, Kansas) for the second demonstration.

4.0 Performance Assessment

4.1 Performance Criteria

Performance criteria that were used to evaluate the performance of the biosensors are given in Table 4-1. The performance criteria have been categorized as primary criteria (the project's performance objectives), or secondary criteria.

Table 4-1. Performance Criteria

Performance Criteria	Description	Primary or Secondary
Sample Throughput	Short analysis time in the field	Primary
Mechanical Reliability	Low incidence of mechanical failure	Primary
Versatility	Acceptable performance under various conditions	Primary
Ease of Use	Minimal user training required	Primary
Accuracy	Correlation between biosensor results and GC/MS results	Primary
Precision	Low relative percent deviation between duplicate analyses	Primary
Sensitivity	Detection limit for 1,2-DCA < 5 µg/L	Primary
Range	Accurate results between <5 and 500 µg/L 1,2-DCA	Primary
Hazardous Materials	Little or no hazardous material generated during use of biosensors	Secondary
Process Waste	Little of no process waste generator during biosensor use	Secondary
Factors Affecting Technology Performance	Few interferences and accurate operation possible over a wide range of groundwater quality and field conditions	Secondary
Maintenance	Easily kept in operating order with infrequent part replacement	Secondary
Scale-Up Constraints	Can biosensors be easily produced commercially	Secondary

4.2 Performance Confirmation Methods

The primary method of evaluating the biosensors' performance was to determine the correlation between the biosensor results and the laboratory GC/MS method results for duplicate samples that were collected from the same well. However, other methods, metrics, and criteria were also used to evaluate performance of the biosensors. Table 4-2 presents a summary of these and lists them as either primary criteria (performance objectives) or secondary criteria. Within these two categories, the criteria are further divided as being qualitative or quantitative.

Table 4-2. Expected Performance and Performance Confirmation Methods

Performance Criteria	Expected Performance Metric (pre-demonstration)	Performance Confirmation Method	Actual (post-demonstration)
PRIMARY CRITERIA (Performance Objectives) (Qualitative)			
Sample Throughput	> 6 samples per day	Experience from demonstration operation	For vial measurements, > 6 samples per day
Mechanical Reliability	Low breakdown incidence	Experience from demonstration operation	Further development needed to improve mechanical reliability of biosensor tips. Hardware reliability was high.
Versatility	Applicability to all conditions tested	Comparison of results from different wells and laboratory testing	Further development needed for the biosensors to address interference of pH on measurements.
Ease of Use	Operator training and labor required similar to other field equipment	Comparison to operator requirements for other commonly used field instruments	Ease of operation similar to other field instruments, although calibration could be simplified.
PRIMARY CRITERIA (Performance Objectives) (Quantitative)			
Accuracy	Relative Percent Difference (RPD) < 25 percent (the RPD for EPA Method 8060B) $r^2 > 0.9$	Correlation with GC/MS reference method.	Accuracy was dependent on ability to correct for non-analyte related pH changes. For vial measurements: $r^2 = 0.934$
Precision	RPD for biosensor equal to or less than RPD for reference method	RPD between replicates taking into account best RPD attained with the GC/MS reference method.	Average RPD for vial measurements: 45.6% Overall, RPDs higher than reference method.
Sensitivity	Detection limit for 1,2-DCA < 5 µg/L	Detection of 1,2-DCA concentrations less than 5 µg/L as determined by GC/MS reference method.	Detection limit for 1,2-DCA < 5 µg/L.

Table 4-2. Expected Performance and Performance Confirmation Methods

Performance Criteria	Expected Performance Metric (pre-demonstration)	Performance Confirmation Method	Actual (post-demonstration)
Range	> 500 µg/L 1,2-DCA	Ability to quantify 1,2-DCA concentrations greater than 500 µg/L as determined by GC/MS reference method.	> 500 µg/L 1,2-DCA.
SECONDARY PERFORMANCE CRITERIA (Qualitative)			
Hazardous Materials	No hazardous materials produced	Evaluate materials needed for operation	No hazardous materials produced
Process Waste	No process waste produced	Observation	No process waste produced.
Factors Affecting Performance ▪ throughput ▪ groundwater quality	▪ analysis rate ≥ 6 samples/day ▪ no interferences under typical groundwater conditions	▪ time/sample analysis ▪ performance not affected by groundwater characteristics	▪ analysis rate ≥ 6 samples/day ▪ in some cases, pH changes interfered with biosensor analysis
Maintenance	Maintenance requirements similar to other field instruments	Comparison of field records to operator requirements for other commonly used field instruments	Biosensor tips need refrigeration and have a finite shelf life. Durability of tip could be improved. Hardware maintenance not dissimilar to other field instruments.
Scale up Constraints	No commercialization constraints	Investigate ability to easily produce commercially	Likely no commercialization constraints; however, depends on further development results.

4.3 Data Analysis, Interpretation, and Evaluation

This section presents the results for the various types of biosensor measurements taken during the second demonstration at SUBASE Bangor. The first demonstration was ineffective due to damage to the biosensor hardware during shipping to the site. The hardware was repaired on-site; however, few useable measurements were collected. As previously discussed, valuable experience was obtained during the first demonstration (logistics, sampling methods, field calibration, etc.) The following sections describe results from the second demonstration.

4.3.1 Vial Measurements

Results of the biosensor and the offsite laboratory measurements (GC/MS) are summarized in Table 4-3. Daily field report forms for the biosensor measurements are provided in Appendix B. Laboratory reports for the vial measurements are provided in Appendix C. The biosensor results for these measurements are plotted against results of the laboratory method (GC/MS) in Figures 4-1a and b. The correlation coefficient (r^2 value) for the two methods was 0.934. This indicates good agreement between biosensor readings and the laboratory results under the conditions of the vial measurements.

Figure 4-1b shows the biosensor results for vial measurements plotted against the laboratory GC/MS results. The one-to-one correlation line is shown as the dashed line. The 50% and 100% error lines represent the areas of the graph where points must fall to be within 50 and 100% of the one-to-one correlation.

Table 4-3 also presents the RPD values for the biosensor and laboratory analyses. The average RPD for nine vial samples was 45.6 %, with a range of 16.2 to 80.0%. This is greater than the RPD for the reference method (EPA Method 8260B for GC/MS) of 25%.

Table 4-3 data show that samples with high 1,2-DCA concentrations had high concentrations of aromatic VOCs (e.g., benzene). No correlation between aromatic VOC concentrations or chlorinated VOC concentrations and the RPD of laboratory and biosensor measurements were observed. This indicates that the biosensors were not affected by the presence of relatively high concentrations of these co-contaminants.

The vial measurement results indicate that at their current state of development, the biosensors would be appropriately used as a Level 1 instrument, providing semi-quantitative screening concentration data.

4.3.2 Flow-Through Cell Measurements

Flow-through cell measurements were taken with the biosensors at two monitoring wells – 8MW47 and 8MW33. Figure 4-2 shows the setup for taking biosensor readings in a flow-through cell. As biosensor readings were taken in the flow-through cell, measurements of pH, specific conductivity, temperature, ORP, and DO were also recorded.

8MW47

Figure 4-3 shows the flow-through cell setup at 8MW47. Figures 4-4, 4-5, and 4-6 show the flow-through cell biosensor readings plotted along with pH, ORP, and DO readings, respectively. Since flow-through cell measurements are frequently used to indicate when a well has been pumped sufficiently to allow for sampling of groundwater, it is of interest to note that the biosensor measurements were steady before ORP and at about the same time as DO and pH. The data in these three figures do not indicate a strong correlation between ORP or DO with the biosensor response (and none is expected). Since the biosensor signal is composed of a response to the analyte concentration as well as a response to the environmental pH (see Section 3.5.7.2), some correlation of the biosensor response with pH signal might be expected. This was not the case in the first 15 minutes of the test, suggesting that changes in analyte concentration were dominant during this period (recall that lower biosensor signal indicates increased analyte concentration). These two effects could be resolved by including a second optical fiber on the instrument for measurement of pH.

8MW33

Figures 4-7 and 4-8 show the flow-through cell setup at 8MW33. Figures 4-9, 4-10, and 4-11 show the flow-through cell biosensor readings plotted along with pH, ORP, and DO readings, respectively.

The results were similar to those obtained from 8MW47 in that the biosensor measurements did not correlate with ORP or DO. The influence of pH on the biosensor measurements can be noted when the two data sets are parallel (after approximately 15 minutes of pumping). However, in the initial phase of the experiment, the biosensor and pH measurements change at different rates, indicating that the biosensor measurements reached a steady value earlier. Inclusion of an optical pH measurement as a second channel on the biosensor instrument would allow analyte measurements to be separated from these environmental pH changes (not related directly to the analyte).

Overall, the results indicate that the biosensors can be used to determine when water quality during pumping and sampling has reached stable conditions. At these wells (at least 8MW33), the water could have been sampled earlier based on the stable biosensor readings. The results are classified as Level 1.

4.3.3 Down-Hole Profiling

A biosensor was placed in a protective sheath (Figure 4-12) to take measurements down-hole for the purpose of defining the 1,2-DCA vertical profile within a monitoring well. This setup was lowered into well 8MW47 and readings were recorded at 2-foot intervals from the water table to the bottom of the screened zone. The results are shown in Figure 4-13. This figure shows measurements in millivolts because calibration procedures for a flow-through setup have not yet been developed to effectively translate millivolts readings to 1,2-DCA concentrations. Although a firm assessment of 1,2-DCA concentrations can not be made without having an optical pH measurement at the same location as the biosensor, a preliminary evaluation of the data in Figure 4-13 suggests that the concentration of 1,2-DCA was highest at the surface, decreased over the next 5 feet until a layer of higher concentration was reached, then decreased again (recall from Figure 2-3 that higher 1,2-DCA concentrations lead to lower fluorescence measurements). Small amounts of LNAPL were encountered in this well, and thus it is possible that the high surface concentrations were caused by 1,2-DCA that was partitioned into the LNAPL.

These biosensor readings may be among the first near real time readings to allow detection of varying 1,2-DCA concentrations with varying hydraulic conductivity in a vertical profile. The results clearly show that stratification within the screened interval occurs. Therefore, the typical pumped samples will depend on placement of the pump and the mixing of stratification that occurs. Development of a tool to measure stratification in situ is a significant advancement. The results are classified as Level 1 (no quantitative data were obtained). However, estimates of the changes in concentrations between the depths were made and the changes were significant.

4.3.4 Sentinel Well Measurements

A biosensor was placed down-hole in the protective sheath used for down-hole profiling in monitoring well 8MW-47 and was left in place for 24 hours. Periodically, readings were recorded by connecting the hardware to the biosensor. The results are shown in Figure 4-14. The biosensor signal decreased about 20% over the first 18 hours and the signal was essentially constant from 15 to 18 hours. However, the biosensor output then dropped another 65% in the next 6 hours. Since the biosensors were shown to have significantly longer lifetimes in laboratory studies (Figures 2-28 and 2-29), the observed decline was expected to be caused by a factor other than loss of enzyme activity. Visual inspection of the tip of the biosensor after 24 hours down-hole indicated the alginate layer containing the bacteria (and enzyme) had become detached from the tip. If the biosensors are to be used in a down-hole mode, then the biosensor tips need to be stabilized to allow for long-term immersion in groundwater. This can be accomplished by cross-linking the alginate polymer or by choosing a different immobilization matrix.

4.3.5 Conclusions

In general, the biosensors functioned as Level 1 measurement devices and provided measurements that were not impacted by the presence of other groundwater contaminants. When used in flow-through cells and for vertical profiling, the biosensors produced significant data that were not readily available by other means. Three factors that limit the performance and utility of this measurement technology must be addressed:

1. The influence of pH on the biosensor measurement -- Because the biosensor measures small pH changes produced by the reaction of an enzyme with 1,2-DCA, methods are required to distinguish these pH changes from pH changes due to other processes. This can readily be accomplished by adding an optical fiber (bundled with the biosensor) and a second measurement channel to the hardware, thus providing optical pH measurement for correction of the pH changes.

2. Calibration Procedures –An adequate calibration procedure has been developed for vial measurements; however, calibration procedures must still be developed for flow-through cell and down-hole measurements

3. Robustness – The biosensor tips should be designed to be more durable. Methods to do this (e.g., cross-linking the alginate layer) have been tested in the laboratory and appear to be feasible.

The biosensors can be used to collect Level 2 data when used in the vial measurement mode; however, further investigation into development and testing of the biosensors is required for them to be reliable field instruments for all of the applications originally intended.

4.4 Publication of Results

The following is a list of publications and presentations regarding biosensor development and testing:

Acha, V. and K.F. Reardon. Measurement of 1,2-Dichloroethane at pM Levels using a Dehalogenase-Based Fiber-Optic Biosensor. In preparation.

Acha, V. and K.F. Reardon. Fiber-Optic Biosensor Measurement of Trichloroethene. In preparation.

Acha, V., C. Jensen, J.J. Eisenbeis, R.L. Olsen, and K.F. Reardon. Field Measurements of 1,2-Dichloroethane in Groundwater using Fiber-Optic Biosensors. In preparation.

Acha, V. and K.F. Reardon. Fiber-Optic Biosensor Development for the Detection of Paraoxon at pM Levels. In preparation.

Acha, V. and K.F. Reardon. Fiber-Optic Biosensor Development for the Detection of Atrazine at Parts-per-Trillion Levels. In preparation.

Acha, V. and K.F. Reardon. Comparison of Dehalogenases for Detection of Halogenated Methanes using Fiber-Optic Biosensors. In preparation.

Acha, V. and K.F. Reardon. Sensitive Detection of Halogenated Pesticides using Fiber-Optic Biosensors based on LinB Haloalkane Dehalogenase. In preparation.

Acha, V., W.B. Willis, N. Das, and K.F. Reardon. 2003. Fiber Optic Biosensors for Halogenated Organics in Ground Water. Proceedings of the 225th American Chemical Society National Meeting.

Presentations (reverse chronological order))

Reardon, K.F., V. Acha, C.D. Jensen, D.S. Dandy, K.L. Lear, J.J. Eisenbeis, and R.L Olsen. 2004. Field Measurements of Groundwater Contaminants using Fiber Optic Enzymatic Biosensors. Annual Meeting of the American Institute of Chemical Engineers, Austin, TX, 7-12 November.

Acha, V. and K.F. Reardon. 2003. Laboratory and Field Measurements of Groundwater Contaminants with Fiber Optic Biosensors. Annual Meeting of the American Institute of Chemical Engineers, San Francisco, CA, November 16-21.

Acha, V., W.B. Willis, N. Das, and K.F. Reardon. 2003. Fiber Optic Biosensors for Halogenated Organics in Ground Water. 225th American Chemical Society National Meeting, New Orleans, LA, March 23-27.

Reardon, K.F., W.B. Willis, M.O. Herigstad, J.J. Eisenbeis, and R.L. Olsen. 2002. Use of Fiber Optic Biosensors to Monitor Dichloroethane in Groundwater. 3rd International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA, May 20-23.

Willis, W.B. and K.F. Reardon. 2001. Environmental Effects on Biosensor Quantification of Ethylene Dibromide in Groundwater. Annual Meeting of the American Institute of Chemical Engineers, Reno, NV, November 4-9.

Table 4-3. Comparison Of Biosensor And Laboratory (GC/MS) Measurements Of 1,2-DCA Concentrations From Second Demonstration Sampling, Along With Laboratory Data On Co-Contaminants In Each Well.

Well	Lab DCA (µg/L)	Biosensor DCA (µg/L)	RPD (%)	Aromatic VOCs (µg/L)	Chlorinated VOCs (µg/L)
8MW35	17	10	51.8	ND	18.4
8MW33	18	38	71.4	ND	55
8MW33	19	15	23.5	78	51
8MW33	18	36	66.7	77	52
MW-05	900	475	61.8	14,090	1,520
8MW49	730	610	17.9	40,460	730
8MW06	990	842	16.2	4,548	1,031
8MW25	< 1	< 27*	-	ND	ND
8MW03	6	14	80.0	ND	6
8MW47	600	483	21.6	38,100	600
8MW08	<20	<107*	-	9,780	58
Average			45.6		

* Unreliable delta V/pH (pho)

Table 4-4. Comparison Of Biosensor And Laboratory (GC/MS) Measurements Of 1,2-DCA Concentrations From Second Demonstration Sampling, Along With Field Parameter Results For Sampled Groundwater.

Well	Laboratory DCA (µg/L)	Biosensor DCA (µg/L)	pH (S.U.)	ORP (mV)	DO (mg/L)	Spec. Cond. (µS/cm)
8MW35	17	10	6.7	132	0.07	128
8MW33	18,19, 18	38, 15, 36	7.1	92	0.11	346
MW-05	900	475	6.5	-46	0.13	457
8MW25	<1	<27	6.6	22	1.11	131
8MW03	6	14	6.7	46	1.63	140
8MW47	600	483	6.7	-59	0.09	704
8MW08	<20	13	6.6	6	1.18	764

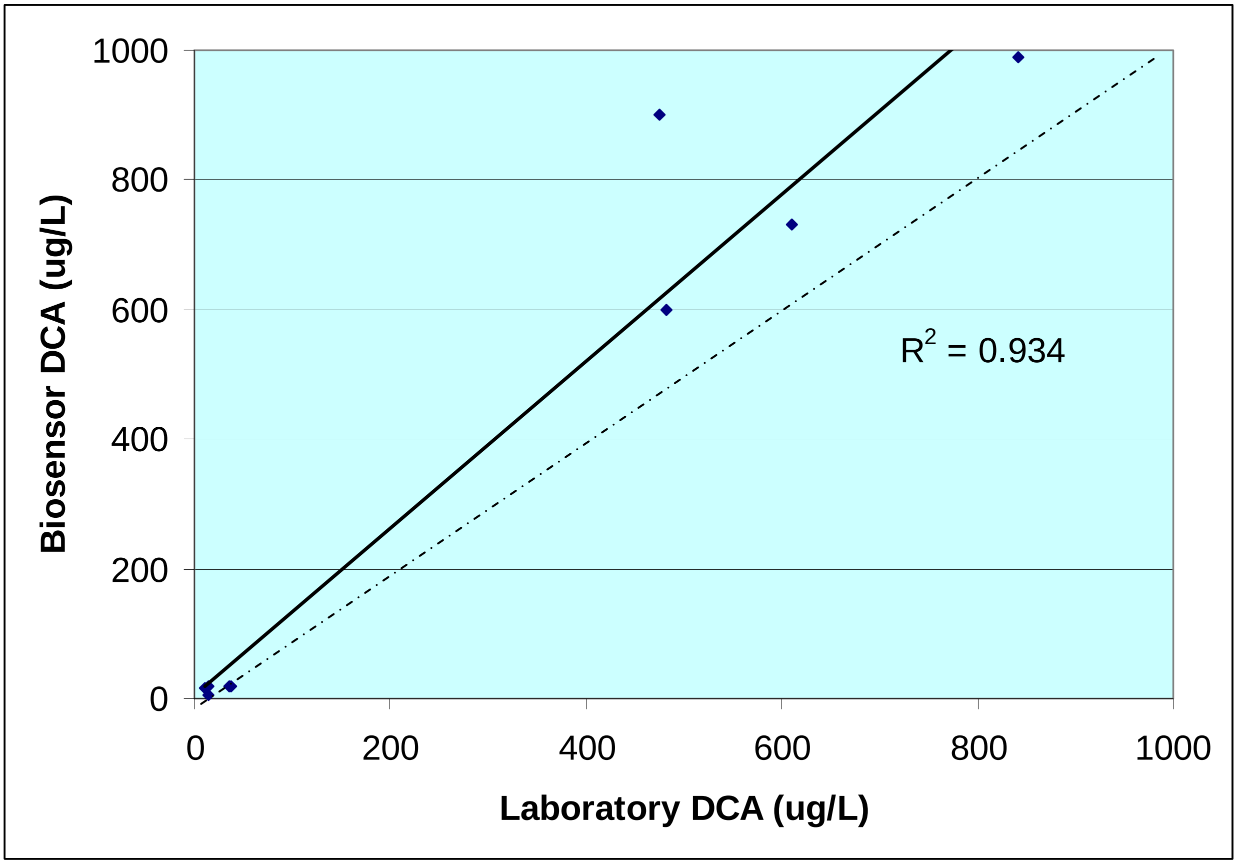


Figure 4-1a. Correlation between biosensor and laboratory results
(dashed line is the one-to-one correlation line)

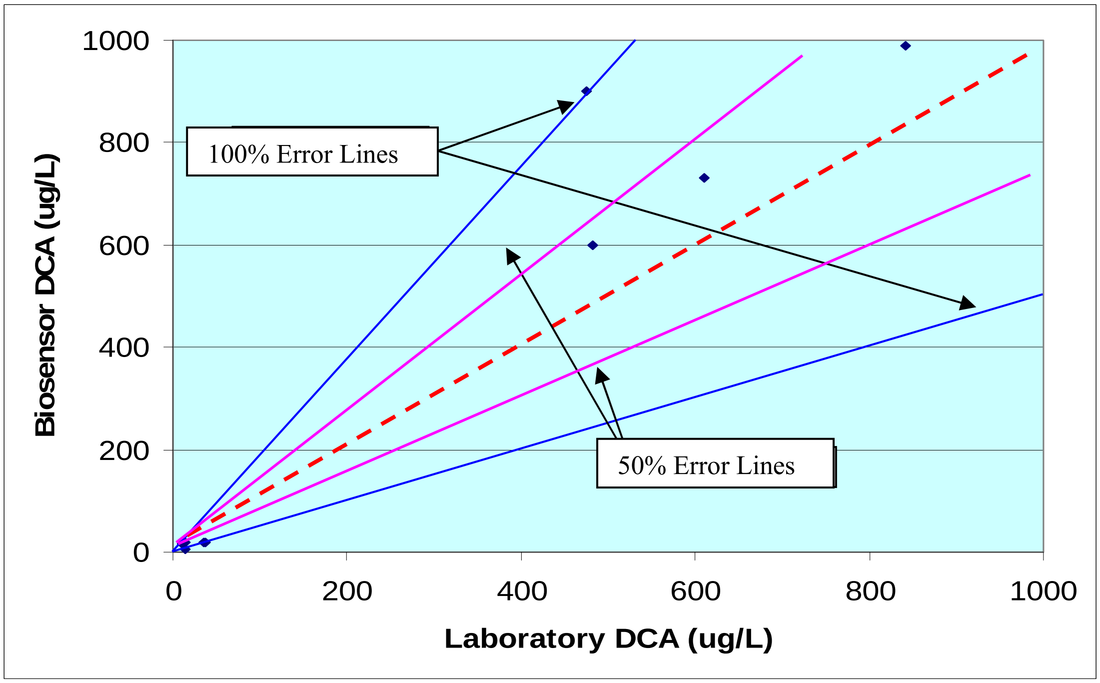


Figure 4-1b. Biosensor and laboratory results for vial samples shown with percent error lines.

Figure 4-2. Flow-through cell set up

Figure 4-3. Flow-through cell set up at 8MW47

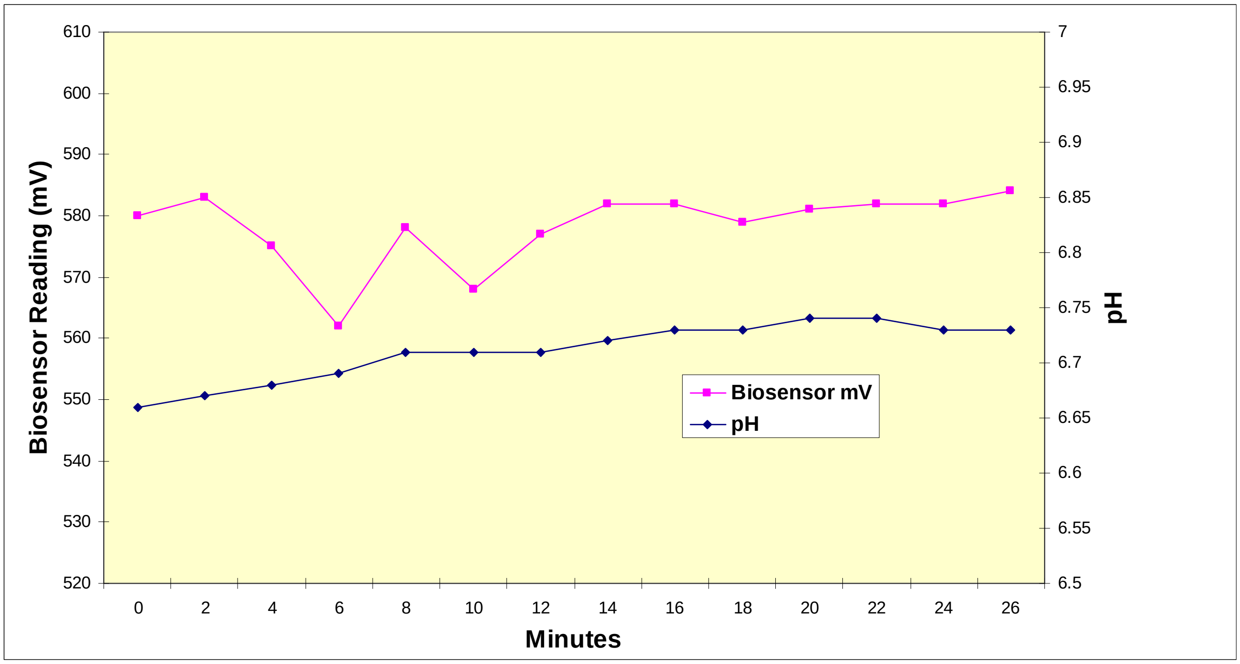


Figure 4-4. Flow-through cell results at 8MW47 – pH vs. biosensor readings

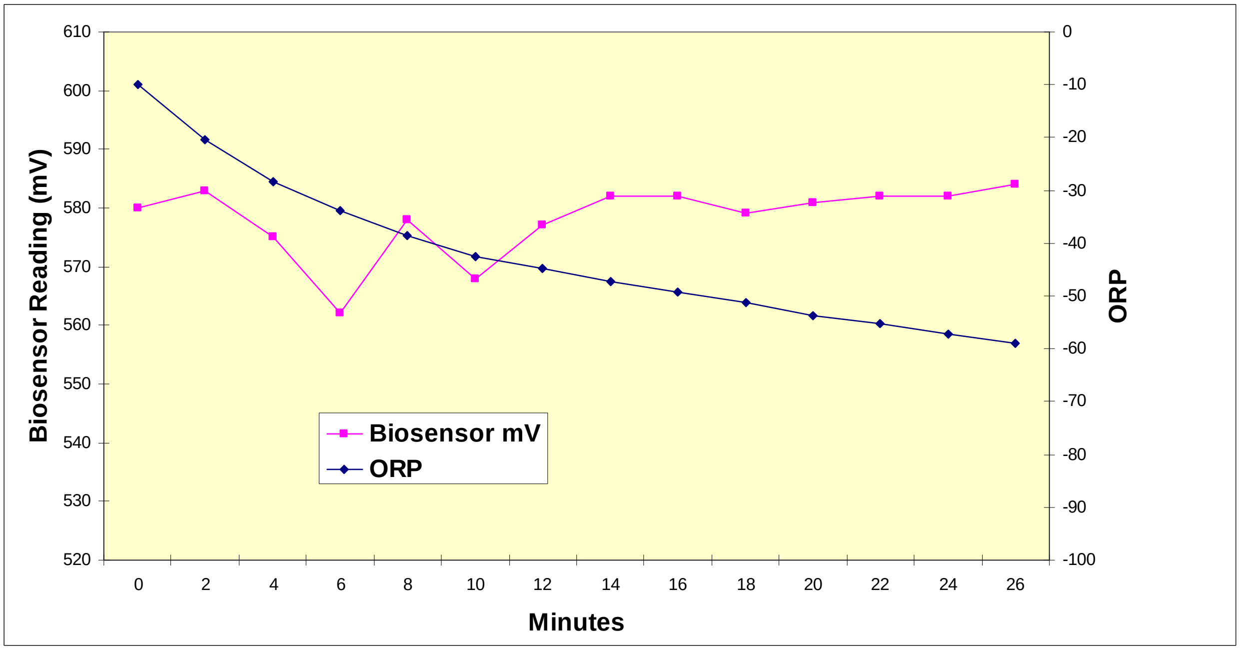


Figure 4-5. Flow-through cell results at 8MW47 – ORP vs. biosensor reading

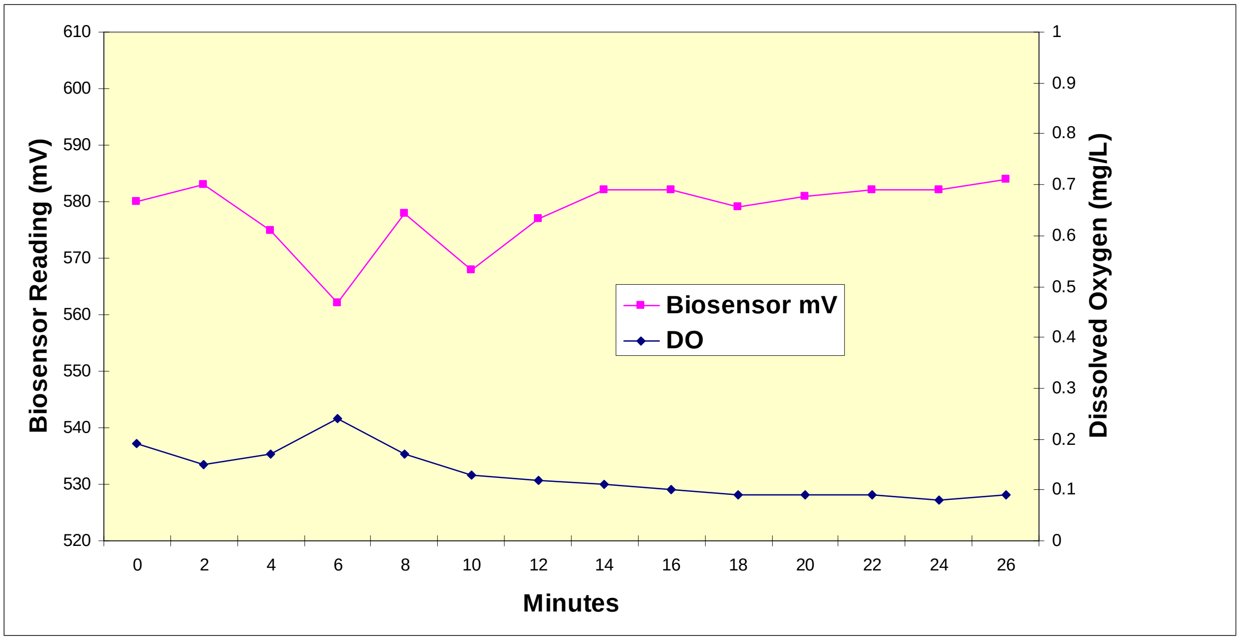


Figure 4-6. Flow-through cell results at 8MW47 – DO vs. biosensor reading

Figure 4-7. Flow-through setup at 8MW33.

Figure 4-8. Flow-through cell readout setup.

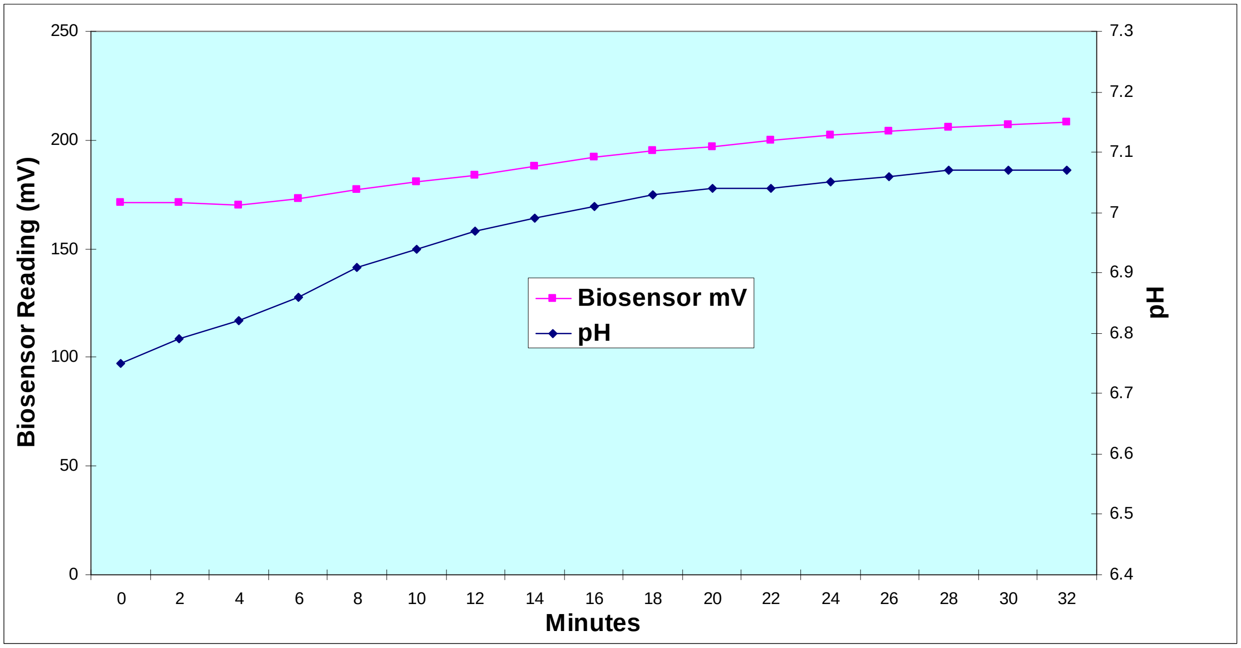


Figure 4-9. Flow-through cell results at 8MW33 – pH vs. biosensor reading

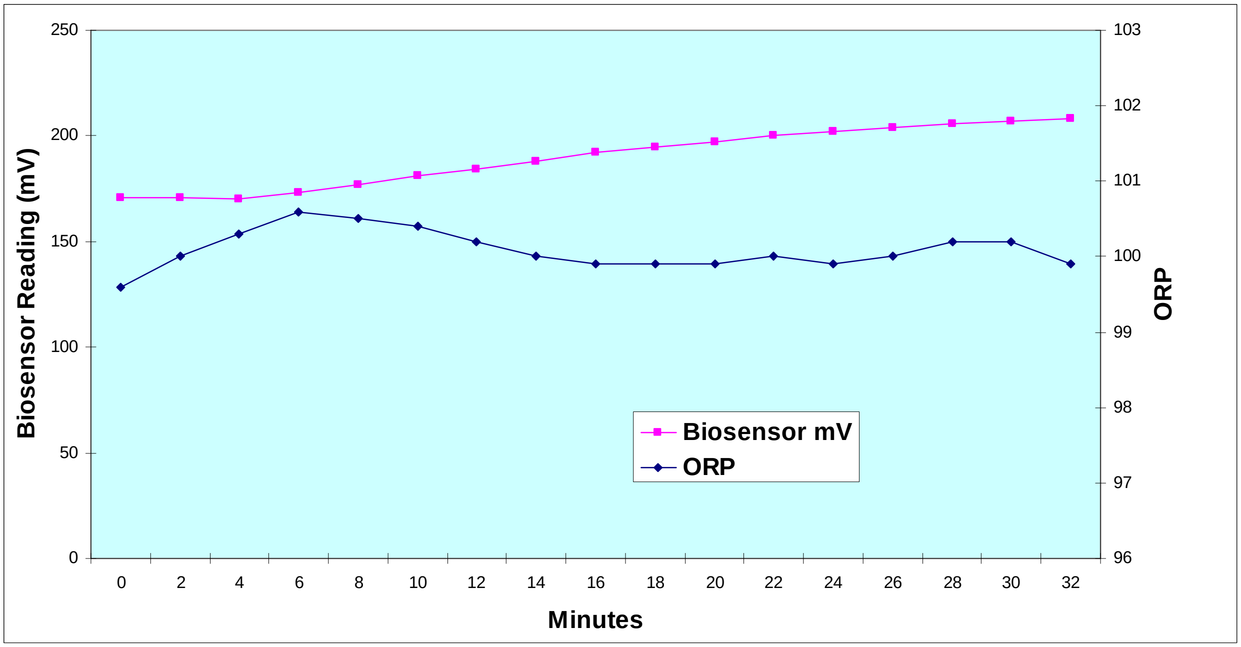


Figure 4-10. Flow-through cell results at 8MW33 – ORP vs. biosensor reading

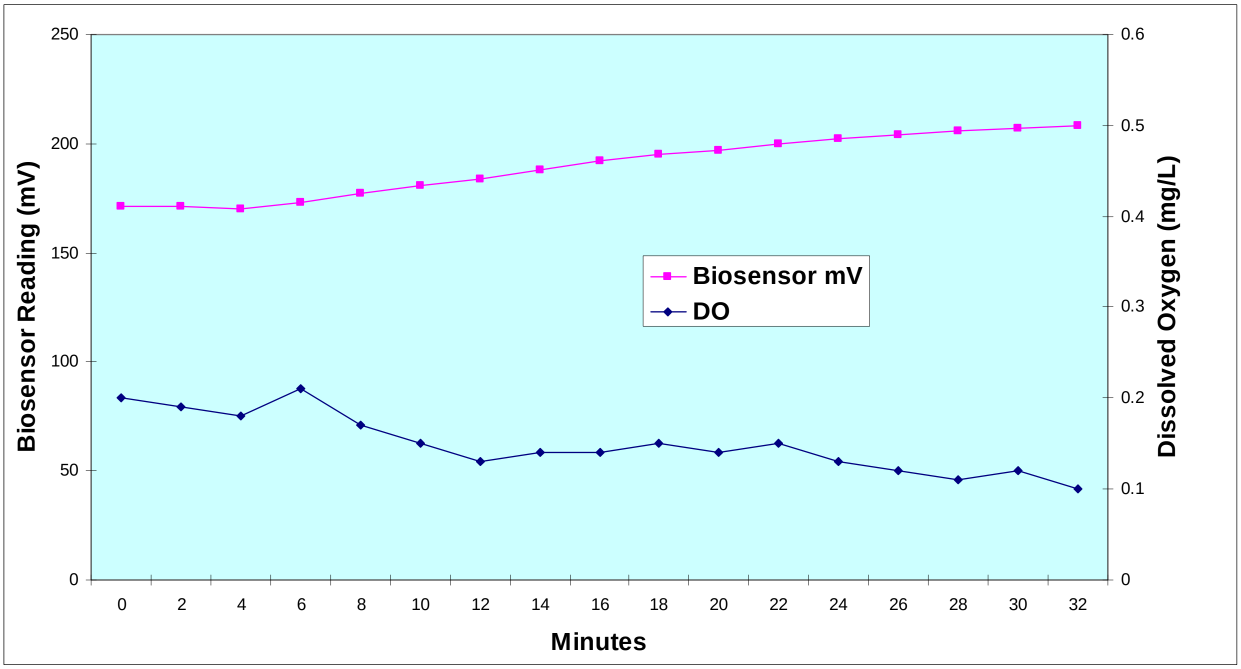


Figure 4-11. Flow-through cell results at 8MW33 – DO vs. biosensor reading

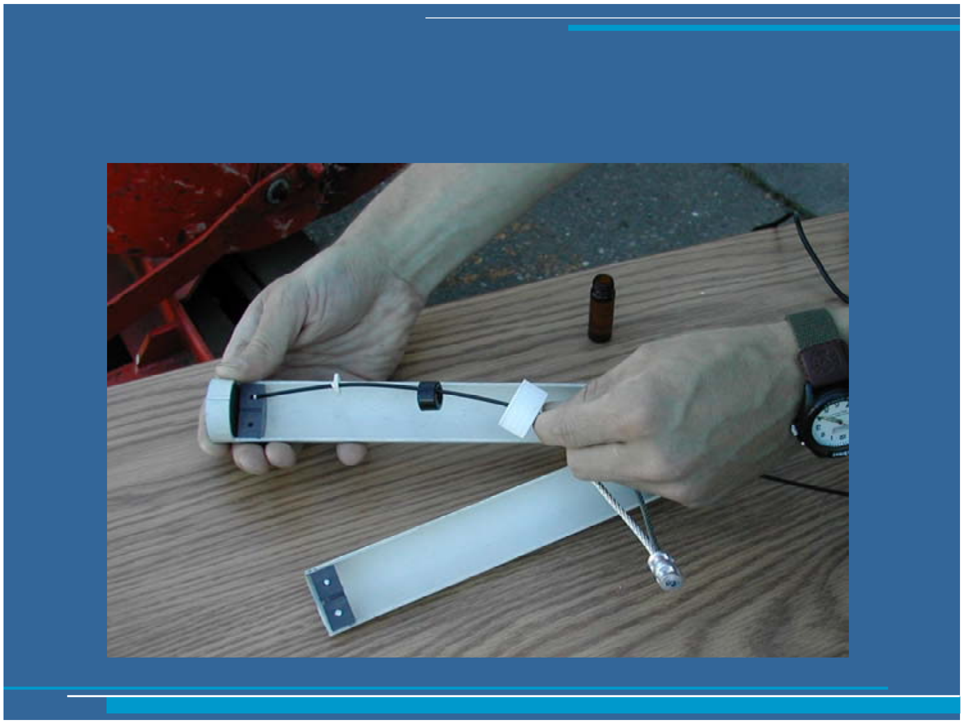


Figure 4-12. Down-hole profiling setup.

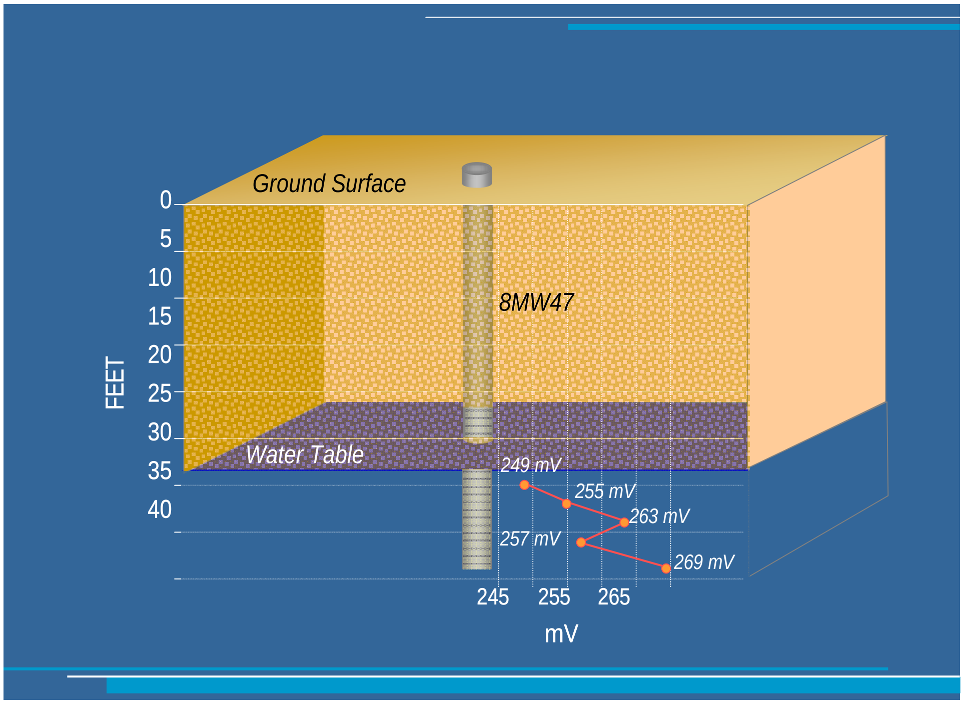


Figure 4-13. Down-hole profiling results (biosensor readings vs. depth)

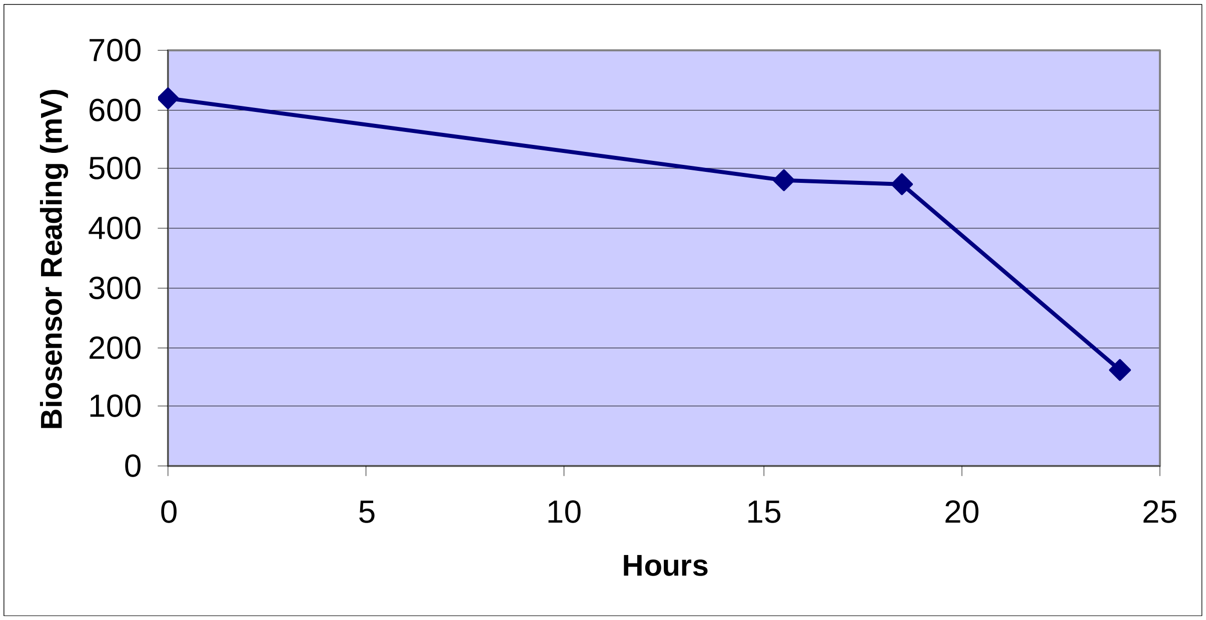


Figure 4-14. Sentinel well results for 8MW47

5.0 Cost Assessment

5.1 Cost Reporting/Analysis

Given the developmental requirements of the biosensors before they can be commercialized and at ESTCP's direction (telephone communication from Dr. Andrea Leeson, December 2005), no costs for their use have been developed at this time.

After further development, the potential benefits of using biosensors in groundwater monitoring can be assessed by comparing the costs associated with biosensor use with conventional monitoring methods (i.e., laboratory using methods similar to EPA Method 8260) on a per well basis as well as on a sampling event basis.

The primary cost driver for the biosensor technology is the capital cost of the optical-electronic system that includes the light source and detection units. Although the cost of this unit is currently approximately $5,000, the figure is for custom construction. If manufactured commercially, the price would be substantially lower.

One cost issue with biosensors is the length of time a biosensor tip will last during regular use. To date, biosensor tips have been prepared with very good activity retention over 10 days and further improvements are anticipated. However, the biosensor tips themselves are inexpensive to prepare and thus should not be costly to purchase. Installation of new tips and disposal of old ones is not labor intensive. Recalibration must be done periodically, regardless of whether a new tip has been installed or an old tip is being used in a new location.

6.0 Implementation Issues

6.1 Environmental Checklist

No permits would be needed to operate the biosensors.

6.2 Other Regulatory Issues

Comparison of the biosensor results to conventional results will be necessary to obtain regulatory approval of biosensor use. With respect to execution of the demonstration, minimal regulatory involvement was needed since this was a demonstration of analytical technology and not of a remediation technology.

6.3 End-User Issues

Potential end-user issues that exist for the use of biosensors for groundwater monitoring include:

- Is the instrument easy to use?
- Is calibration an easy process?
- Are the results accurate and repeatable for conditions at the site?
- What is the detection limit and does it change with changing conditions?
- Can biosensors detect other and/or multiple compounds?

The demonstration was designed to address each of these issues. Ease of use and calibration procedures were documented. The evaluation criteria that have been presented for comparing biosensor and convention laboratory method results address accuracy, interference, and detection limit issues.

After the required additional development, procurement of the biosensor technology is expected to be straightforward. Although CSU is pursuing patent protection for this technology (a provisional patent application, Reardon, K.F. and N. Das, *Optical Biosensor with Enhanced Activity Retention for Detection of Halogenated Organic Compounds* has been filed), this is being done with the purpose of providing incentive for an equipment manufacturer that would require intellectual property protection to commercialize the device. The goal is to license the patent to such a company, which would then manufacture the biosensors commercially with no restrictions; i.e., the biosensors would be available to DoD and remediation professionals similar to oxygen and pH sensors.

6.3.1 Future Development Needs

This demonstration showed that while the biosensors are not yet ready for commercialization, with further development they can be a valuable tool for providing accurate field analyses of several groundwater contaminants. This further development needs to focus on:

- Improving calibration methods to increase accuracy and precision

- Improving field usability
- Adding multi-channel capability to hardware to facilitate calibration and analyze multiple compounds

Also, the long-term performance of this sensor technology is an important factor for its commercialization. Although this performance characteristic was not within the scope of this demonstration, we have evidence from laboratory tests that storage lifetimes of at least 50 days are possible with less than 10% loss in sensitivity. If sensitivity loss is limited to the same, low rate when the biosensors are in frequent or continual use, this would mean that recalibration would need to occur only weekly in the vial or depth profiling measurement modes. For down-hole monitoring, that rate of sensitivity loss would mean that the biosensors would need to be recalibrated every 50 days to retain accuracy within 10%. However, if only semi-quantitative or presence/absence signals are required, recalibration could occur much less frequently. Future research could target this aspect of the biosensor performance. Once the cause(s) of sensitivity loss (e.g., enzyme leakage from the biosensor tip, enzyme degradation, fluorophore bleaching) are evaluated, the appropriate re-design could take place.

7.0 References

CDM and CSU, 2001. *Demonstration Plan – Fiber Optic Biosensors for Contaminant Monitoring – ESTCP Project Number CU-0115* September

The Environmental Company. 2001. Environmental Services Monitoring - Long-Term Monitoring. Draft Round 3 Monitoring Report - Monitored Natural Attenuation OU8 Naval Submarine Base Bangor, Bangor, Washington. June.

The Environmental Company. 2000. *Final Site Specific Health and Safety Plan Monitoring Natural Attenuation Operable Unit 8 Submarine Base Bangor Washington.* October 30.

ESTCP (Environmental Security Technology Certification Program). 2000. *Demonstration Plan Guidance for Cleanup, Site Characterization, and UXO Projects.* June.

Reardon, K.F. and N. Das. 2001. *Optical Biosensor with Enhanced Activity Retention for Detection of Halogenated Organic Compounds*. Provisional Patent Application.

Reardon, K.F., D.W. Campbell, and C. Müller. 1998. *Biosensor for Halogenated Hydrocarbons*. Provisional Patent Application 60/099,890.

8.0 Points of Contact

Point of Contact	Organization Address	Phone/Fax/e-mail	Role in Project
Roger Olsen	CDM 1331 17th St. Ste 1200 Denver, CO 80202	p) 303-298-1311 f) 303-293-8236 olsenrl@cdm.com	PI
Ken Reardon	CSU Dept. Chem. Eng. 200 West Lake Fort Collins, Co 80523-1370	p) 970-491-6505 f) 970-491-7369	Technical Lead
Herbert Fredrickson	U.S. Army Engineer Research & Development Center Environmental Laboratory at Waterways Experiment Station CEERD-EP 3909 Halls Ferry Road Vicksburg, Mississippi 39180-6199	p) 601-634-3716 f) 601-634-3410 fredrih@wes.army.mil	Contract Office Rep.
Andrea Leeson	SERDP/ESTCP Cleanup Program Mgr. 901 Stuart St., Suite 303 Arlington, VA 22203	p) 703-696-2118 f) 703-696-2114	Reviewer

Roger L. Olsen, Ph. D. Date
Principal Investigator
Camp Dresser & McKee, Inc.

Appendix A
SUBASE Bangor
Site Information

Table F-1 Site Selection Information for SUBASE Bangor

(Source: EA, January 2000)

Well Information		
Number of wells	76	
Well depth	Shallow Wells: are screened within 30 ft below the water table	
	Intermediate Wells are screened within the middle 40 ft of the Vashon aquifer thickness	
	Deep Wells are screened within 30 ft of Lawton Clay	
Well development	Yes	
Extraction flow rate	500 mL /minute	
Groundwater Information		
Depth to GW	19 – 22 ft bgs (EFA NW comments 10/25/00)	
Groundwater sampling	Low-flow purge sampling techniques w/ peristaltic pump	
Aquifer thickness	(approximately 125 ft thick in public works area)	
GW flow direction	Southeast	
Hydraulic conductivity	67 ft/day	
Soil Information		
Soil Types	**Thickness**	**Depth (ft)**
Construction Fill		2 to 3 ft bgs
Vashon Till	20 to 40 ft	15 to 45 ft bgs
Vashon Advanced Outwash	100 to 130 ft	30 to 160 ft bgs
Silty Transition zone	20 to 50 ft	110 to 160 ft bgs
Lawton Clay		100 to 160 ft bgs

Contaminant Information (Based on wells in Appendix A, EA, January, 2000)

Contaminants	**Depth to Contaminants**	**Max. (µg/L)**	**Min. (µg/L)**	**Average (µg/L)**
1,2-DCA	Shallow	1500	0	214
Benzene	Shallow	7800	0	1330
1,1,2-TCA	Shallow	2.1	0	0.16

Contaminants	**Depth to contaminants**	**Max. (µg/L)**	**Min. µg/L)**	**Average (µg/L)**
1,2-DCA	Intermediate	48	0	8.9
Benzene	Intermediate	2.3	0	0.30
1,1,2-TCA	Intermediate	29	0	3.5

	Shallow				**Intermediate**	
Groundwater Chemistry	**Max.**	**Min.**	**Average**	**Max.**	**Min.**	**Average**
Turbidity (NTU)	644	0	220	280	0	53
Temperature (C)	27.4	10.22	14.6	24.9	10.1	14.1
Sulfide (mg/L)	1.2	0	0.16	0	0	0
Sulfate (mg/L)	27	0	6.7	12	5	6.6
pH	7.24	6	6.54	7.42	6.25	6.91
BOD(mg/L)	34.5	0	11.7	0	0	0
Nitrite (mg-N/L)	0.57	0	0.04	0	0	0
Nitrate (mg-N/L)	4	0	0.52	1.0	0	0.31
N as Ammonia (mg/L)	0.47	0	0.21	0.26	0.11	0.16
Methane (mg/L)	1.48	0	0.14	0.02	0	0
Manganese (µg/L)	6730	0	3410	2700	0	400
Iron-II (mg/L)	1.35	0.04	1.35	1.4	0	0.34
Iron (µg/L)	15200	0	2460	734	0	116
Hydrogen (nM)	36.72	0	4.0	10.84	0	1.82
Eh (mV)	187	-217	-9.2	149	-26	63.9
DO (mg/L)	7.7	0	1.6	4.63	0.08	1.22
Conductivity (mS/cm)	0.86	.095	0.42	0.28	0.1	0.17
Chloride (mg/L)	61	2.8	11.3	7.7	1.4	3.8
TIC (mg/L)	128	13.2	79.3	55	14.4	26.6
TOC (mg/L)	114	0	16.1	2.1	0	0.52
Carbon dioxide (mg/L)	400	47.8	190	118	20	51.8
Bromide (mg/L)	1.1	0	0.23	0	0	0
Total Alkalinity	447	61.2	242	276	58.4	123

Appendix B
Daily Field Reports

Biosensor Measurement Datasheet

Second Bangor Demonstration, September 2004

40 mL Vial Number: mow-1-1 (B)
Biosensor ID: 422
pH Optode ID: 105
pH Optode Sensitivity: 32 **PMT:** 600V

Analyst: Victor ACHA
Date: 09/20/04
Time:

Checked By:
Date Checked:

Subsample Number (4.85 mL Vial)	Biosensor or Optode Reading?	Step Number	Step Description	Solution Removed and Volume (uL)	Solution Added and Volume (uL)	Start Time	Start Volts	End Time	End Volts	Delta T	Delta V
	Bio	1	mow-1-1	100	100	8:23	6.66	8:30	6.355	7	0.306
	BIO	2	dca (100ppb)	50	50	8:33	6.363	8:42	6.115	9	0.248
	BIO	3	dca (100ppb)	25	25	8:49	5.97	9:07	5.369	18	0.601
	BIO	4	dca (100ppb	75	75	9:16	4.305	9:34	3.258	18	1.047
	BIO	5	HCl (1mM)	50	50	9:36	3.31	9:40	3.02	4	0.29
	BIO	6	HCl (1mM)	25	25	9:43	3.01	9:47	2.77	4	0.24
	BIO	7	HCl (1mM)	75	75	9:50	2.75	9:58	2.37	8	0.378
	pH opt	8	mow-1-1	100	100	10:01	9.732	10:04	9.37	3	0.362
	pH opt	9	DCA (100ppb)	50	50	10:05	9.37	10:12	8.62	5	0.75
	pH opt	10	DCA (100ppb)	25	25	10:14	8.64	10:20	8.06	6	0.58 0.58
	pH opt	11	DCA (100ppb)	75	75	10:21	8.00	10:28	6.98	6	1.02
	pH opt	12	ACl (1mM)	50	50	10:30	7.54	10:37	7.38	7	0.16
	pH opt	13	HCl (1mM)	25	25	10:38	7.37	10:49	6.86	11	0.51
	pH opt	14	HCl (1mM)	75	75	10:50	6.86	10:57	6.18	7	0.68

Comments:

Uncorrected DCA Concentration of Unknown (ug/L) =

Corrected DCA Concentration of Unknown (ug/L) =

Biosensor Measurement Datasheet
Second Bangor Demonstration, September 2004

40 mL Vial Number: MOW-1-1
Biosensor ID: 422
pH Optode ID: 105
pH Optode Sensitivity: 32 **PMT:** 600

Analyst: Victor ACHA
Date: 09/20/04
Time: 2:11 PM

Checked By:
Date Checked:

Subsample Number (4.85 mL Vial)	Biosensor or Optode Reading?	Step Number	Step Description	Solution Removed and Volume (uL)	Solution Added and Volume (uL)	Start Time	Start Volts	End Time	End Volts	Delta T	Delta V
	Bio	1	MOW-1-1	100	100	2:11	8.232	2:15	8.159	4	0.073
	Bio	2	DCA (100 ppb)	50	50	2:21	8.351	2:24	8.278	3	0.073
	Bio	3	DCA (100 ppb)	25	25	2:31	8.3935	2:35	8.243	4	0.1505
	BIO	4	DCA (100 ppb)	75	75	2:45	8.393	2:49	8.244	4	0.149
	BIO	5	HCl (1mM)	50	50	3:50	9.576	3:53	9.507	3	0.069
	BIO	6	HCl (1mM)	25	25	4:01	9.436	4:03	9.391	2	0.045
	BIO	7	HCl (1mM)	75	75	4:08	9.482	4:11	9.383	3	0.1
	pH op	8	MOW-1-1	100	100	4:41	11.313	4:44	11.261	3	0.057
	pH op	9	DCA (100 ppb)	50	50	4:43	11.26	4:47	11.078	2	0.182
	pH op	10	DCA (100 ppb)	25	25	4:50	11.057	4:52	10.909	2	0.149
	pH op	11	DCA (100 ppb)	75	75	4:59	10.47	5:06	9.863	7	0.615
	pH op	12	HCl (1mM)	50	50	5:15	10.884	5:17	10.829	2	0.055
	pH op	13	HCl (1mM)	25	25	5:19	10.808	5:20	10.779	1	0.029
	pH op	14	HCl (1mM)	75	75	5:22	10.74	5:25	10.635	3	0.105

Comments:

Uncorrected DCA Concentration of Unknown (ug/L) =

Corrected DCA Concentration of Unknown (ug/L) =

Biosensor Measurement Datasheet
Second Bangor Demonstration, September 2004

40 mL Vial Number: mow-2-1
Biosensor ID: 422
pH Optode ID: 105
pH Optode Sensitivity: 32 **PMT:** 600 v

Analyst: Victor ACHA
Date: 9/20/04
Time: 11:13 PM

Checked By:
Date Checked:

Subsample Number (4.85 mL Vial)	Biosensor or Optode Reading?	Step Number	Step Description	Solution Removed and Volume (uL)	Solution Added and Volume (uL)	PM Start Time	Start Volts	End Time	End Volts	min Delta T	Delta V
	Bio	1	mow-2-1	100	100	11:13	10.456	11:26	10.173	13	0.283 (0.283)
	Bio	2	DCA (100 ppb)	50	50	11:26	10.173	11:34	10.01	8	0.163
	Bio	3	DCA (100 ppb)	25	25	11:36	10.004	11:43	9.82	7	0.184
	Bio	4	DCA (100 ppb)	75	75	11:45	9.782	11:59	9.39	14	0.392
	Bio	5	HCl (1 mM)	50	50	9/21/04 AM 00:21	8.554	00:26	8.31	5	0.2435
	Bio	6	HCl (1 mM)	25	25	AM 00:28	8.205	00:32	7.965	4	0.24 (0.24)
	Bio	7	HCl (1 mM)	75	75	AM 00:35	7.97	00:42	7.586	7	0.384
	pH opt	8	mow-2-1	100	100	00:54	8.632	00:56	8.38	2	0.252
	pH opt	9	DCA (100 ppb)	50	50	00:57	8.386	01:01	7.593	4	0.793
	pH opt	10	DCA (100 ppb)	25	25	01:03	7.5185	1:10	6.947	7	0.5715
	pH opt	11	DCA (100 ppb)	75	75	1:11	6.923	1:18	5.84	7	1.083
	pH opt	12	HCl (1 mM)	50	50	1:29	7.919	1:35	7.76	6	0.159
	pH opt	13	HCl (1 mM)	25	25	1:37	7.746	1:49	7.314	12	0.432
	pH opt	14	HCl (1 mM)	75	75	1:50	7.322	1:58	6.616	8	0.706

Comments:

Uncorrected DCA Concentration of Unknown (ug/L) =

Corrected DCA Concentration of Unknown (ug/L) =

Biosensor Measurement Datasheet
Second Bangor Demonstration, September 2004

40 mL Vial Number: MO~~W~~N-3-2 16H30 9/20/04	**Analyst:** Victor Acha	**Checked By:**
Biosensor ID: 422	**Date:** 9/21/04	**Date Checked:**
pH Optode ID: 105	**Time:**	
pH Optode Sensitivity: 32 **PMT:** 600V		

Subsample Number (4.85 mL Vial)	Biosensor or Optode Reading?	Step Number	Step Description	Solution Removed and Volume (uL)	Solution Added and Volume (uL)	Start Time	Start Volts	End Time	End Volts	Delta T	Delta V	
	Bio	1	mow-3-2	100	100	8:32	11.255	8:33	11.224	1	0.031	
	Bio	2	DCA (100ppb)	50	50	8:38	11.2365	8:41	11.21	3	0.0265	
	Bio	3	DCA (100ppb)	25	25	8:45	11.2465	8:47	11.202	2	0.0445	
	Bio	4	DCA (100ppb)	75	75	8:49	11.2015	8:53	11.1225	4	0.079	✓
	BIO	5	HCl (1mM)	50	50	9:08	10.97	9:09	10.932	1	0.038	0.025
	BIO	6	HCl (1mM)	25	25	9:09	10.942	9:11	10.9115	2	0.0335	0.043
	BIO	7	HCl (1mM)	75	75	9:21	10.96	9:24	10.924	3	0.036	0.051
	pHopt	8	mow-3-2	100	100	9:47	11.383	9:52	10.783	5	0.598	(0.5995
	pHopt	9	DCA (100ppb)	50	50	9:57	10.784	10:01	10.554	4	0.23	
	pHopt	10	DCA (100ppb)	25	25	10:03	10.57	10.13	10.37	10	0.2	
	pHopt	11	DCA (100ppb)	75	75	10:14	10.35	10:18	10.022	4	0.328	
	pHopt	12	HCl (1mM)	50	50	11:49	11.234	12.01	11.125	12	0.109	
			HCl (1mM)	25	25	12:01	11.124	12:05	11.08	4	0.044	
			HCl (1mM)	75	75	12:08	11.047	12:14	10.90 65	6	0.1405	

Comments:

75uL HCl additions
1) - 0.01
2) - 0.02

Uncorrected DCA Concentration of Unknown (ug/L) =

Corrected DCA Concentration of Unknown (ug/L) =

Appendix C
Analytical Laboratory Result Reports

Pace Analytical®
www.pacelabs.com

Pace Analytical Services, Inc.
9608 Loiret Blvd.
Lenexa, KS 66219
Phone: 913.599.5665
Fax: 913.599.1759

September 24, 2004

Dr. John Eisenbeis
Camp Dresser & McKee Inc.
1331 17th Street
Suite 1200
Denver, CO 80202

RE: Lab Project Number: 6087072
Client Project ID: Bangor

Dear Dr. Eisenbeis:

Enclosed are the analytical results for sample(s) received by the laboratory on September 22, 2004. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report please feel free to contact me.

Sincerely,

Adam Taylor

Adam Taylor
adam.taylor@pacelabs.com
Project Manager

Kansas/NELAP Certification Number E-10116

Enclosures

SAMPLE SUMMARY

Pace Analytical Services, Inc.
9608 Loiret Blvd.
Lenexa, KS 66219
Phone: 913.599.5665
Fax: 913.599.1759

Lab Project Number: 6087072
Client Project ID: Bangor

Project Sample Number	Sample Number	Client Sample ID	Matrix	Date Collected	Date Received
6087072-001	607500071	MON 1-1	Water	09/20/04 12:10	09/22/04 08:50
6087072-002	607500089	MON 2-1	Water	09/20/04 15:30	09/22/04 08:50
6087072-003	607500097	MON 3-1	Water	09/20/04 16:30	09/22/04 08:50
6087072-004	607500105	TUES 6-1	Water	09/21/04 10:00	09/22/04 08:50
6087072-005	607500113	TUES 7-1	Water	09/21/04 13:30	09/22/04 08:50
6087072-006	607500121	TUES 8-1	Water	09/21/04 14:00	09/22/04 08:50

SAMPLE ANALYTE COUNT

Lab Project Number: 6087072
Client Project ID: Bangor

Project Sample Number	Sample No	Client Sample ID	Analysis Code	Analysis Description	Analytes Reported
6087072-001	607500071	MON 1-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087072-002	607500089	MON 2-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087072-003	607500097	MON 3-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087072-004	607500105	TUES 6-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087072-005	607500113	TUES 7-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087072-006	607500121	TUES 8-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72

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www.pacelabs.com

Pace Analytical Services, Inc.
9608 Loiret Blvd.
Lenexa, KS 66219
Phone: 913.599.5665
Fax: 913.599.1759

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500071   Project Sample Number: 6087072-001   Date Collected: 09/20/04 12:10
Client Sample ID: MON 1-1   Matrix: Water   Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	10.	1.0	09/23/04 14:12	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/23/04 14:12	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/23/04 14:12	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/23/04 14:12	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-34-3		
1,2-Dichloroethane	17.	ug/l	1.0	1.0	09/23/04 14:12	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	540-59-0		
1,1-Dichloroethene	1.4	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	563-58-6		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500071
Project Sample Number: 6087072-001
Date Collected: 09/20/04 12:10
Client Sample ID: MON 1-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/23/04 14:12	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/23/04 14:12	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/23/04 14:12	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/23/04 14:12	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/23/04 14:12	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/23/04 14:12	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/23/04 14:12	KBL1	95-47-6		
pH	1.0			1.0	09/23/04 14:12	KBL1			
Toluene-d8 (S)	106	%		1.0	09/23/04 14:12	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	91	%		1.0	09/23/04 14:12	KBL1	460-00-4		
Dibromofluoromethane (S)	102	%		1.0	09/23/04 14:12	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	108	%		1.0	09/23/04 14:12	KBL1	17060-07-0		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500089
Project Sample Number: 6087072-002
Date Collected: 09/20/04 15:30
Client Sample ID: MON 2-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	10.	1.0	09/23/04 14:29	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/23/04 14:29	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/23/04 14:29	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/23/04 14:29	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-34-3		
1,2-Dichloroethane	18.	ug/l	1.0	1.0	09/23/04 14:29	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	540-59-0		
1,1-Dichloroethene	12.	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	156-60-5		
1,2-Dichloropropane	5.2	ug/l	1.0	1.0	09/23/04 14:29	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	563-58-6		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500089
Project Sample Number: 6087072-002
Date Collected: 09/20/04 15:30
Client Sample ID: MON 2-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/23/04 14:29	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/23/04 14:29	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/23/04 14:29	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	71-55-6		
1,1,2-Trichloroethane	20.	ug/l	1.0	1.0	09/23/04 14:29	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/23/04 14:29	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/23/04 14:29	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/23/04 14:29	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/23/04 14:29	KBL1	95-47-6		
pH	1.0			1.0	09/23/04 14:29	KBL1			
Toluene-d8 (S)	103	%		1.0	09/23/04 14:29	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	108	%		1.0	09/23/04 14:29	KBL1	460-00-4		
Dibromofluoromethane (S)	103	%		1.0	09/23/04 14:29	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	104	%		1.0	09/23/04 14:29	KBL1	17060-07-0		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500097
Project Sample Number: 6087072-003
Date Collected: 09/20/04 16:30
Client Sample ID: MON 3-1
Matrix: Water
Date Received: 09/22/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	1000	100	09/24/04 14:42	KBL1	67-64-1		
Benzene	7100	ug/l	100	100	09/24/04 14:42	KBL1	71-43-2		
Bromobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-27-4		
Bromoform	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-25-2		
Bromomethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	1000	100	09/24/04 14:42	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	500	100	09/24/04 14:42	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	100	100	09/24/04 14:42	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	108-90-7		
Chloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-00-3		
Chloroform	ND	ug/l	100	100	09/24/04 14:42	KBL1	67-66-3		
Chloromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	100	100	09/24/04 14:42	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	100	100	09/24/04 14:42	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	250	100	09/24/04 14:42	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	100	100	09/24/04 14:42	KBL1	106-93-4		
Dibromomethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-34-3		
1,2-Dichloroethane	900	ug/l	100	100	09/24/04 14:42	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	100	100	09/24/04 14:42	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	100	100	09/24/04 14:42	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	100	100	09/24/04 14:42	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	100	100	09/24/04 14:42	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	100	100	09/24/04 14:42	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	100	100	09/24/04 14:42	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	100	100	09/24/04 14:42	KBL1	563-58-6		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500097 Project Sample Number: 6087072-003 Date Collected: 09/20/04 16:30
Client Sample ID: MON 3-1 Matrix: Water Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	100	100	09/24/04 14:42	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	100	100	09/24/04 14:42	KBL1	10061-02-6		
Ethylbenzene	230	ug/l	100	100	09/24/04 14:42	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	100	100	09/24/04 14:42	KBL1	87-68-3		
2-Hexanone	ND	ug/l	1000	100	09/24/04 14:42	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	100	100	09/24/04 14:42	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	100	100	09/24/04 14:42	KBL1	99-87-6		
Methylene chloride	210	ug/l	100	100	09/24/04 14:42	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	1000	100	09/24/04 14:42	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	100	100	09/24/04 14:42	KBL1	1634-04-4		
Naphthalene	ND	ug/l	1000	100	09/24/04 14:42	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	103-65-1		
Styrene	ND	ug/l	100	100	09/24/04 14:42	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	100	100	09/24/04 14:42	KBL1	127-18-4		
Toluene	2200	ug/l	100	100	09/24/04 14:42	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	100	100	09/24/04 14:42	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	79-00-5		
Trichloroethene	410	ug/l	100	100	09/24/04 14:42	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	250	100	09/24/04 14:42	KBL1	96-18-4		
1,2,4-Trimethylbenzene	520	ug/l	100	100	09/24/04 14:42	KBL1	95-63-6		
1,3,5-Trimethylbenzene	440	ug/l	100	100	09/24/04 14:42	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	100	100	09/24/04 14:42	KBL1	75-01-4		
Xylene (Total)	3600	ug/l	300	100	09/24/04 14:42	KBL1	1330-20-7		
m&p-Xylene	2200	ug/l	200	100	09/24/04 14:42	KBL1			
o-Xylene	1500	ug/l	100	100	09/24/04 14:42	KBL1	95-47-6		
pH	1.0			1.0	09/24/04 14:42	KBL1			
Toluene-d8 (S)	103	%		1.0	09/24/04 14:42	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	99	%		1.0	09/24/04 14:42	KBL1	460-00-4		
Dibromofluoromethane (S)	98	%		1.0	09/24/04 14:42	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	107	%		1.0	09/24/04 14:42	KBL1	17060-07-0		

Lab Sample No: 607500105
Project Sample Number: 6087072-004
Date Collected: 09/21/04 10:00
Client Sample ID: TUES 6-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	200	20.0	09/24/04 15:15	KBL1	67-64-1		
Benzene	3500	ug/l	20.	20.0	09/24/04 15:15	KBL1	71-43-2		
Bromobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-27-4		
Bromoform	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-25-2		
Bromomethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	200	20.0	09/24/04 15:15	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	100	20.0	09/24/04 15:15	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	108-90-7		
Chloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-00-3		
Chloroform	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	67-66-3		
Chloromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	50.	20.0	09/24/04 15:15	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	106-93-4		
Dibromomethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-34-3		
1,2-Dichloroethane	990	ug/l	20.	20.0	09/24/04 15:15	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	563-58-6		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500105 Project Sample Number: 6087072-004 Date Collected: 09/21/04 10:00
Client Sample ID: TUES 6-1 Matrix: Water Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	10061-02-6		
Ethylbenzene	280	ug/l	20.	20.0	09/24/04 15:15	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	87-68-3		
2-Hexanone	ND	ug/l	200	20.0	09/24/04 15:15	KBL1	591-78-6		
Isopropylbenzene (Cumene)	34.	ug/l	20.	20.0	09/24/04 15:15	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	99-87-6		
Methylene chloride	41.	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	200	20.0	09/24/04 15:15	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	1634-04-4		
Naphthalene	ND	ug/l	200	20.0	09/24/04 15:15	KBL1	91-20-3		
n-Propylbenzene	92.	ug/l	20.	20.0	09/24/04 15:15	KBL1	103-65-1		
Styrene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	127-18-4		
Toluene	170	ug/l	20.	20.0	09/24/04 15:15	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	79-00-5		
Trichloroethene	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	50.	20.0	09/24/04 15:15	KBL1	96-18-4		
1,2,4-Trimethylbenzene	140	ug/l	20.	20.0	09/24/04 15:15	KBL1	95-63-6		
1,3,5-Trimethylbenzene	82.	ug/l	20.	20.0	09/24/04 15:15	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	20.	20.0	09/24/04 15:15	KBL1	75-01-4		
Xylene (Total)	250	ug/l	60.	20.0	09/24/04 15:15	KBL1	1330-20-7		
m&p-Xylene	170	ug/l	40.	20.0	09/24/04 15:15	KBL1			
o-Xylene	80.	ug/l	20.	20.0	09/24/04 15:15	KBL1	95-47-6		
pH	1.0			1.0	09/24/04 15:15	KBL1			
Toluene-d8 (S)	105	%		1.0	09/24/04 15:15	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	89	%		1.0	09/24/04 15:15	KBL1	460-00-4		
Dibromofluoromethane (S)	98	%		1.0	09/24/04 15:15	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	103	%		1.0	09/24/04 15:15	KBL1	17060-07-0		

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No: 607500113 | Project Sample **Number: 6087072-005** | Date Collected: 09/21/04 13:30
Client Sample ID: TUES 7-1 | Matrix: Water | Date Received: 09/22/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	10.	1.0	09/24/04 14:25	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/24/04 14:25	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/24/04 14:25	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/24/04 14:25	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-34-3		
1,2-Dichloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	563-58-6		

Lab Sample No: 607500113
Project Sample Number: **6087072-005**
Date Collected: 09/21/04 13:30
Client Sample ID: TUES 7-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/24/04 14:25	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/24/04 14:25	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/24/04 14:25	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/24/04 14:25	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/24/04 14:25	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/24/04 14:25	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/24/04 14:25	KBL1	95-47-6		
pH	1.0			1.0	09/24/04 14:25	KBL1			
Toluene-d8 (S)	103	%		1.0	09/24/04 14:25	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	105	%		1.0	09/24/04 14:25	KBL1	460-00-4		
Dibromofluoromethane (S)	102	%		1.0	09/24/04 14:25	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	102	%		1.0	09/24/04 14:25	KBL1	17060-07-0		

Lab Sample No: 607500121
Project Sample Number: 6087072-006
Date Collected: 09/21/04 14:00
Client Sample ID: TUES 8-1
Matrix: Water
Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	10.	1.0	09/23/04 15:35	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/23/04 15:35	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/23/04 15:35	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/23/04 15:35	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-34-3		
1,2-Dichloroethane	6.0	ug/l	1.0	1.0	09/23/04 15:35	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	563-58-6		

Lab Sample No: 607500121 Project Sample Number: 6087072-006 Date Collected: 09/21/04 14:00
Client Sample ID: TUES 8-1 Matrix: Water Date Received: 09/22/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/23/04 15:35	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/23/04 15:35	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/23/04 15:35	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/23/04 15:35	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/23/04 15:35	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/23/04 15:35	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/23/04 15:35	KBL1	95-47-6		
pH	1.0			1.0	09/23/04 15:35	KBL1			
Toluene-d8 (S)	105	%		1.0	09/23/04 15:35	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	105	%		1.0	09/23/04 15:35	KBL1	460-00-4		
Dibromofluoromethane (S)	101	%		1.0	09/23/04 15:35	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	99	%		1.0	09/23/04 15:35	KBL1	17060-07-0		

PARAMETER FOOTNOTES

Dilution factor shown represents the factor applied to the reported result and reporting limit due to changes in sample preparation, dilution of the extract, or moisture content

ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
(S)	Surrogate

QUALITY CONTROL DATA

Pace Analytical Services, Inc.
9608 Loiret Blvd.
Lenexa, KS 66219
Phone: 913.599.5665
Fax: 913.599.1759

Lab Project Number: 6087072
Client Project ID: Bangor

QC Batch: 178434
Analysis Method: EPA 8260
QC Batch Method: EPA 8260
Analysis Description: GC/MS VOCs by 8260 (Low Level)
Associated Lab Samples: 607500071 607500089 607500121

METHOD BLANK: 607503059
Associated Lab Samples: 607500071 607500089 607500121

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Acetone	ug/l	ND	10.	
Benzene	ug/l	ND	1.0	
Bromobenzene	ug/l	ND	1.0	
Bromochloromethane	ug/l	ND	1.0	
Bromodichloromethane	ug/l	ND	1.0	
Bromoform	ug/l	ND	1.0	
Bromomethane	ug/l	ND	1.0	
2-Butanone (MEK)	ug/l	ND	10.	
n-Butylbenzene	ug/l	ND	1.0	
sec-Butylbenzene	ug/l	ND	1.0	
tert-Butylbenzene	ug/l	ND	1.0	
Carbon disulfide	ug/l	ND	5.0	
Carbon tetrachloride	ug/l	ND	1.0	
Chlorobenzene	ug/l	ND	1.0	
Chloroethane	ug/l	ND	1.0	
Chloroform	ug/l	ND	1.0	
Chloromethane	ug/l	ND	1.0	
2-Chlorotoluene	ug/l	ND	1.0	
4-Chlorotoluene	ug/l	ND	1.0	
1,2-Dibromo-3-chloropropane	ug/l	ND	2.5	
Dibromochloromethane	ug/l	ND	1.0	
1,2-Dibromoethane (EDB)	ug/l	ND	1.0	
Dibromomethane	ug/l	ND	1.0	
1,2-Dichlorobenzene	ug/l	ND	1.0	
1,3-Dichlorobenzene	ug/l	ND	1.0	
1,4-Dichlorobenzene	ug/l	ND	1.0	
Dichlorodifluoromethane	ug/l	ND	1.0	
1,1-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethene (Total)	ug/l	ND	1.0	
1,1-Dichloroethene	ug/l	ND	1.0	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

METHOD BLANK: 607503059
Associated Lab Samples: 607500071 607500089 607500121

Parameter	Units	Blank Result	Reporting Limit	Footnotes
cis-1,2-Dichloroethene	ug/l	ND	1.0	
trans-1,2-Dichloroethene	ug/l	ND	1.0	
1,2-Dichloropropane	ug/l	ND	1.0	
1,3-Dichloropropane	ug/l	ND	1.0	
2,2-Dichloropropane	ug/l	ND	1.0	
1,1-Dichloropropene	ug/l	ND	1.0	
cis-1,3-Dichloropropene	ug/l	ND	1.0	
trans-1,3-Dichloropropene	ug/l	ND	1.0	
Ethylbenzene	ug/l	ND	1.0	
Hexachloro-1,3-butadiene	ug/l	ND	1.0	
2-Hexanone	ug/l	ND	10.	
Isopropylbenzene (Cumene)	ug/l	ND	1.0	
p-Isopropyltoluene	ug/l	ND	1.0	
Methylene chloride	ug/l	ND	1.0	
4-Methyl-2-pentanone (MIBK)	ug/l	ND	10.	
Methyl-tert-butyl ether	ug/l	ND	1.0	
Naphthalene	ug/l	ND	10.	
n-Propylbenzene	ug/l	ND	1.0	
Styrene	ug/l	ND	1.0	
1,1,1,2-Tetrachloroethane	ug/l	ND	1.0	
1,1,2,2-Tetrachloroethane	ug/l	ND	1.0	
Tetrachloroethene	ug/l	ND	1.0	
Toluene	ug/l	ND	1.0	
1,2,3-Trichlorobenzene	ug/l	ND	1.0	
1,2,4-Trichlorobenzene	ug/l	ND	1.0	
1,1,1-Trichloroethane	ug/l	ND	1.0	
1,1,2-Trichloroethane	ug/l	ND	1.0	
Trichloroethene	ug/l	ND	1.0	
Trichlorofluoromethane	ug/l	ND	1.0	
1,2,3-Trichloropropane	ug/l	ND	2.5	
1,2,4-Trimethylbenzene	ug/l	ND	1.0	
1,3,5-Trimethylbenzene	ug/l	ND	1.0	
Vinyl chloride	ug/l	ND	1.0	
Xylene (Total)	ug/l	ND	3.0	
m&p-Xylene	ug/l	ND	2.0	
o-Xylene	ug/l	ND	1.0	

METHOD BLANK: 607503059
Associated Lab Samples: 607500071 607500089 607500121

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Toluene-d8 (S)	%	107		
4-Bromofluorobenzene (S)	%	101		
Dibromofluoromethane (S)	%	97		
1,2-Dichloroethane-d4 (S)	%	100		

LABORATORY CONTROL SAMPLE: 607503067

Parameter	Units	Spike Conc.	LCS Result	LCS	% Rec Limits	Footnotes
Acetone	ug/l	20.00	17.52	88	18-147	
Benzene	ug/l	10.00	8.990	90	74-118	
Bromobenzene	ug/l	10.00	8.610	86	79-115	
Bromochloromethane	ug/l	10.00	10.13	101	67-122	
Bromodichloromethane	ug/l	10.00	8.080	81	81-124	
Bromoform	ug/l	10.00	8.460	85	65-125	
Bromomethane	ug/l	10.00	13.26	133	10-150	
2-Butanone (MEK)	ug/l	20.00	15.42	77	35-132	
n-Butylbenzene	ug/l	10.00	9.520	95	67-124	
sec-Butylbenzene	ug/l	10.00	9.520	95	75-121	
tert-Butylbenzene	ug/l	10.00	9.650	96	76-118	
Carbon disulfide	ug/l	20.00	17.09	86	12-132	
Carbon tetrachloride	ug/l	10.00	11.74	117	69-131	
Chlorobenzene	ug/l	10.00	9.290	93	77-115	
Chloroethane	ug/l	10.00	10.51	105	23-140	
Chloroform	ug/l	10.00	8.880	89	74-123	
Chloromethane	ug/l	10.00	12.44	124	25-150	
2-Chlorotoluene	ug/l	10.00	9.440	94	76-118	
4-Chlorotoluene	ug/l	10.00	8.760	88	75-119	
1,2-Dibromo-3-chloropropane	ug/l	10.00	8.740	87	59-124	
Dibromochloromethane	ug/l	10.00	8.780	88	73-125	
1,2-Dibromoethane (EDB)	ug/l	10.00	9.760	98	78-120	
Dibromomethane	ug/l	10.00	9.310	93	71-124	
1,2-Dichlorobenzene	ug/l	10.00	9.430	94	77-117	
1,3-Dichlorobenzene	ug/l	10.00	9.440	94	75-116	
1,4-Dichlorobenzene	ug/l	10.00	8.530	85	72-117	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607503067

Parameter	Units	Spike Conc.	LCS Result	LCS	% Rec Limits	Footnotes
Dichlorodifluoromethane	ug/l	10.00	7.360	74	10-142	
1,1-Dichloroethane	ug/l	10.00	10.02	100	65-126	
1,2-Dichloroethane	ug/l	10.00	10.95	110	71-126	
1,2-Dichloroethene (Total)	ug/l	20.00	19.88	99	73-124	
1,1-Dichloroethene	ug/l	10.00	10.60	106	63-135	
cis-1,2-Dichloroethene	ug/l	10.00	9.060	91	74-120	
trans-1,2-Dichloroethene	ug/l	10.00	10.82	108	68-131	
1,2-Dichloropropane	ug/l	10.00	9.430	94	74-117	
1,3-Dichloropropane	ug/l	10.00	9.360	94	78-118	
2,2-Dichloropropane	ug/l	10.00	11.57	116	47-145	
1,1-Dichloropropene	ug/l	10.00	11.61	116	73-130	
cis-1,3-Dichloropropene	ug/l	10.00	9.500	95	73-124	
trans-1,3-Dichloropropene	ug/l	10.00	10.28	103	72-124	
Ethylbenzene	ug/l	10.00	9.310	93	76-119	
Hexachloro-1,3-butadiene	ug/l	10.00	9.680	97	63-122	
2-Hexanone	ug/l	20.00	18.49	92	43-117	
Isopropylbenzene (Cumene)	ug/l	10.00	8.750	88	73-113	
p-Isopropyltoluene	ug/l	10.00	9.270	93	71-117	
Methylene chloride	ug/l	10.00	10.04	100	65-133	
4-Methyl-2-pentanone (MIBK)	ug/l	20.00	17.73	89	44-113	
Methyl-tert-butyl ether	ug/l	10.00	10.11	101	54-129	
Naphthalene	ug/l	10.00	10.43	104	46-127	
n-Propylbenzene	ug/l	10.00	10.98	110	74-119	
Styrene	ug/l	10.00	9.070	91	78-121	
1,1,1,2-Tetrachloroethane	ug/l	10.00	9.810	98	78-122	
1,1,2,2-Tetrachloroethane	ug/l	10.00	9.200	92	69-121	
Tetrachloroethene	ug/l	10.00	9.710	97	72-121	
Toluene	ug/l	10.00	9.360	94	76-116	
1,2,3-Trichlorobenzene	ug/l	10.00	9.710	97	59-122	
1,2,4-Trichlorobenzene	ug/l	10.00	9.590	96	59-121	
1,1,1-Trichloroethane	ug/l	10.00	11.54	115	71-125	
1,1,2-Trichloroethane	ug/l	10.00	9.710	97	78-121	
Trichloroethene	ug/l	10.00	9.750	98	75-120	
Trichlorofluoromethane	ug/l	10.00	10.87	109	55-141	
1,2,3-Trichloropropane	ug/l	10.00	9.010	90	74-126	
1,2,4-Trimethylbenzene	ug/l	10.00	9.710	97	77-116	
1,3,5-Trimethylbenzene	ug/l	10.00	9.900	99	76-117	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607503067

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
Vinyl chloride	ug/l	10.00	10.99	110	50-131	
Xylene (Total)	ug/l	30.00	28.20	94	78-120	
m&p-Xylene	ug/l	20.00	18.40	92	74-120	
o-Xylene	ug/l	10.00	9.800	98	77-120	
Toluene-d8 (S)				104	88-110	
4-Bromofluorobenzene (S)				102	86-115	
Dibromofluoromethane (S)				99	86-118	
1,2-Dichloroethane-d4 (S)				105	80-120	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

QC Batch: 178584 Analysis Method: EPA 8260
QC Batch Method: EPA 8260 Analysis Description: GC/MS VOCs by 8260 (Low Level)
Associated Lab Samples: 607500097 607500105 607500113

METHOD BLANK: 607510583
Associated Lab Samples: 607500097 607500105 607500113

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Acetone	ug/l	ND	10.	
Benzene	ug/l	ND	1.0	
Bromobenzene	ug/l	ND	1.0	
Bromochloromethane	ug/l	ND	1.0	
Bromodichloromethane	ug/l	ND	1.0	
Bromoform	ug/l	ND	1.0	
Bromomethane	ug/l	ND	1.0	
2-Butanone (MEK)	ug/l	ND	10.	
n-Butylbenzene	ug/l	ND	1.0	
sec-Butylbenzene	ug/l	ND	1.0	
tert-Butylbenzene	ug/l	ND	1.0	
Carbon disulfide	ug/l	ND	5.0	
Carbon tetrachloride	ug/l	ND	1.0	
Chlorobenzene	ug/l	ND	1.0	
Chloroethane	ug/l	ND	1.0	
Chloroform	ug/l	ND	1.0	
Chloromethane	ug/l	ND	1.0	
2-Chlorotoluene	ug/l	ND	1.0	
4-Chlorotoluene	ug/l	ND	1.0	
1,2-Dibromo-3-chloropropane	ug/l	ND	2.5	
Dibromochloromethane	ug/l	ND	1.0	
1,2-Dibromoethane (EDB)	ug/l	ND	1.0	
Dibromomethane	ug/l	ND	1.0	
1,2-Dichlorobenzene	ug/l	ND	1.0	
1,3-Dichlorobenzene	ug/l	ND	1.0	
1,4-Dichlorobenzene	ug/l	ND	1.0	
Dichlorodifluoromethane	ug/l	ND	1.0	
1,1-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethene (Total)	ug/l	ND	1.0	
1,1-Dichloroethene	ug/l	ND	1.0	

Lab Project Number: 6087072
Client Project ID: Bangor

METHOD BLANK: 607510583
Associated Lab Samples: 607500097 607500105 607500113

Parameter	Units	Blank Result	Reporting Limit	Footnotes
cis-1,2-Dichloroethene	ug/l	ND	1.0	
trans-1,2-Dichloroethene	ug/l	ND	1.0	
1,2-Dichloropropane	ug/l	ND	1.0	
1,3-Dichloropropane	ug/l	ND	1.0	
2,2-Dichloropropane	ug/l	ND	1.0	
1,1-Dichloropropene	ug/l	ND	1.0	
cis-1,3-Dichloropropene	ug/l	ND	1.0	
trans-1,3-Dichloropropene	ug/l	ND	1.0	
Ethylbenzene	ug/l	ND	1.0	
Hexachloro-1,3-butadiene	ug/l	1.3	1.0	1
2-Hexanone	ug/l	ND	10.	
Isopropylbenzene (Cumene)	ug/l	ND	1.0	
p-Isopropyltoluene	ug/l	ND	1.0	
Methylene chloride	ug/l	ND	1.0	
4-Methyl-2-pentanone (MIBK)	ug/l	ND	10.	
Methyl-tert-butyl ether	ug/l	ND	1.0	
Naphthalene	ug/l	ND	10.	
n-Propylbenzene	ug/l	ND	1.0	
Styrene	ug/l	ND	1.0	
1,1,1,2-Tetrachloroethane	ug/l	ND	1.0	
1,1,2,2-Tetrachloroethane	ug/l	ND	1.0	
Tetrachloroethene	ug/l	ND	1.0	
Toluene	ug/l	ND	1.0	
1,2,3-Trichlorobenzene	ug/l	ND	1.0	
1,2,4-Trichlorobenzene	ug/l	ND	1.0	
1,1,1-Trichloroethane	ug/l	ND	1.0	
1,1,2-Trichloroethane	ug/l	ND	1.0	
Trichloroethene	ug/l	ND	1.0	
Trichlorofluoromethane	ug/l	ND	1.0	
1,2,3-Trichloropropane	ug/l	ND	2.5	
1,2,4-Trimethylbenzene	ug/l	ND	1.0	
1,3,5-Trimethylbenzene	ug/l	ND	1.0	
Vinyl chloride	ug/l	ND	1.0	
Xylene (Total)	ug/l	ND	3.0	
m&p-Xylene	ug/l	ND	2.0	
o-Xylene	ug/l	ND	1.0	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

METHOD BLANK: 607510583
Associated Lab Samples: 607500097 607500105 607500113

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Toluene-d8 (S)	%	105		
4-Bromofluorobenzene (S)	%	103		
Dibromofluoromethane (S)	%	105		
1,2-Dichloroethane-d4 (S)	%	106		

LABORATORY CONTROL SAMPLE: 607510591

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
Acetone	ug/l	20.00	18.25	91	18-147	
Benzene	ug/l	10.00	9.870	99	74-118	
Bromobenzene	ug/l	10.00	9.840	98	79-115	
Bromochloromethane	ug/l	10.00	9.430	94	67-122	
Bromodichloromethane	ug/l	10.00	8.540	85	81-124	
Bromoform	ug/l	10.00	8.980	90	65-125	
Bromomethane	ug/l	10.00	14.91	149	10-150	
2-Butanone (MEK)	ug/l	20.00	17.95	90	35-132	
n-Butylbenzene	ug/l	10.00	9.630	96	67-124	
sec-Butylbenzene	ug/l	10.00	9.830	98	75-121	
tert-Butylbenzene	ug/l	10.00	9.050	90	76-118	
Carbon disulfide	ug/l	20.00	17.45	87	12-132	
Carbon tetrachloride	ug/l	10.00	12.12	121	69-131	
Chlorobenzene	ug/l	10.00	9.740	97	77-115	
Chloroethane	ug/l	10.00	10.45	105	23-140	
Chloroform	ug/l	10.00	9.700	97	74-123	
Chloromethane	ug/l	10.00	14.15	142	25-150	
2-Chlorotoluene	ug/l	10.00	9.100	91	76-118	
4-Chlorotoluene	ug/l	10.00	9.360	94	75-119	
1,2-Dibromo-3-chloropropane	ug/l	10.00	8.400	84	59-124	
Dibromochloromethane	ug/l	10.00	9.640	96	73-125	
1,2-Dibromoethane (EDB)	ug/l	10.00	11.52	115	78-120	
Dibromomethane	ug/l	10.00	9.700	97	71-124	
1,2-Dichlorobenzene	ug/l	10.00	9.270	93	77-117	
1,3-Dichlorobenzene	ug/l	10.00	9.060	91	75-116	
1,4-Dichlorobenzene	ug/l	10.00	9.280	93	72-117	

QUALITY CONTROL DATA

Lab Project Number: 6087072
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607510591

Parameter	Units	Spike Conc.	LCS Result	LCS	% Rec Limits	Footnotes
Dichlorodifluoromethane	ug/l	10.00	8.380	84	10-142	
1,1-Dichloroethane	ug/l	10.00	10.72	107	65-126	
1,2-Dichloroethane	ug/l	10.00	11.37	114	71-126	
1,2-Dichloroethene (Total)	ug/l	20.00	20.01	100	73-124	
1,1-Dichloroethene	ug/l	10.00	10.84	108	63-135	
cis-1,2-Dichloroethene	ug/l	10.00	9.630	96	74-120	
trans-1,2-Dichloroethene	ug/l	10.00	10.38	104	68-131	
1,2-Dichloropropane	ug/l	10.00	10.02	100	74-117	
1,3-Dichloropropane	ug/l	10.00	9.880	99	78-118	
2,2-Dichloropropane	ug/l	10.00	11.73	117	47-145	
1,1-Dichloropropene	ug/l	10.00	12.41	124	73-130	
cis-1,3-Dichloropropene	ug/l	10.00	9.530	95	73-124	
trans-1,3-Dichloropropene	ug/l	10.00	11.16	112	72-124	
Ethylbenzene	ug/l	10.00	9.820	98	76-119	
Hexachloro-1,3-butadiene	ug/l	10.00	10.34	103	63-122	
2-Hexanone	ug/l	20.00	15.27	76	43-117	
Isopropylbenzene (Cumene)	ug/l	10.00	8.970	90	73-113	
p-Isopropyltoluene	ug/l	10.00	9.120	91	71-117	
Methylene chloride	ug/l	10.00	10.46	105	65-133	
4-Methyl-2-pentanone (MIBK)	ug/l	20.00	18.71	94	44-113	
Methyl-tert-butyl ether	ug/l	10.00	9.650	96	54-129	
Naphthalene	ug/l	10.00	9.330	93	46-127	
n-Propylbenzene	ug/l	10.00	11.00	110	74-119	
Styrene	ug/l	10.00	10.08	101	78-121	
1,1,1,2-Tetrachloroethane	ug/l	10.00	9.550	96	78-122	
1,1,2,2-Tetrachloroethane	ug/l	10.00	8.900	89	69-121	
Tetrachloroethene	ug/l	10.00	10.03	100	72-121	
Toluene	ug/l	10.00	10.42	104	76-116	
1,2,3-Trichlorobenzene	ug/l	10.00	9.410	94	59-122	
1,2,4-Trichlorobenzene	ug/l	10.00	8.880	89	59-121	
1,1,1-Trichloroethane	ug/l	10.00	12.06	121	71-125	
1,1,2-Trichloroethane	ug/l	10.00	9.910	99	78-121	
Trichloroethene	ug/l	10.00	9.700	97	75-120	
Trichlorofluoromethane	ug/l	10.00	10.54	105	55-141	
1,2,3-Trichloropropane	ug/l	10.00	10.96	110	74-126	
1,2,4-Trimethylbenzene	ug/l	10.00	9.230	92	77-116	
1,3,5-Trimethylbenzene	ug/l	10.00	9.490	95	76-117	

Lab Project Number: 6087072
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607510591

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
Vinyl chloride	ug/l	10.00	11.83	118	50-131	
Xylene (Total)	ug/l	30.00	30.01	100	78-120	
m&p-Xylene	ug/l	20.00	20.32	102	74-120	
o-Xylene	ug/l	10.00	9.690	97	77-120	
Toluene-d8 (S)				100	88-110	
4-Bromofluorobenzene (S)				97	86-115	
Dibromofluoromethane (S)				100	86-118	
1,2-Dichloroethane-d4 (S)				103	80-120	

QUALITY CONTROL DATA PARAMETER FOOTNOTES

Consistent with EPA guidelines, unrounded concentrations are displayed and have been used to calculate % Rec and RPD values.

LCS(D)	Laboratory Control Sample (Duplicate)
MS(D)	Matrix Spike (Duplicate)
DUP	Sample Duplicate
ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
RPD	Relative Percent Difference
(S)	Surrogate
[1]	This compound was detected above the reporting limit in the blank. It was not detected above the reporting limit in the associated samples, therefore the amount detected in the blank does not affect the usability of the reported results

QUALITY CONTROL DATA

CROSS REFERENCE TABLE

Lab Project Number: 6087072
Client Project ID: Bangor

Lab Sample No Identifier	Client Sample Identifier	QC Batch Method	QC Batch Identifier	Analytical Method	Analytical Batch Identifier
607500071	MON 1-1	EPA 8260	178434		
607500089	MON 2-1	EPA 8260	178434		
607500121	TUES 8-1	EPA 8260	178434		
607500097	MON 3-1	EPA 8260	178584		
607500105	TUES 6-1	EPA 8260	178584		
607500113	TUES 7-1	EPA 8260	178584		

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September 28, 2004

Dr. John Eisenbeis
Camp Dresser & McKee Inc.
1331 17th Street
Suite 1200
Denver, CO 80202

RE: Lab Project Number: 6087145
Client Project ID: Bangor

Dear Dr. Eisenbeis:

Enclosed are the analytical results for sample(s) received by the laboratory on September 23, 2004. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report please feel free to contact me.

Sincerely,

Adam Taylor

Adam Taylor
adam.taylor@pacelabs.com
Project Manager

Kansas/NELAP Certification Number E-10116

Enclosures

SAMPLE SUMMARY

Lab Project Number: 6087145
Client Project ID: Bangor

Project Sample Number	Sample Number	Client Sample ID	Matrix	Date Collected	Date Received
6087145-001	607504727	TUE-9-1	Water	09/21/04 18:15	09/23/04 08:50
6087145-002	607504735	WED-10-1	Water	09/22/04 11:00	09/23/04 08:50
6087145-003	607504750	WED-11-1	Water	09/22/04 11:05	09/23/04 08:50
6087145-004	607504776	TUES-5-1	Water	09/21/04 09:30	09/23/04 08:50
6087145-005	607504818	RINSATE 9-22-04	Water	09/22/04 11:45	09/23/04 08:50
6087145-006	607504834	TRIP BLANK	Water	09/22/04	09/23/04 08:50

SAMPLE ANALYTE COUNT

Lab Project Number: 6087145
Client Project ID: Bangor

Project Sample Number	Sample No	Client Sample ID	Analysis Code	Analysis Description	Analytes Reported
6087145-001	607504727	TUE-9-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087145-002	607504735	WED-10-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087145-003	607504750	WED-11-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087145-004	607504776	TUES-5-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087145-005	607504818	RINSATE 9-22-04	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72
6087145-006	607504834	TRIP BLANK	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72

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Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504727
Project Sample Number: 6087145-001
Date Collected: 09/21/04 18:15
Client Sample ID: TUE-9-1
Matrix: Water
Date Received: 09/23/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	500	50.0	09/25/04 17:06	KBL1	67-64-1		
Benzene	11000	ug/l	200	200	09/27/04 18:17	KBL1	71-43-2		
Bromobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-27-4		
Bromoform	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-25-2		
Bromomethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	500	50.0	09/25/04 17:06	KBL1	78-93-3		
n-Butylbenzene	200	ug/l	50.	50.0	09/25/04 17:06	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	250	50.0	09/25/04 17:06	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	108-90-7		
Chloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-00-3		
Chloroform	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	67-66-3		
Chloromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	120	50.0	09/25/04 17:06	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	106-93-4		
Dibromomethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-34-3		
1,2-Dichloroethane	600	ug/l	50.	50.0	09/25/04 17:06	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	563-58-6		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504727
Client Sample ID: TUE-9-1

Project Sample Number: 6087145-001
Matrix: Water

Date Collected: 09/21/04 18:15
Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	10061-02-6		
Ethylbenzene	1200	ug/l	50.	50.0	09/25/04 17:06	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	87-68-3		
2-Hexanone	ND	ug/l	500	50.0	09/25/04 17:06	KBL1	591-78-6		
Isopropylbenzene (Cumene)	76.	ug/l	50.	50.0	09/25/04 17:06	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	99-87-6		
Methylene chloride	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	500	50.0	09/25/04 17:06	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	1634-04-4		
Naphthalene	2800	ug/l	500	50.0	09/25/04 17:06	KBL1	91-20-3		
n-Propylbenzene	330	ug/l	50.	50.0	09/25/04 17:06	KBL1	103-65-1		
Styrene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	127-18-4		
Toluene	15000	ug/l	200	200	09/27/04 18:17	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	79-00-5		
Trichloroethene	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	120	50.0	09/25/04 17:06	KBL1	96-18-4		
1,2,4-Trimethylbenzene	1300	ug/l	50.	50.0	09/25/04 17:06	KBL1	95-63-6		
1,3,5-Trimethylbenzene	390	ug/l	50.	50.0	09/25/04 17:06	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	50.	50.0	09/25/04 17:06	KBL1	75-01-4		
Xylene (Total)	5800	ug/l	150	50.0	09/25/04 17:06	KBL1	1330-20-7		
m&p-Xylene	3900	ug/l	100	50.0	09/25/04 17:06	KBL1			
o-Xylene	1900	ug/l	50.	50.0	09/25/04 17:06	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 17:06	KBL1			
Toluene-d8 (S)	106	%		1.0	09/25/04 17:06	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	112	%		1.0	09/25/04 17:06	KBL1	460-00-4		
Dibromofluoromethane (S)	96	%		1.0	09/25/04 17:06	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	110	%		1.0	09/25/04 17:06	KBL1	17060-07-0		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504735
Project Sample Number: 6087145-002
Date Collected: 09/22/04 11:00
Client Sample ID: WED-10-1
Matrix: Water
Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	10.	1.0	09/25/04 14:03	KBL1	67-64-1		
Benzene	12.	ug/l	1.0	1.0	09/25/04 14:03	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/25/04 14:03	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/25/04 14:03	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/25/04 14:03	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-34-3		
1,2-Dichloroethane	19.	ug/l	1.0	1.0	09/25/04 14:03	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	540-59-0		
1,1-Dichloroethene	11.	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	156-60-5		
1,2-Dichloropropane	5.2	ug/l	1.0	1.0	09/25/04 14:03	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	563-58-6		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504735 Project Sample Number: 6087145-002 Date Collected: 09/22/04 11:00
Client Sample ID: WED-10-1 Matrix: Water Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	10061-02-6		
Ethylbenzene	2.5	ug/l	1.0	1.0	09/25/04 14:03	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/25/04 14:03	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/25/04 14:03	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/25/04 14:03	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	127-18-4		
Toluene	42.	ug/l	1.0	1.0	09/25/04 14:03	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	71-55-6		
1,1,2-Trichloroethane	16.	ug/l	1.0	1.0	09/25/04 14:03	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/25/04 14:03	KBL1	96-18-4		
1,2,4-Trimethylbenzene	1.9	ug/l	1.0	1.0	09/25/04 14:03	KBL1	95-63-6		
1,3,5-Trimethylbenzene	2.8	ug/l	1.0	1.0	09/25/04 14:03	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/25/04 14:03	KBL1	75-01-4		
Xylene (Total)	14.	ug/l	3.0	1.0	09/25/04 14:03	KBL1	1330-20-7		
m&p-Xylene	9.0	ug/l	2.0	1.0	09/25/04 14:03	KBL1			
o-Xylene	5.5	ug/l	1.0	1.0	09/25/04 14:03	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 14:03	KBL1			
Toluene-d8 (S)	101	%		1.0	09/25/04 14:03	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	100	%		1.0	09/25/04 14:03	KBL1	460-00-4		
Dibromofluoromethane (S)	101	%		1.0	09/25/04 14:03	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	109	%		1.0	09/25/04 14:03	KBL1	17060-07-0		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504750
Project Sample Number: 6087145-003
Date Collected: 09/22/04 11:05
Client Sample ID: WED-11-1
Matrix: Water
Date Received: 09/23/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	10.	1.0	09/25/04 14:20	KBL1	67-64-1		
Benzene	11.	ug/l	1.0	1.0	09/25/04 14:20	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/25/04 14:20	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/25/04 14:20	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/25/04 14:20	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-34-3		
1,2-Dichloroethane	18.	ug/l	1.0	1.0	09/25/04 14:20	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	540-59-0		
1,1-Dichloroethene	12.	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	156-60-5		
1,2-Dichloropropane	4.9	ug/l	1.0	1.0	09/25/04 14:20	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	563-58-6		

Lab Sample No: 607504750 Project Sample Number: 6087145-003 Date Collected: 09/22/04 11:05
Client Sample ID: WED-11-1 Matrix: Water Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	10061-02-6		
Ethylbenzene	2.7	ug/l	1.0	1.0	09/25/04 14:20	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/25/04 14:20	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/25/04 14:20	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/25/04 14:20	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	127-18-4		
Toluene	43.	ug/l	1.0	1.0	09/25/04 14:20	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	71-55-6		
1,1,2-Trichloroethane	17.	ug/l	1.0	1.0	09/25/04 14:20	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/25/04 14:20	KBL1	96-18-4		
1,2,4-Trimethylbenzene	2.0	ug/l	1.0	1.0	09/25/04 14:20	KBL1	95-63-6		
1,3,5-Trimethylbenzene	2.9	ug/l	1.0	1.0	09/25/04 14:20	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/25/04 14:20	KBL1	75-01-4		
Xylene (Total)	15.	ug/l	3.0	1.0	09/25/04 14:20	KBL1	1330-20-7		
m&p-Xylene	10.	ug/l	2.0	1.0	09/25/04 14:20	KBL1			
o-Xylene	5.2	ug/l	1.0	1.0	09/25/04 14:20	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 14:20	KBL1			
Toluene-d8 (S)	108	%		1.0	09/25/04 14:20	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	101	%		1.0	09/25/04 14:20	KBL1	460-00-4		
Dibromofluoromethane (S)	102	%		1.0	09/25/04 14:20	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	96	%		1.0	09/25/04 14:20	KBL1	17060-07-0		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504776
Project Sample Number: 6087145-004
Date Collected: 09/21/04 09:30
Client Sample ID: TUES-5-1
Matrix: Water
Date Received: 09/23/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	500	50.0	09/25/04 17:22	KBL1	67-64-1		
Benzene	10000	ug/l	500	500	09/27/04 18:34	KBL1	71-43-2		
Bromobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-27-4		
Bromoform	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-25-2		
Bromomethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	500	50.0	09/25/04 17:22	KBL1	78-93-3		
n-Butylbenzene	190	ug/l	50.	50.0	09/25/04 17:22	KBL1	104-51-8		
sec-Butylbenzene	1800	ug/l	50.	50.0	09/25/04 17:22	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	250	50.0	09/25/04 17:22	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	108-90-7		
Chloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-00-3		
Chloroform	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	67-66-3		
Chloromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	120	50.0	09/25/04 17:22	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	110	ug/l	50.	50.0	09/25/04 17:22	KBL1	106-93-4		
Dibromomethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-34-3		
1,2-Dichloroethane	730	ug/l	50.	50.0	09/25/04 17:22	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	563-58-6		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504776
Project Sample Number: 6087145-004
Date Collected: 09/21/04 09:30
Client Sample ID: TUES-5-1
Matrix: Water
Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	10061-02-6		
Ethylbenzene	1300	ug/l	50.	50.0	09/25/04 17:22	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	87-68-3		
2-Hexanone	ND	ug/l	500	50.0	09/25/04 17:22	KBL1	591-78-6		
Isopropylbenzene (Cumene)	51.	ug/l	50.	50.0	09/25/04 17:22	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	99-87-6		
Methylene chloride	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	500	50.0	09/25/04 17:22	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	1634-04-4		
Naphthalene	1100	ug/l	500	50.0	09/25/04 17:22	KBL1	91-20-3		
n-Propylbenzene	290	ug/l	50.	50.0	09/25/04 17:22	KBL1	103-65-1		
Styrene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	127-18-4		
Toluene	12000	ug/l	500	500	09/27/04 18:34	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	79-00-5		
Trichloroethene	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	120	50.0	09/25/04 17:22	KBL1	96-18-4		
1,2,4-Trimethylbenzene	2100	ug/l	50.	50.0	09/25/04 17:22	KBL1	95-63-6		
1,3,5-Trimethylbenzene	520	ug/l	50.	50.0	09/25/04 17:22	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	50.	50.0	09/25/04 17:22	KBL1	75-01-4		
Xylene (Total)	11000	ug/l	150	50.0	09/25/04 17:22	KBL1	1330-20-7		
m&p-Xylene	8300	ug/l	100	50.0	09/25/04 17:22	KBL1			
o-Xylene	3100	ug/l	50.	50.0	09/25/04 17:22	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 17:22	KBL1			
Toluene-d8 (S)	105	%		1.0	09/25/04 17:22	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	109	%		1.0	09/25/04 17:22	KBL1	460-00-4		
Dibromofluoromethane (S)	93	%		1.0	09/25/04 17:22	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	106	%		1.0	09/25/04 17:22	KBL1	17060-07-0		

Lab Sample No: 607504818 Project Sample Number: 6087145-005 Date Collected: 09/22/04 11:45
Client Sample ID: RINSATE 9-22-04 Matrix: Water Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
GC/MS Volatiles									
GC/MS VOCs by 8260 (Low Level)	Method: EPA 8260								
Acetone	ND	ug/l	10.	1.0	09/25/04 14:36	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/25/04 14:36	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/25/04 14:36	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-00-3		
Chloroform	1.0	ug/l	1.0	1.0	09/25/04 14:36	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/25/04 14:36	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-34-3		
1,2-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	563-58-6		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504818 Project Sample Number: 6087145-005 Date Collected: 09/22/04 11:45
Client Sample ID: RINSATE 9-22-04 Matrix: Water Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/25/04 14:36	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/25/04 14:36	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/25/04 14:36	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/25/04 14:36	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/25/04 14:36	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/25/04 14:36	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/25/04 14:36	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 14:36	KBL1			
Toluene-d8 (S)	101	%		1.0	09/25/04 14:36	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	99	%		1.0	09/25/04 14:36	KBL1	460-00-4		
Dibromofluoromethane (S)	98	%		1.0	09/25/04 14:36	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	106	%		1.0	09/25/04 14:36	KBL1	17060-07-0		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504834
Project Sample Number: 6087145-006
Date Collected: 09/22/04 00:00
Client Sample ID: TRIP BLANK
Matrix: Water
Date Received: 09/23/04 08:50

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	ND	ug/l	10.	1.0	09/25/04 13:47	KBL1	67-64-1		
Benzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	71-43-2		
Bromobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-27-4		
Bromoform	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-25-2		
Bromomethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	10.	1.0	09/25/04 13:47	KBL1	78-93-3		
n-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	104-51-8		
sec-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	5.0	1.0	09/25/04 13:47	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	108-90-7		
Chloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-00-3		
Chloroform	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	67-66-3		
Chloromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	2.5	1.0	09/25/04 13:47	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	106-93-4		
Dibromomethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-34-3		
1,2-Dichloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	563-58-6		

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No: 607504834
Project Sample Number: 6087145-006
Date Collected: 09/22/04 00:00
Client Sample ID: TRIP BLANK
Matrix: Water
Date Received: 09/23/04 08:50

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	10061-02-6		
Ethylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	87-68-3		
2-Hexanone	ND	ug/l	10.	1.0	09/25/04 13:47	KBL1	591-78-6		
Isopropylbenzene (Cumene)	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	99-87-6		
Methylene chloride	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-09-2		
4-Methyl-2-pentanone (MIBK)	ND	ug/l	10.	1.0	09/25/04 13:47	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	1634-04-4		
Naphthalene	ND	ug/l	10.	1.0	09/25/04 13:47	KBL1	91-20-3		
n-Propylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	103-65-1		
Styrene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	127-18-4		
Toluene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	79-00-5		
Trichloroethene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	2.5	1.0	09/25/04 13:47	KBL1	96-18-4		
1,2,4-Trimethylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	95-63-6		
1,3,5-Trimethylbenzene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	75-01-4		
Xylene (Total)	ND	ug/l	3.0	1.0	09/25/04 13:47	KBL1	1330-20-7		
m&p-Xylene	ND	ug/l	2.0	1.0	09/25/04 13:47	KBL1			
o-Xylene	ND	ug/l	1.0	1.0	09/25/04 13:47	KBL1	95-47-6		
pH	1.0			1.0	09/25/04 13:47	KBL1			
Toluene-d8 (S)	106	%		1.0	09/25/04 13:47	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	95	%		1.0	09/25/04 13:47	KBL1	460-00-4		
Dibromofluoromethane (S)	97	%		1.0	09/25/04 13:47	KBL1	1868-53-7		
1,2-Dichloroethane-d4 (S)	104	%		1.0	09/25/04 13:47	KBL1	17060-07-0		

PARAMETER FOOTNOTES

Dilution factor shown represents the factor applied to the reported result and reporting limit due to changes in sample preparation, dilution of the extract, or moisture content

ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
(S)	Surrogate

Lab Project Number: 6087145
Client Project ID: Bangor

QC Batch: 178587
Analysis Method: EPA 8260
QC Batch Method: EPA 8260
Analysis Description: GC/MS VOCs by 8260 (Low Level)
Associated Lab Samples: 607504727 607504735 607504750 607504776 607504818 607504834

METHOD BLANK: 607510732
Associated Lab Samples: 607504727 607504735 607504750 607504776 607504818 607504834

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Acetone	ug/l	ND	10.	
Benzene	ug/l	ND	1.0	
Bromobenzene	ug/l	ND	1.0	
Bromochloromethane	ug/l	ND	1.0	
Bromodichloromethane	ug/l	ND	1.0	
Bromoform	ug/l	ND	1.0	
Bromomethane	ug/l	ND	1.0	
2-Butanone (MEK)	ug/l	ND	10.	
n-Butylbenzene	ug/l	ND	1.0	
sec-Butylbenzene	ug/l	ND	1.0	
tert-Butylbenzene	ug/l	ND	1.0	
Carbon disulfide	ug/l	ND	5.0	
Carbon tetrachloride	ug/l	ND	1.0	
Chlorobenzene	ug/l	ND	1.0	
Chloroethane	ug/l	ND	1.0	
Chloroform	ug/l	ND	1.0	
Chloromethane	ug/l	ND	1.0	
2-Chlorotoluene	ug/l	ND	1.0	
4-Chlorotoluene	ug/l	ND	1.0	
1,2-Dibromo-3-chloropropane	ug/l	ND	2.5	
Dibromochloromethane	ug/l	ND	1.0	
1,2-Dibromoethane (EDB)	ug/l	ND	1.0	
Dibromomethane	ug/l	ND	1.0	
1,2-Dichlorobenzene	ug/l	ND	1.0	
1,3-Dichlorobenzene	ug/l	ND	1.0	
1,4-Dichlorobenzene	ug/l	ND	1.0	
Dichlorodifluoromethane	ug/l	ND	1.0	
1,1-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethene (Total)	ug/l	ND	1.0	

QUALITY CONTROL DATA

Pace Analytical Services, Inc.
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Lenexa, KS 66219

Phone: 913.599.5665
Fax: 913.599.1759

Lab Project Number: 6087145
Client Project ID: Bangor

METHOD BLANK: 607510732
Associated Lab Samples: 607504727 607504735 607504750 607504776 607504818 607504834

Parameter	Units	Blank Result	Reporting Limit	Footnotes
1,1-Dichloroethene	ug/l	ND	1.0	
cis-1,2-Dichloroethene	ug/l	ND	1.0	
trans-1,2-Dichloroethene	ug/l	ND	1.0	
1,2-Dichloropropane	ug/l	ND	1.0	
1,3-Dichloropropane	ug/l	ND	1.0	
2,2-Dichloropropane	ug/l	ND	1.0	
1,1-Dichloropropene	ug/l	ND	1.0	
cis-1,3-Dichloropropene	ug/l	ND	1.0	
trans-1,3-Dichloropropene	ug/l	ND	1.0	
Ethylbenzene	ug/l	ND	1.0	
Hexachloro-1,3-butadiene	ug/l	ND	1.0	
2-Hexanone	ug/l	ND	10.	
Isopropylbenzene (Cumene)	ug/l	ND	1.0	
p-Isopropyltoluene	ug/l	ND	1.0	
Methylene chloride	ug/l	ND	1.0	
4-Methyl-2-pentanone (MIBK)	ug/l	ND	10.	
Methyl-tert-butyl ether	ug/l	ND	1.0	
Naphthalene	ug/l	ND	10.	
n-Propylbenzene	ug/l	ND	1.0	
Styrene	ug/l	ND	1.0	
1,1,1,2-Tetrachloroethane	ug/l	ND	1.0	
1,1,2,2-Tetrachloroethane	ug/l	ND	1.0	
Tetrachloroethene	ug/l	ND	1.0	
Toluene	ug/l	ND	1.0	
1,2,3-Trichlorobenzene	ug/l	ND	1.0	
1,2,4-Trichlorobenzene	ug/l	ND	1.0	
1,1,1-Trichloroethane	ug/l	ND	1.0	
1,1,2-Trichloroethane	ug/l	ND	1.0	
Trichloroethene	ug/l	ND	1.0	
Trichlorofluoromethane	ug/l	ND	1.0	
1,2,3-Trichloropropane	ug/l	ND	2.5	
1,2,4-Trimethylbenzene	ug/l	ND	1.0	
1,3,5-Trimethylbenzene	ug/l	ND	1.0	
Vinyl chloride	ug/l	ND	1.0	
Xylene (Total)	ug/l	ND	3.0	
m&p-Xylene	ug/l	ND	2.0	

Lab Project Number: 6087145
Client Project ID: Bangor

METHOD BLANK: 607510732

Associated Lab Samples: 607504727 607504735 607504750 607504776 607504818 607504834

Parameter	Units	Blank Result	Reporting Limit	Footnotes
o-Xylene	ug/l	ND	1.0	
Toluene-d8 (S)	%	106		
4-Bromofluorobenzene (S)	%	104		
Dibromofluoromethane (S)	%	100		
1,2-Dichloroethane-d4 (S)	%	106		

LABORATORY CONTROL SAMPLE: 607510740

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	Limits	Footnotes
Acetone	ug/l	20.00	13.55	68	18-147	
Benzene	ug/l	10.00	9.570	96	74-118	
Bromobenzene	ug/l	10.00	8.690	87	79-115	
Bromochloromethane	ug/l	10.00	11.60	116	67-122	
Bromodichloromethane	ug/l	10.00	9.630	96	81-124	
Bromoform	ug/l	10.00	6.970	70	65-125	
Bromomethane	ug/l	10.00	12.35	124	10-150	
2-Butanone (MEK)	ug/l	20.00	30.20	151	35-132	1
n-Butylbenzene	ug/l	10.00	9.740	97	67-124	
sec-Butylbenzene	ug/l	10.00	10.07	101	75-121	
tert-Butylbenzene	ug/l	10.00	9.240	92	76-118	
Carbon disulfide	ug/l	20.00	15.02	75	12-132	
Carbon tetrachloride	ug/l	10.00	12.31	123	69-131	
Chlorobenzene	ug/l	10.00	9.360	94	77-115	
Chloroethane	ug/l	10.00	9.220	92	23-140	
Chloroform	ug/l	10.00	9.890	99	74-123	
Chloromethane	ug/l	10.00	10.38	104	25-150	
2-Chlorotoluene	ug/l	10.00	8.440	84	76-118	
4-Chlorotoluene	ug/l	10.00	8.300	83	75-119	
1,2-Dibromo-3-chloropropane	ug/l	10.00	6.030	60	59-124	
Dibromochloromethane	ug/l	10.00	8.740	87	73-125	
1,2-Dibromoethane (EDB)	ug/l	10.00	9.400	94	78-120	
Dibromomethane	ug/l	10.00	9.570	96	71-124	
1,2-Dichlorobenzene	ug/l	10.00	9.040	90	77-117	
1,3-Dichlorobenzene	ug/l	10.00	8.860	89	75-116	

QUALITY CONTROL DATA

Lab Project Number: 6087145
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607510740

Parameter	Units	Spike Conc.	LCS Result	LCS	% Rec Limits	Footnotes
1,4-Dichlorobenzene	ug/l	10.00	8.660	87	72-117	
Dichlorodifluoromethane	ug/l	10.00	3.500	35	10-142	
1,1-Dichloroethane	ug/l	10.00	10.75	108	65-126	
1,2-Dichloroethane	ug/l	10.00	11.86	119	71-126	
1,2-Dichloroethene (Total)	ug/l	20.00	26.97	135	73-124	2
1,1-Dichloroethene	ug/l	10.00	9.190	92	63-135	
cis-1,2-Dichloroethene	ug/l	10.00	16.19	162	74-120	3
trans-1,2-Dichloroethene	ug/l	10.00	10.78	108	68-131	
1,2-Dichloropropane	ug/l	10.00	10.04	100	74-117	
1,3-Dichloropropane	ug/l	10.00	10.47	105	78-118	
2,2-Dichloropropane	ug/l	10.00	15.99	160	47-145	1
1,1-Dichloropropene	ug/l	10.00	12.27	123	73-130	
cis-1,3-Dichloropropene	ug/l	10.00	9.160	92	73-124	
trans-1,3-Dichloropropene	ug/l	10.00	8.450	84	72-124	
Ethylbenzene	ug/l	10.00	9.270	93	76-119	
Hexachloro-1,3-butadiene	ug/l	10.00	10.51	105	63-122	
2-Hexanone	ug/l	20.00	17.49	88	43-117	
Isopropylbenzene (Cumene)	ug/l	10.00	7.960	80	73-113	
p-Isopropyltoluene	ug/l	10.00	8.700	87	71-117	
Methylene chloride	ug/l	10.00	9.590	96	65-133	
4-Methyl-2-pentanone (MIBK)	ug/l	20.00	18.09	90	44-113	
Methyl-tert-butyl ether	ug/l	10.00	9.290	93	54-129	
Naphthalene	ug/l	10.00	8.580	86	46-127	
n-Propylbenzene	ug/l	10.00	10.22	102	74-119	
Styrene	ug/l	10.00	9.360	94	78-121	
1,1,1,2-Tetrachloroethane	ug/l	10.00	10.47	105	78-122	
1,1,2,2-Tetrachloroethane	ug/l	10.00	7.880	79	69-121	
Tetrachloroethene	ug/l	10.00	9.870	99	72-121	
Toluene	ug/l	10.00	9.670	97	76-116	
1,2,3-Trichlorobenzene	ug/l	10.00	8.710	87	59-122	
1,2,4-Trichlorobenzene	ug/l	10.00	8.670	87	59-121	
1,1,1-Trichloroethane	ug/l	10.00	12.29	123	71-125	
1,1,2-Trichloroethane	ug/l	10.00	11.43	114	78-121	
Trichloroethene	ug/l	10.00	10.36	104	75-120	
Trichlorofluoromethane	ug/l	10.00	9.480	95	55-141	
1,2,3-Trichloropropane	ug/l	10.00	10.51	105	74-126	
1,2,4-Trimethylbenzene	ug/l	10.00	8.760	88	77-116	

QUALITY CONTROL DATA

Lab Project Number: 6087145
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607510740

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
1,3,5-Trimethylbenzene	ug/l	10.00	9.210	92	76-117	
Vinyl chloride	ug/l	10.00	9.200	92	50-131	
Xylene (Total)	ug/l	30.00	28.28	94	78-120	
m&p-Xylene	ug/l	20.00	18.83	94	74-120	
o-Xylene	ug/l	10.00	9.450	94	77-120	
Toluene-d8 (S)				103	88-110	
4-Bromofluorobenzene (S)				91	86-115	
Dibromofluoromethane (S)				104	86-118	
1,2-Dichloroethane-d4 (S)				107	80-120	

QUALITY CONTROL DATA PARAMETER FOOTNOTES

Consistent with EPA guidelines, unrounded concentrations are displayed and have been used to calculate % Rec and RPD values.

LCS(D)	Laboratory Control Sample (Duplicate)
MS(D)	Matrix Spike (Duplicate)
DUP	Sample Duplicate
ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
RPD	Relative Percent Difference
(S)	Surrogate
[1]	The compound or surrogate recovery exceeds the laboratory generated acceptance limits. While the recovery was elevated, the compound was not detected above the reporting limit in the associated samples; therefore, the high bias does not affect the usability of the reported sample results.
[2]	Spike recovery was outside of QC limits high. Therefore samples with this compound detected may have a slightly high bias.
[3]	Spike recovery was outside of QC limits high. Therefore samples with this compound detected may have a slightly high bias.

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QUALITY CONTROL DATA

CROSS REFERENCE TABLE

Lab Project Number: 6087145
Client Project ID: Bangor

Lab Sample No Identifier	Client Sample Identifier	QC Batch Method	QC Batch Identifier	Analytical Method	Analytical Batch Identifier
607504727	TUE-9-1	EPA 8260	178587		
607504735	WED-10-1	EPA 8260	178587		
607504750	WED-11-1	EPA 8260	178587		
607504776	TUES-5-1	EPA 8260	178587		
607504818	RINSATE 9-22-04	EPA 8260	178587		
607504834	TRIP BLANK	EPA 8260	178587		

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September 29, 2004

Dr. John Eisenbeis
Camp Dresser & McKee Inc.
1331 17th Street
Suite 1200
Denver, CO 80202

RE: Lab Project Number: 6087199
Client Project ID: Bangor

Dear Dr. Eisenbeis:

Enclosed are the analytical results for sample(s) received by the laboratory on September 24, 2004. Results reported herein conform to the most current NELAC standards, where applicable, unless otherwise narrated in the body of the report.

If you have any questions concerning this report please feel free to contact me.

Sincerely,

Adam Taylor

Adam Taylor
adam.taylor@pacelabs.com
Project Manager

Kansas/NELAP Certification Number E-10116

Enclosures

SAMPLE SUMMARY

Lab Project Number: 6087199
Client Project ID: Bangor

Project Sample Number	Sample Number	Client Sample ID	Matrix	Date Collected	Date Received
6087199-001	607509056	THURS-13-1	Water	09/23/04 07:45	09/24/04 09:15

SAMPLE ANALYTE COUNT

Lab Project Number: 6087199
Client Project ID: Bangor

Project Sample Number	Sample No	Client Sample ID	Analysis Code	Analysis Description	Analytes Reported
6087199-001	607509056	THURS-13-1	826LL WEPA	GC/MS VOCs by 8260 (Low Level)	72

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Lab Project Number: 6087199
Client Project ID: Bangor

Lab Sample No: 607509056
Project Sample Number: 6087199-001
Date Collected: 09/23/04 07:45
Client Sample ID: THURS-13-1
Matrix: Water
Date Received: 09/24/04 09:15

GC/MS Volatiles

GC/MS VOCs by 8260 (Low Level) Method: EPA 8260

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
Acetone	440	ug/l	200	20.0	09/29/04 14:22	KBL1	67-64-1		
Benzene	2300	ug/l	20.	20.0	09/29/04 14:22	KBL1	71-43-2		
Bromobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	108-86-1		
Bromochloromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	74-97-5		
Bromodichloromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-27-4		
Bromoform	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-25-2		
Bromomethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	74-83-9		
2-Butanone (MEK)	ND	ug/l	200	20.0	09/29/04 14:22	KBL1	78-93-3		
n-Butylbenzene	130	ug/l	20.	20.0	09/29/04 14:22	KBL1	104-51-8		
sec-Butylbenzene	22.	ug/l	20.	20.0	09/29/04 14:22	KBL1	135-98-8		
tert-Butylbenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	98-06-6		
Carbon disulfide	ND	ug/l	100	20.0	09/29/04 14:22	KBL1	75-15-0		
Carbon tetrachloride	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	56-23-5		
Chlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	108-90-7		
Chloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-00-3		
Chloroform	35.	ug/l	20.	20.0	09/29/04 14:22	KBL1	67-66-3		
Chloromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	74-87-3		
2-Chlorotoluene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	95-49-8		
4-Chlorotoluene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	106-43-4		
1,2-Dibromo-3-chloropropane	ND	ug/l	50.	20.0	09/29/04 14:22	KBL1	96-12-8		
Dibromochloromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	124-48-1		
1,2-Dibromoethane (EDB)	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	106-93-4		
Dibromomethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	74-95-3		
1,2-Dichlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	95-50-1		
1,3-Dichlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	541-73-1		
1,4-Dichlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	106-46-7		
Dichlorodifluoromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-71-8		
1,1-Dichloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-34-3		
1,2-Dichloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	107-06-2		
1,2-Dichloroethene (Total)	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	540-59-0		
1,1-Dichloroethene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-35-4		
cis-1,2-Dichloroethene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	156-59-2		
trans-1,2-Dichloroethene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	156-60-5		
1,2-Dichloropropane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	78-87-5		
1,3-Dichloropropane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	142-28-9		
2,2-Dichloropropane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	594-20-7		
1,1-Dichloropropene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	563-58-6		

Lab Project Number: 6087199
Client Project ID: Bangor

Lab Sample No: 607509056
Project Sample Number: 6087199-001
Date Collected: 09/23/04 07:45
Client Sample ID: THURS-13-1
Matrix: Water
Date Received: 09/24/04 09:15

Parameters	Results	Units	Report Limit	DF	Analyzed	By	CAS No.	Qual	RegLmt
cis-1,3-Dichloropropene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	10061-01-5		
trans-1,3-Dichloropropene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	10061-02-6		
Ethylbenzene	760	ug/l	20.	20.0	09/29/04 14:22	KBL1	100-41-4		
Hexachloro-1,3-butadiene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	87-68-3		
2-Hexanone	1200	ug/l	200	20.0	09/29/04 14:22	KBL1	591-78-6		
Isopropylbenzene (Cumene)	51.	ug/l	20.	20.0	09/29/04 14:22	KBL1	98-82-8		
p-Isopropyltoluene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	99-87-6		
Methylene chloride	23.	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-09-2	1,2	
4-Methyl-2-pentanone (MIBK)	ND	ug/l	200	20.0	09/29/04 14:22	KBL1	108-10-1		
Methyl-tert-butyl ether	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	1634-04-4		
Naphthalene	320	ug/l	200	20.0	09/29/04 14:22	KBL1	91-20-3		
n-Propylbenzene	180	ug/l	20.	20.0	09/29/04 14:22	KBL1	103-65-1		
Styrene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	100-42-5		
1,1,1,2-Tetrachloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	630-20-6		
1,1,2,2-Tetrachloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	79-34-5		
Tetrachloroethene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	127-18-4		
Toluene	97.	ug/l	20.	20.0	09/29/04 14:22	KBL1	108-88-3		
1,2,3-Trichlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	87-61-6		
1,2,4-Trichlorobenzene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	120-82-1		
1,1,1-Trichloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	71-55-6		
1,1,2-Trichloroethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	79-00-5		
Trichloroethene	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	79-01-6		
Trichlorofluoromethane	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-69-4		
1,2,3-Trichloropropane	ND	ug/l	50.	20.0	09/29/04 14:22	KBL1	96-18-4		
1,2,4-Trimethylbenzene	1500	ug/l	20.	20.0	09/29/04 14:22	KBL1	95-63-6		
1,3,5-Trimethylbenzene	280	ug/l	20.	20.0	09/29/04 14:22	KBL1	108-67-8		
Vinyl chloride	ND	ug/l	20.	20.0	09/29/04 14:22	KBL1	75-01-4		
Xylene (Total)	2500	ug/l	60.	20.0	09/29/04 14:22	KBL1	1330-20-7		
m&p-Xylene	2400	ug/l	40.	20.0	09/29/04 14:22	KBL1			
o-Xylene	88.	ug/l	20.	20.0	09/29/04 14:22	KBL1	95-47-6		
pH	1.0			1.0	09/29/04 14:22	KBL1			
Toluene-d8 (S)	98	%		1.0	09/29/04 14:22	KBL1	2037-26-5		
4-Bromofluorobenzene (S)	100	%		1.0	09/29/04 14:22	KBL1	460-00-4		
Dibromofluoromethane (S)	83	%		1.0	09/29/04 14:22	KBL1	1868-53-7	3	
1,2-Dichloroethane-d4 (S)	89	%		1.0	09/29/04 14:22	KBL1	17060-07-0		

PARAMETER FOOTNOTES

Dilution factor shown represents the factor applied to the reported result and reporting limit due to changes in sample preparation, dilution of the extract, or moisture content

ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
(S)	Surrogate
[1]	Analyte is found in the associated blank as well as in the sample (CLP B-Flag).
[2]	Compound was detected in the method blank at approximately the same level on the instrument. Therefore it is expected that this concentration is laboratory contamination.
[3]	Low surrogate recovery was confirmed as a matrix effect by a second analysis.

Lab Project Number: 6087199
Client Project ID: Bangor

QC Batch: 178887
Analysis Method: EPA 8260
QC Batch Method: EPA 8260
Analysis Description: GC/MS VOCs by 8260 (Low Level)
Associated Lab Samples: 607509056

METHOD BLANK: 607524014
Associated Lab Samples: 607509056

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Acetone	ug/l	ND	10.	
Benzene	ug/l	ND	1.0	
Bromobenzene	ug/l	ND	1.0	
Bromochloromethane	ug/l	ND	1.0	
Bromodichloromethane	ug/l	ND	1.0	
Bromoform	ug/l	ND	1.0	
Bromomethane	ug/l	ND	1.0	
2-Butanone (MEK)	ug/l	ND	10.	
n-Butylbenzene	ug/l	ND	1.0	
sec-Butylbenzene	ug/l	ND	1.0	
tert-Butylbenzene	ug/l	ND	1.0	
Carbon disulfide	ug/l	ND	5.0	
Carbon tetrachloride	ug/l	ND	1.0	
Chlorobenzene	ug/l	ND	1.0	
Chloroethane	ug/l	ND	1.0	
Chloroform	ug/l	ND	1.0	
Chloromethane	ug/l	ND	1.0	
2-Chlorotoluene	ug/l	ND	1.0	
4-Chlorotoluene	ug/l	ND	1.0	
1,2-Dibromo-3-chloropropane	ug/l	ND	2.5	
Dibromochloromethane	ug/l	ND	1.0	
1,2-Dibromoethane (EDB)	ug/l	ND	1.0	
Dibromomethane	ug/l	ND	1.0	
1,2-Dichlorobenzene	ug/l	ND	1.0	
1,3-Dichlorobenzene	ug/l	ND	1.0	
1,4-Dichlorobenzene	ug/l	ND	1.0	
Dichlorodifluoromethane	ug/l	ND	1.0	
1,1-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethane	ug/l	ND	1.0	
1,2-Dichloroethene (Total)	ug/l	ND	1.0	
1,1-Dichloroethene	ug/l	ND	1.0	

QUALITY CONTROL DATA

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Lab Project Number: 6087199
Client Project ID: Bangor

METHOD BLANK: 607524014
Associated Lab Samples: 607509056

Parameter	Units	Blank Result	Reporting Limit	Footnotes
cis-1,2-Dichloroethene	ug/l	ND	1.0	
trans-1,2-Dichloroethene	ug/l	ND	1.0	
1,2-Dichloropropane	ug/l	ND	1.0	
1,3-Dichloropropane	ug/l	ND	1.0	
2,2-Dichloropropane	ug/l	ND	1.0	
1,1-Dichloropropene	ug/l	ND	1.0	
cis-1,3-Dichloropropene	ug/l	ND	1.0	
trans-1,3-Dichloropropene	ug/l	ND	1.0	
Ethylbenzene	ug/l	ND	1.0	
Hexachloro-1,3-butadiene	ug/l	ND	1.0	
2-Hexanone	ug/l	ND	10.	
Isopropylbenzene (Cumene)	ug/l	ND	1.0	
p-Isopropyltoluene	ug/l	ND	1.0	
Methylene chloride	ug/l	2.5	1.0	
4-Methyl-2-pentanone (MIBK)	ug/l	ND	10.	
Methyl-tert-butyl ether	ug/l	ND	1.0	
Naphthalene	ug/l	ND	10.	
n-Propylbenzene	ug/l	ND	1.0	
Styrene	ug/l	ND	1.0	
1,1,1,2-Tetrachloroethane	ug/l	ND	1.0	
1,1,2,2-Tetrachloroethane	ug/l	ND	1.0	
Tetrachloroethene	ug/l	ND	1.0	
Toluene	ug/l	ND	1.0	
1,2,3-Trichlorobenzene	ug/l	ND	1.0	
1,2,4-Trichlorobenzene	ug/l	ND	1.0	
1,1,1-Trichloroethane	ug/l	ND	1.0	
1,1,2-Trichloroethane	ug/l	ND	1.0	
Trichloroethene	ug/l	ND	1.0	
Trichlorofluoromethane	ug/l	ND	1.0	
1,2,3-Trichloropropane	ug/l	ND	2.5	
1,2,4-Trimethylbenzene	ug/l	ND	1.0	
1,3,5-Trimethylbenzene	ug/l	ND	1.0	
Vinyl chloride	ug/l	ND	1.0	
Xylene (Total)	ug/l	ND	3.0	
m&p-Xylene	ug/l	ND	2.0	
o-Xylene	ug/l	ND	1.0	

QUALITY CONTROL DATA

Lab Project Number: 6087199
Client Project ID: Bangor

METHOD BLANK: 607524014
Associated Lab Samples: 607509056

Parameter	Units	Blank Result	Reporting Limit	Footnotes
Toluene-d8 (S)	%	106		
4-Bromofluorobenzene (S)	%	104		
Dibromofluoromethane (S)	%	103		
1,2-Dichloroethane-d4 (S)	%	119		

LABORATORY CONTROL SAMPLE: 607524022

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
Acetone	ug/l	20.00	17.02	85	18-147	
Benzene	ug/l	10.00	9.470	95	74-118	
Bromobenzene	ug/l	10.00	8.420	84	79-115	
Bromochloromethane	ug/l	10.00	11.87	119	67-122	
Bromodichloromethane	ug/l	10.00	8.930	89	81-124	
Bromoform	ug/l	10.00	9.820	98	65-125	
Bromomethane	ug/l	10.00	12.91	129	10-150	
2-Butanone (MEK)	ug/l	20.00	18.84	94	35-132	
n-Butylbenzene	ug/l	10.00	9.490	95	67-124	
sec-Butylbenzene	ug/l	10.00	9.380	94	75-121	
tert-Butylbenzene	ug/l	10.00	8.850	88	76-118	
Carbon disulfide	ug/l	20.00	17.08	85	12-132	
Carbon tetrachloride	ug/l	10.00	11.81	118	69-131	
Chlorobenzene	ug/l	10.00	10.59	106	77-115	
Chloroethane	ug/l	10.00	10.33	103	23-140	
Chloroform	ug/l	10.00	9.760	98	74-123	
Chloromethane	ug/l	10.00	9.660	97	25-150	
2-Chlorotoluene	ug/l	10.00	9.210	92	76-118	
4-Chlorotoluene	ug/l	10.00	9.190	92	75-119	
1,2-Dibromo-3-chloropropane	ug/l	10.00	7.330	73	59-124	
Dibromochloromethane	ug/l	10.00	9.490	95	73-125	
1,2-Dibromoethane (EDB)	ug/l	10.00	10.45	105	78-120	
Dibromomethane	ug/l	10.00	9.250	92	71-124	
1,2-Dichlorobenzene	ug/l	10.00	9.700	97	77-117	
1,3-Dichlorobenzene	ug/l	10.00	9.060	91	75-116	
1,4-Dichlorobenzene	ug/l	10.00	8.770	88	72-117	

QUALITY CONTROL DATA

Lab Project Number: 6087199
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607524022

Parameter	Units	Spike Conc.	LCS Result	LCS	% Rec Limits	Footnotes
Dichlorodifluoromethane	ug/l	10.00	7.240	72	10-142	
1,1-Dichloroethane	ug/l	10.00	11.18	112	65-126	
1,2-Dichloroethane	ug/l	10.00	11.68	117	71-126	
1,2-Dichloroethene (Total)	ug/l	20.00	20.83	104	73-124	
1,1-Dichloroethene	ug/l	10.00	9.350	94	63-135	
cis-1,2-Dichloroethene	ug/l	10.00	9.950	100	74-120	
trans-1,2-Dichloroethene	ug/l	10.00	10.87	109	68-131	
1,2-Dichloropropane	ug/l	10.00	9.720	97	74-117	
1,3-Dichloropropane	ug/l	10.00	9.960	100	78-118	
2,2-Dichloropropane	ug/l	10.00	12.76	128	47-145	
1,1-Dichloropropene	ug/l	10.00	12.16	122	73-130	
cis-1,3-Dichloropropene	ug/l	10.00	9.450	94	73-124	
trans-1,3-Dichloropropene	ug/l	10.00	11.50	115	72-124	
Ethylbenzene	ug/l	10.00	9.320	93	76-119	
Hexachloro-1,3-butadiene	ug/l	10.00	12.50	125	63-122	1
2-Hexanone	ug/l	20.00	18.61	93	43-117	
Isopropylbenzene (Cumene)	ug/l	10.00	8.190	82	73-113	
p-Isopropyltoluene	ug/l	10.00	8.640	86	71-117	
Methylene chloride	ug/l	10.00	11.32	113	65-133	
4-Methyl-2-pentanone (MIBK)	ug/l	20.00	18.38	92	44-113	
Methyl-tert-butyl ether	ug/l	10.00	9.130	91	54-129	
Naphthalene	ug/l	10.00	8.110	81	46-127	
n-Propylbenzene	ug/l	10.00	10.73	107	74-119	
Styrene	ug/l	10.00	9.850	98	78-121	
1,1,1,2-Tetrachloroethane	ug/l	10.00	10.47	105	78-122	
1,1,2,2-Tetrachloroethane	ug/l	10.00	8.710	87	69-121	
Tetrachloroethene	ug/l	10.00	10.66	107	72-121	
Toluene	ug/l	10.00	10.01	100	76-116	
1,2,3-Trichlorobenzene	ug/l	10.00	8.170	82	59-122	
1,2,4-Trichlorobenzene	ug/l	10.00	8.230	82	59-121	
1,1,1-Trichloroethane	ug/l	10.00	12.14	121	71-125	
1,1,2-Trichloroethane	ug/l	10.00	11.88	119	78-121	
Trichloroethene	ug/l	10.00	9.640	96	75-120	
Trichlorofluoromethane	ug/l	10.00	9.730	97	55-141	
1,2,3-Trichloropropane	ug/l	10.00	9.940	99	74-126	
1,2,4-Trimethylbenzene	ug/l	10.00	9.130	91	77-116	
1,3,5-Trimethylbenzene	ug/l	10.00	9.020	90	76-117	

Lab Project Number: 6087199
Client Project ID: Bangor

LABORATORY CONTROL SAMPLE: 607524022

Parameter	Units	Spike Conc.	LCS Result	LCS % Rec	% Rec Limits	Footnotes
Vinyl chloride	ug/l	10.00	10.92	109	50-131	
Xylene (Total)	ug/l	30.00	29.83	99	78-120	
m&p-Xylene	ug/l	20.00	19.88	99	74-120	
o-Xylene	ug/l	10.00	9.950	100	77-120	
Toluene-d8 (S)				107	88-110	
4-Bromofluorobenzene (S)				92	86-115	
Dibromofluoromethane (S)				102	86-118	
1,2-Dichloroethane-d4 (S)				106	80-120	

QUALITY CONTROL DATA PARAMETER FOOTNOTES

Consistent with EPA guidelines, unrounded concentrations are displayed and have been used to calculate % Rec and RPD values.

LCS(D)	Laboratory Control Sample (Duplicate)
MS(D)	Matrix Spike (Duplicate)
DUP	Sample Duplicate
ND	Not detected at or above adjusted reporting limit
NC	Not Calculable
J	Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit
MDL	Adjusted Method Detection Limit
RPD	Relative Percent Difference
(S)	Surrogate
[1]	The compound or surrogate recovery exceeds the laboratory generated acceptance limits. While the recovery was elevated, the compound was not detected above the reporting limit in the associated samples; therefore, the high bias does not affect the usability of the reported sample results.

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QUALITY CONTROL DATA

CROSS REFERENCE TABLE

Lab Project Number: 6087199
Client Project ID: Bangor

Lab Sample No Identifier	Client Sample Identifier	QC Batch Method	QC Batch Identifier	Analytical Method	Analytical Batch Identifier
607509056	THURS-13-1	EPA 8260	178887		

Date: 09/29/04

Appendix D
Sample Calibration Calculation

SAMPLE	**TUE-4-1**
baseline solution	BMS
	[10 mM MES pH 7.0 in 0.15 M (8.85 g/L) NaCl + 0.025 M (~2.5 g/L) CaCl2]
Date	20-Sep-04

Biosensor	30
pH optode	77
Hardware	Model 1 with PMT at 600 V

total volume 4850 uL
always removed same volume as was to be injected

Data from measurement of sample and stand s:

vol (uL)	**soln**	**co pb)**	**biosensor ΔV_{obs}**	**pH optode ΔV**
100	GW	??	0.107	0.022
100	DCA standard	100	0.312	0.026
50	DCA standard	100	0.157	0.013
25	DCA standard	100	0.086	0.007

Data for correlation of pH response:
(performed in same baseline solution as above)

use correlation for biosensor 30 and pH optode 77 on separate worksheet

so ΔVpH (bio30) = ΔVpH (pH77) * 3.58

so ΔVpH experienced by biosensor is:

vol (uL)	**soln**	**conc (ppb)**	**biosensor ΔV_{pH}**
100	GW	??	0.079
100	DCA standard	100	0.093
50	DCA standard	100	0.047
25	DCA standard	100	0.025

then, since:

$\mathbf{\Delta V_{obs} = \Delta V_{pH} + \Delta V_{DCA}}$

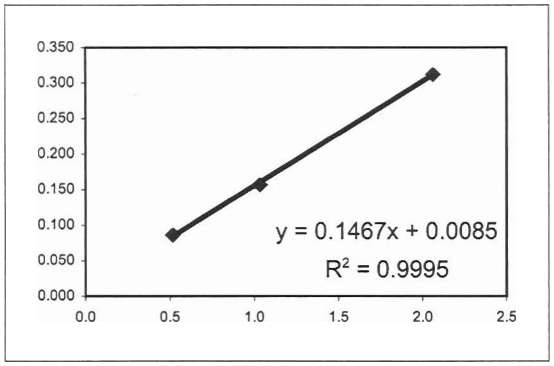
can calculate ΔV_{DCA} (biosensor response due to DCA only):

vol (uL)	**soln**	**conc (ppb)**	**biosensor ΔV_{DCA}**
100	GW	??	0.028
100	DCA standard	100	0.219
50	DCA standard	100	0.110
25	DCA standard	100	0.061

Calculation with no corrections:

0

vol (uL)	soln	conc (ppb)	Δ conc (ppb)	osensor ΔVobs
100	GW	??		0.107
100	DCA standard	100	2.1	0.312
50	DCA standard	100	1.0	0.157
25	DCA standard	100	0.5	0.086



GW ΔC = 0.7

GW DCA = 32.6

Calculation including mass removed effects only:

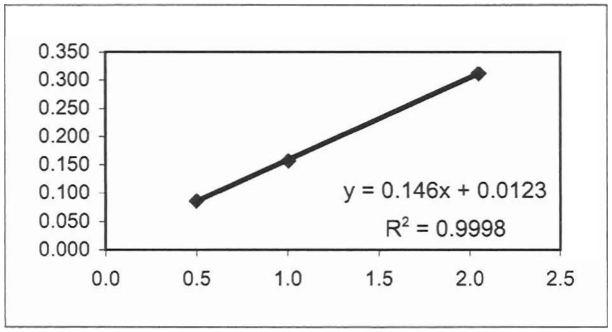
Initial concentration in baseline solution is:

0 ppb

Then starting conc in vial is: 0 ppb

Guess GW conc 32 ppb

vol (uL)	soln	conc (ppb)	conc after spike	Δ conc (ppb)	biosensor ΔVobs
100	GW	??	0.7	0.7	0.107
100	DCA standard	100	2.7	2.0	0.312
50	DCA standard	100	3.7	1.0	0.157
25	DCA standard	100	4.2	0.5	0.086



0.6

31.5

Calculation including volume & pH effects:

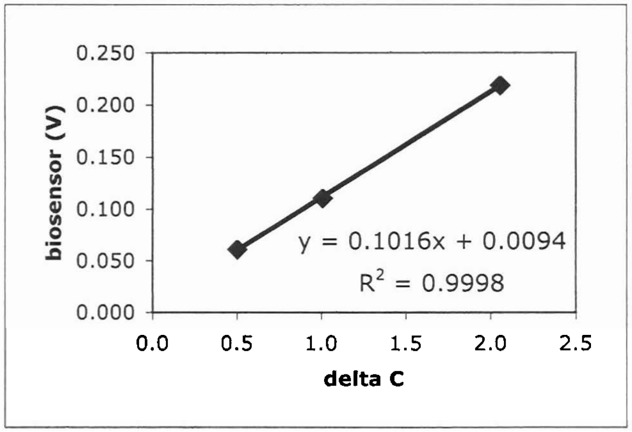
Initial concentration in baseline solution is:

0 ppb

Then starting conc in vial is: 0 ppb

Guess GW conc 9 ppb

vol (uL)	soln	conc (ppb)	conc after spike	Δ conc (ppb)	biosensor ΔV_{DCA}
100	GW	??	0.2	0.2	0.028
100	DCA standard	100	2.2	2.1	0.219
50	DCA standard	100	3.3	1.0	0.110
25	DCA standard	100	3.8	0.5	0.061



GW ΔC = 0.2

GW DCA = 9.0

Snap™ Samplers

AECOM
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[City, state, zip]

919.872.6600 tel
919.872.7996 fax

Telephone Call Summary

By:	Matt Zenker	Date:	December 8, 2010
Talked with:	Sandy Britt	Project number:	
From (company):	ProHydro, Inc.	Project name:	Pinewood Landfill
Phone number:	(585) 385-0023	Subject:	Snap samplers for groundwater

Distribution: Project file

Discussed use of Snap sampler for groundwater. The unit requires a specialized sampler housing, 'trigger' and well cap (docking cap). Total capital cost to implement would be about $400 per well, although cost may be more expensive if larger volumes are required. Volume per sampler is variable, but the max sampler container is about 350 mL. Some sample modification is necessary post sampling to prepare for shipping/analysis. For example, acid must be added to sample vials for VOA analysis. Sample containers include a spring that 'snaps' the sample caps in place. The sample bottles are $20/bottle and must be replaced after each event. The analytical laboratory must be prepared to receive the samples, as they look different than standard VOA vials. A toolkit (~$50) is also required for sampling activities.

THE SNAP SAMPLER®

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US PAT. 7,178,435 UK PAT. GB 2,417,722

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Snap Samplers:

Snap Samplers

PH40 (40 ml) Plastic (Acetal) Snap Sampler	$165.00 each
PH125 (125 ml) Plastic (Acetal) Snap Sampler (holds 125ml *and 350ml* bottles)	$165.00 each

Stack in any combination (up to 6 with electric or pneumatic triggers)

Triggers:

Light Duty Mechanical Trigger *(for deployments up to ~50 feet/15m)*

Trigger Construction	$30.00 each
Plus Trigger line per foot	$1.25/ft
Or Trigger line per meter	$4.00/m

Electric Trigger *(for deployments up to 2500ft/750m)*

Downhole Electric Actuator (1.3Ω, 6.3Ω, 16.5Ω)	$325.00 each
Electric Trigger Line Construction (submersible connectors, jacks, wire mesh hangar)	$85.00 each
Plus polyurethane electric wire line per foot	$1.75/ft
Or polyurethane electric wire line per meter	$5.50/m

Pneumatic Trigger *(for deployments up to 300ft/90m)*

Downhole Pneumatic Actuator (approx 30psi to activate, any depth)	$195.00 each
Trigger Air Line Construction (cut to length, plus hangar and fittings)	$25.00 each
Plus air line per foot (1/4 x 1/8 HDPE)	$0.25/ft
Plus cable trigger line per meter	$3.10/m

Weights are recommended with pneumatics deeper than ~50ft

Well Docks/Weights:

(for secure well head protection and support of Snap Trigger lines)

2-Inch (5-cm) Dock (locking well cap plus support ring, for SCH40 and SCH80 PVC)	$32.00 each
4-Inch (10-cm) Dock (locking well cap plus support ring, for SCH40 and SCH80 PVC)	$42.00 each
Custom Dock	on request
5lb/2.5kg stainless steel weight	$38.00 each.

Bottles:

Package of ***two*** 40 ml Snap Sampler VOA vials, includes septa caps and labels	$32.00/pack
Amber VOA vials are also available for just $4 more	$36.00/pack
Package of ***one*** 125 ml Snap Sampler POLY bottle, includes septa caps and label	$16.00 each
Package of ***one*** 350 ml Snap Sampler POLY bottle, includes septa caps and label	$16.00 each

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THE SNAP SAMPLER®

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Tools and Supplies:

Standard Tool Kit (includes two driver tools, one nipper tool, Standard Operating Procedure, laminated instruction cards, and tool storage box)	$49/ea.

Electric Trigger Switch and Tool Kits

Up to 75 feet *(shallow sampling--simple hand carried battery pack—charge will last all day!)*

28 Volt Switch (Requires 28V battery and charger) for 1.3Ω actuator	$125
(1) 28V Milwaukee Lithium-Ion Battery and Charger	$195

Up to 350 feet *(shallow and mid-depth--simple hand carried battery pack—charge will last all day!)*

28/56 Volt Switch (Requires 2-28V batteries and charger) for 6.3Ω actuator	$175
(2) 28V Milwaukee Lithium-Ion Batteries and Charger	$335

Up to 2500 feet *(Good for all depths but requires external power)*

110 Volt A/C plug-in FWBR switch (Requires 110 A/C source or Inverter) for 16.5Ω actuator	$125
12V Auto Battery Inverter (1400w max-A/C out to FWBR switch, incl. batt. clips)	$145

Pelican Carry Case for Battery trigger switch, batteries, charger and Standard Tool Kit	$225
Pelican Carry Case for Plug-in trigger switch, and Standard Tool Kit	$175

Pneumatic Trigger Activation and Tool Kits

Pressure block with 100psi pressure gauge; Schrader (bicycle pump) valve; pressure-relief valve; 3ft air line tubing and fittings to attach to downhole air line	$125
12v air pump	$65
Pelican Carry Case for Pressure Block, Air Pump, and Standard Tool Kit	$175

Supplies and Replacement Parts

Spare Screw Driver Tool	$12.00/ea
Spare Nipper Tool	$22.00/ea
Replacement Stainless Ball Fitting Connector Cable (to connect between multiple Snap Samplers; *Connector Cables included with initial Snap Sampler purchases*)	$12.00/ea.
Plastic-end, FEP-coated connector cable *(for most challenging geochemistries)*	$22.00/ea.
Release pin set (set of 3 upper/lower/lever pieces for 40ml Snap Sampler)	$12.00/set
Release pin set (set of 3 upper/lower/lever pieces for 125ml Snap Sampler)	$12.00/set
Pack of replacement blue screws (12)	$10.00/pk

Don't forget to ask about out Pilot to Purchase Program (p3)
($50 for each Snap Sampler, defer final purchase until second round of sampling)

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Passive Sampling Devices

FINAL

Results Report for the Demonstration of No-Purge Groundwater Sampling Devices at Former McClellan Air Force Base, California

Prepared For

U.S. Army Corps of Engineers
Omaha District

and

Air Force Center for Environmental Excellence

and

Air Force Real Property Agency

U.S. AIR FORCE

Contract F44650-99-D-0005
Delivery Order DK01

October 2005

FINAL

RESULTS REPORT FOR THE DEMONSTRATION OF NO-PURGE GROUNDWATER SAMPLING DEVICES AT FORMER MCCLELLAN AIR FORCE BASE, CALIFORNIA

October 2005

Prepared for:

U.S. Army Corps of Engineers, Omaha District

And

Air Force Center for Environmental Excellence

And

Air Force Real Property Agency

CONTRACT NO. F44650-99-D-0005
Delivery Order DK01

Prepared by:

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1700 Broadway Suite 900
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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFRPA	Air Force Real Property Agency
AFCEE/ERT	Air Force Center for Environmental Excellence, Technology Transfer Division
BRAC	Base Realignment and Closure
CAS	Columbia Analytical Services
cm	centimeter
CRWQCB	California Regional Water Quality Control Board
°C	degrees Celcius
DO	dissolved oxygen
DoD	Department of Defense
gpm	gallon(s) per minute
HDPE	high-density polyethylene
IDW	investigation-derived waste
ITRC	Interstate Technology and Regulatory Council
LDPE	low-density polyethylene
LTM	long-term monitoring
MDL	method detection limit
mL	milliliter(s)
McClellan	former McClellan Air Force Base
MS/MSD	matrix spike/matrix spike duplicate
MTBE	methyl tert-butyl ether
ND	not detected
NTU	nephelometric turbidity unit
OD	outside diameter
ORP	oxidation-reduction potential
Parsons	Parsons Engineering Science, Inc.
PDBS	passive diffusion bag sampler
PDS	passive diffusion sampler
PFA	perfluoroalkoxy
PQL	practical quantitation limit
PsMS	polysulfone membrane sampler
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
R^2	goodness-of-fit parameter/correlation coefficient
RCS	regenerated cellulose sampler
redox	reduction-oxidation
RPD	relative percent difference
RPO	remedial process optimization
RPPS	rigid porous polyethylene sampler
Sequoia	Sequoia Analytical Services
SOP	standard operating procedure
SVOC	semi-volatile organic compound
TAL	target analyte list
TCE	trichloroethene

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

URS	URS Corporation
USACE	US Department of the Army, Corps of Engineers
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
VOA	volatile organics analysis
VOC	volatile organic compound

SECTION 1

INTRODUCTION

1.1 PROJECT DESCRIPTION AND LOCATION

On 22 January 2002, Parsons Engineering Science, Inc. (Parsons) was awarded delivery order DK01 under United States Department of the Army, Corps of Engineers (USACE) Contract Number F44650-99-D-0005. The scope of this delivery order is to provide services, technical labor-hours, and materials to support Remedial Process Optimization (RPO) evaluations and demonstrate the effectiveness of Passive Diffusion Bag Samplers (PDBSs) for sampling volatile organic compounds (VOCs) in existing groundwater monitoring programs at selected Base Realignment and Closure (BRAC) installations administered by the Air Force Real Property Agency (AFRPA). The former Technology Transfer Division of the Air Force Center for Environmental Excellence (AFCEE/ERT) initiated the PDBS demonstration to introduce this technology to multiple Department of Defense (DoD) installations and to improve the cost effectiveness of groundwater monitoring programs for VOCs.

This report describes the activities and results of a field demonstration of six different diffusion and grab groundwater sampling devices at the former McClellan Air Force Base (McClellan), located in Sacramento, California. Analytical results from these samplers are compared to ‘baseline’ analytical results from samples collected using conventional (low-flow and three-casing-volume purge) techniques for all analytes. As described at the beginning of Section 6, conventional techniques represent baseline data only in the sense that they are the commonly-used sampling methods that are generally accepted by the regulatory community. They do not necessarily represent the *correct* answer (only a *different* answer). The activities described in this report were performed in accordance with the *Final Work Plan for the Demonstration of Passive Groundwater Sampling Devices at Former McClellan AFB, California* (Work Plan) (Parsons, 2004a). The geology and hydrogeology of McClellan are briefly described in the Work Plan (Appendix E).

This demonstration project included an assessment of diffusion and grab samplers (i.e., no-purge samplers) for collection of groundwater samples to be analyzed for VOCs, metals, and selected contaminants listed as California emergent chemicals (California Regional Water Quality Control Board [CRWQCB], 2003), including 1,4 dioxane and hexavalent chromium. The six sampling devices demonstrated were classified as either diffusion or grab samplers depending on the predominant operative mechanism of the sampling device. The group designated as diffusion samplers was comprised of the PDBS, a rigid porous polyethylene sampler (RPPS), a polysulfone membrane sampler (PsMS), and a regenerated cellulose sampler (RCS). The group designated as grab samplers included the Snap Sampler™ manufactured by ProHydro, Inc. and the HydraSleeve® manufactured by GeoInsight. It should be noted that the membrane pore size of the RPPS and PsMS may be sufficiently large to permit some limited advection of water molecules through the sampler wall. However, diffusion is believed to be the dominant mechanism for transport of dissolved constituents into these samplers. All of the diffusion and grab samplers tested at McClellan are “no-purge” sampling devices in that they are intended to be used to collect groundwater samples without prior purging of the well.

The diffusion and grab sampling devices tested are relatively new approaches to groundwater sampling that eliminate the need for well purging. Typically, a capsule (e.g., diffusive membrane or self-sealing “grab” container) is deployed at a specified position within the screened interval of a well. Depending on the type of sampler, the capsule may either be filled with purified water and sealed at the surface prior to deployment (e.g., PDBS, RPPS, PsMS, RCS), or it is deployed empty and filled with groundwater and sealed upon retrieval (e.g., Snap Sampler™ and HydraSleeve®). With the PDBS, RPPS, PsMS, and RCS, the constituents in the groundwater enter the sealed sampler through the process of diffusion, and the water quality inside the sampler reaches equilibrium with groundwater quality in the surrounding well. The sampler is subsequently retrieved from the well, and the water in the sampler is transferred to a sample container and submitted for laboratory analysis. The grab samplers are empty when deployed and, following an equilibration period, they are either closed remotely to trap ambient groundwater (Snap Sampler™) or they are filled and sealed during the retrieval process (HydraSleeve®). Potential benefits of using diffusion or grab sampling methods include reduced sampling costs and reduced generation of investigation-derived waste (i.e., purge water).

1.2 TECHNOLOGY BACKGROUND

To date, the primary application of diffusion samplers has been to sample for VOCs in groundwater using PDBSs. The PDBS technology has been validated through various studies (Vroblesky and Hyde, 1997; Parsons, 1999, 2003b and 2004b; Church, 2000; Hare, 2000; McClellan AFB, 2000; Vroblesky *et al*., 2000; Vroblesky and Peters, 2000; Vroblesky and Petkewich, 2000), and a guidance document for their use has been developed (Vroblesky, 2001). The Interstate Technology and Regulatory Council (ITRC) has formed a workgroup to expand on the PDBS guidance document and to address technical and regulatory implementation issues as they arise.

Use of the PDBS method can provide significant long-term cost savings compared to conventional sampling methods. However, LTM programs at many sites include sampling and analysis for non-volatile parameters (e.g., metals, semi-volatile organic compounds [SVOCs] inorganic anions and cations, dissolved gases, and other geochemical parameters) that cannot be targeted using PDBSs. In addition, although studies performed to date have indicated that the PDBS method is capable of accurately monitoring concentrations of VOCs dissolved in groundwater in most instances, this method is not suitable for all VOCs. For example, methyl tert-butyl ether (MTBE) does not efficiently pass through the wall of the PDBS, and therefore this method cannot be used to sample for this compound. As a result of these limitations, development and testing of other no-purge samplers that can be used for a wider variety of analytes is desirable to take advantage of the cost effectiveness of this approach, while at the same time meeting sampling objectives for non-volatile analytes.

1.3 OBJECTIVES

The overall objective of this demonstration is to evaluate and demonstrate the use of selected diffusion and grab sampling technologies that potentially represent useful and cost-effective alternatives to conventional groundwater sampling approaches (e.g., three-volume purge/sample and low-flow purge/sample) for analytes other than VOCs. Specifically, technologies that potentially can be used to sample for non-volatile constituents such as metals, anions, and 1,4 dioxane are evaluated. Expansion of the suite of accepted no-purge sampling methods could be useful in augmenting or possibly substituting for the PDBS method in certain applications.

In addition, the comparative sampler demonstration at McClellan has the following specific objectives:

- Compare analytical results obtained using each sampling method with analytical results for the same constituents obtained via each of the other sampling methods;
- Evaluate how each diffusion and grab sampler reflects any observed chemical stratification in wells included in the demonstration;
- Identify variables that could explain observed differences in the sampling results obtained using the various sampling methods; and
- Compare the approximate costs of the various sampling methods (including conventional methods).

1.4 SCOPE

The sampling demonstration at McClellan required three field mobilizations to the site as described in Section 3.1.1.

The samplers selected for this demonstration monitor chemical conditions in a well. Conventional sampling methods (e.g., purge and sample) disrupt well and aquifer equilibrium for an unknown period of time. Therefore, for this demonstration an effort was made to target only those wells that were not scheduled to be sampled during the regular April-May 2004 basewide LTM conventional sampling event. In the event that a well was selected for use in this demonstration that also was sampled with conventional methods during the LTM event, a minimum time lag of at least one month between the LTM and no-purge sampling demonstration events was used as a well selection criterion.

A total of 20 wells at McClellan were included in this demonstration project. Parsons coordinated with both McClellan and the base LTM contractor (URS Corporation [URS]) to determine which wells should be included in the demonstration.

1.5 SCOPING GUIDELINES

The following general scoping guidelines were developed for this comparative sampler evaluation:

- Sampling devices selected for field testing will be suitable for at least a sub-group of the analytes of interest, and will yield sufficient sample volume to enable testing for the analytes of interest.
- Sampling devices selected for field testing can be deployed at multiple depths within a single well to evaluate vertical stratification of analytes, and each sampler cluster (consisting of multiple types of samplers) can be deployed at a similar depth. This will allow comparison of sampling results from less-depth-discrete methods (i.e., 3-volume purge and low-flow purge) with results from more depth-discrete methods. This topic is of interest in part because the degree to which low-flow purge provides a depth-discrete sample is not well-defined.

- Time lag between sample collection using different methods will be minimized to avoid bias of the comparative evaluation by temporal fluctuations in groundwater quality.
- Analyte reporting limits specified in the McClellan Quality Assurance Project Plan (QAPP) (URS, 2003) will be met to the extent feasible given sample volume limitations and the capabilities of the selected analytical laboratory.
- One or more 'baseline' sampling methods will be included to provide data against which the results of the alternative passive diffusion samplers (PDSs) and grab samplers can be compared.
- Standard operating procedures (SOPs) will be used that minimize loss or transformation of the analytes of interest during the sample collection, handling, shipping, and analysis process, and that ensure the representativeness of the sample to the greatest degree possible.
- Sufficient data will be collected to allow use of appropriate qualitative and quantitative data analysis methods (e.g., graphs, tables, statistical tests) in order to compare results obtained using the various sampling devices/approaches and determine which alternative samplers can be used in place of the current, conventional sampling methods and therefore warrant further evaluation.

1.6 DOCUMENT ORGANIZATION

This report is organized into eight sections, including this introduction, and six appendices. Section 2 is a brief summary description of the sampling technologies used in this demonstration. Section 3 is a description of field activities and the laboratory analytical approach. Section 4 is a presentation and discussion of analytical results. A cost analysis is presented in Section 5. Conclusions and recommendations are presented in Sections 6 and 7, respectively. References cited in this report are presented in Section 8. Appendix A is a Data Quality Assessment Report. Well-specific plots depicting vertical stratification of various target compounds are included as Appendix B. Appendix C includes results of tests for normality performed on the data sets. Appendix D contains X-Y scatter plots comparing the results of each sampling device/method to each of the other devices/methods. Appendix E is a compact disk containing an electronic version of the analytical data in various formats as well as an electronic version of the Work Plan (Parsons, 2004a). Field notes are contained in Appendix F.

SECTION 2

DESCRIPTION OF TECHNOLOGIES

No-purge samplers rely on the natural flow of groundwater through a well screen, and therefore the results obtained using these devices will not always be comparable to results obtained using conventional sampling methods which induce groundwater flow into a well by creating a hydraulic gradient through well purging. In the absence of vertical flow, the no-purge devices will primarily monitor groundwater migrating through the well screen at the discrete depth intervals at which the samplers are placed. If vertical flow exists in the well, no-purge sampler results likely will be representative of the aquifer zone with the highest hydraulic head. Groundwater flows from high- to low-head zones, and the zone with the highest hydraulic head will be the source for groundwater flowing vertically through the well, and will therefore be the zone monitored by the no-purge sampler.

As described in Section 1, a total of four diffusion (PDBS, RPPS, PsMS, and RCS) and two grab (HydraSleeve® and Snap Sampler™) sampling devices were selected for this demonstration. Additionally, these methods were compared to two conventional sampling methods (low-flow purge/sample and three-volume purge/sample). Specific design and method details for each of these sampling techniques are presented in Table 2.1 and the following subsections. Note that the sampler dimensions and volumes listed in Table 2.1 correspond to the versions used in this McClellan AFB field demonstration; other versions of these samplers may be available.

2.1 DIFFUSION SAMPLERS

For diffusion samplers, chemical constituents in the groundwater diffuse across the membrane over time, and the chemical content of the water inside the sampler reaches equilibrium with the chemical content of groundwater in that interval of the well. The sampler is subsequently removed from the well, and the water in the diffusion sampler is transferred to a sample container and submitted for laboratory analysis. Once a diffusion sampler is placed in a well, it remains in place until chemical equilibrium is achieved between the water in the well casing and the water in the diffusion sampler. There is a time-lag between the time groundwater enters a well and the diffusion of the chemicals in the groundwater into a diffusion sampler. This time-lag is variable depending on several factors such as the groundwater temperature, the physicochemical properties of the compound of interest, and the diffusive membrane used in the sampler. Because of this quality, diffusion samplers are representative of a time-weighted average of chemical concentrations in groundwater.

TABLE 2.1
SUMMARY OF NO-PURGE SAMPLING DEVICES TESTED
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Sampler	Dimensions	Construction Material	Membrane Pore Size (microns)	Liquid Volume Capacity (mL)
PDBS	17.7 inches long by 2 inches OD	LDPE	0.001	350
RPPS	6.2 inches long by 1.5 inches OD	Polyethylene	6 to 15	150
PsMS	2 inches long by 2 inches OD	Polysulfone® (HT Tuffryn)	0.2	108 per canister
RCS	13 inches long by 1 inch OD	PVC, LDPE, regenerated cellulose	0.0018	400
Snap Sampler™	10 inches long by 1.6 inches OD	Glass, Teflon®, perfluoroalkoxy-coated stainless steel	NA	40 per vial[a/]
HydraSleeve®	30 inches long by 2.75 inches OD	Polyethylene	NA	2,000

mL = milliliters, cm = centimeters, LDPE = low-density polyethylene, OD = outside diameter, PVC = polyvinyl chloride, NA = not applicable.

a/ Multiple 40-ml vials can be combined to increase the volume of sample obtained. A 125-ml sampler also has been developed.

2.1.1 Passive Diffusion Bag Sampler (PDBS)

The PDBS used in this demonstration is constructed of a 45-centimeter (cm)-long section of 5.08-cm-diameter, 4-mil-thick, low-density polyethylene (LDPE) tubing that is permanently sealed on one end and sealed on the other end with a high-density polyethylene (HDPE) cap (Figure 2.1). The pore size of the LDPE is approximately 0.001 micron, which does not permit the flux of water molecules (i.e., it does not leak). The sampler, which holds approximately 350 milliliters (mL) of purified water, is placed in "flex-guard" polyethylene mesh tubing for abrasion protection, attached to a weighted rope, and lowered to a predetermined depth within the screened interval of a well. The rope is weighted to ensure that the sampling devices are positioned at the correct depth and that they do not float upward through the water column.

FIGURE 2.1
STANDARD PDBS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Depending on the hydrogeologic characteristics of the aquifer, the diffusion samplers can reach equilibrium within 3 to 4 days (Vroblesky, 2001). Groundwater samples collected using the diffusion samplers are thought to be representative of water present within the well during the previous 24 to 72 hours. However, the recommended minimum equilibration time for water temperatures above 10 degrees Celsius (°C) is two weeks (ITRC, 2004).

PDB samples are not susceptible to matrix interferences caused by turbidity because the membrane used in the device is not permeable to colloids or other particles larger in diameter than approximately 0.001 micron. PDB samples also are not subject to volatilization loss by degassing during effervescence when the samples are acidified for preservation in highly alkaline waters because the alkalinity from the aquifer does not penetrate the membrane.

2.1.2 RIGID POROUS POLYETHYLENE SAMPLER (RPPS)

RPPSs have recently been tested in a laboratory setting by the US Geological Survey (USGS). The tested samplers consisted of a 1.5-inch outside diameter (OD), 6.2-inch-long, rigid polyethylene tube having a pore size of 6 to 15 microns (Figure 2.2). Given the relatively large pore size, the RPPS could potentially be used to sample for a relatively wide variety of volatile and non-volatile analytes. The bench-scale test results indicated that this type of sampler can yield accurate results for VOCs (including MTBE), chromium, and chloride (Vroblesky, 2004). Potential disadvantages of this sampler include the following:

- The porous polyethylene sampler pores tend to retain air even when submerged. Because the entrapped air reduces sampler permeability, the air should be removed prior to use by flushing the samplers with water.

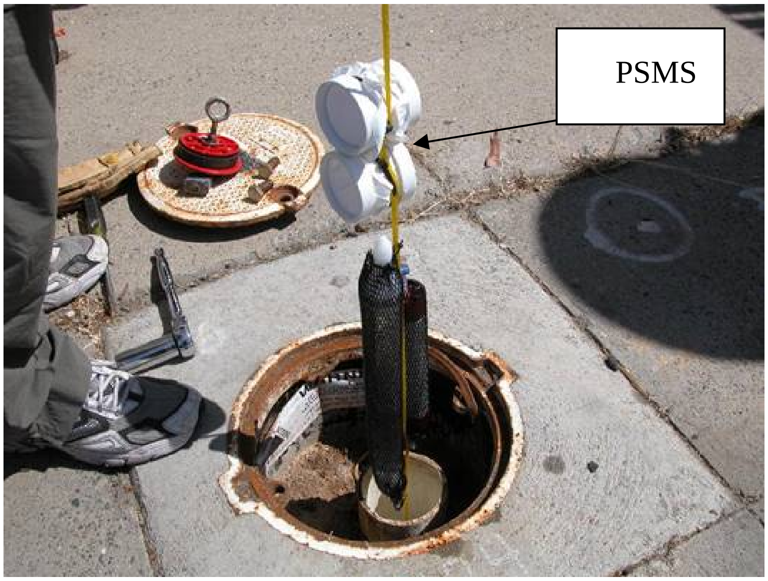
FIGURE 2.2
STANDARD RPPS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

- Tests performed to date indicate that the maximum feasible sampler dimensions are approximately 1.5 inches OD by 7.5 inches long (volume equal to approximately 175 mL). Use of a longer sampler would result in leakage of water out of the sampler walls due to the higher head pressure present in the sampler (Vroblesky, 2004).

2.1.3 POLYSULFONE MEMBRANE SAMPLER (PsMS)

Testing of 'Peeper' samplers performed by (among others) Dr. Andrew Jackson of Texas Tech University has indicated that dissolved concentrations of non-volatile groundwater constituents can pass through a polysulfone (e.g., HT® Tuffryn) membrane having a sufficient pore size (Jackson, 2003). Peeper samplers are rigid structures that can hold volumes of water separated from the environment by porous membranes to monitor dissolved constituents in saturated environments. The same polysulfone material used in some Peeper samplers also can be used to construct PSDs. The samplers constructed for use in the McClellan study were comprised of a rigid 2-inch-long section of 2-inch-OD PVC pipe that was covered on both ends with the flexible polysulfone membrane. The polysulfone membrane was held in place by sliding a PVC coupling over the end of the pipe (Figure 2.3). The coupling was held in place by friction. The samplers were filled with purified water prior to deployment. The pore size of the polysulfone material that was used is 0.2 micron. The volume of each sampler canister was approximately 108 mL, and two of these canisters were deployed at each sample depth. One conclusion from a previous diffusion sampler demonstration at Grissom Air Reserve Base (Parsons, 2004b) was that the orientation of the porous membrane relative to the assumed direction of groundwater flow was potentially an important consideration. Because of this, samplers were deployed in an orientation such that the plane of the membrane was positioned orthogonally to horizontal groundwater flow. Due to the lack of field- or bench-scale testing of PsMSs, potential advantages or disadvantages of this sampler have not been quantified.

FIGURE 2.3
STANDARD PSMS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA



2.1.4 REGENERATED CELLULOSE SAMPLER (RCS)

Regenerated cellulose samplers have been successfully tested in wells for inorganic and volatile organic constituents in groundwater (Vroblesky *et al*., 2002; Ehlke *et al*., 2004). The sampler used in this investigation consisted of a perforated PVC pipe inside a sleeve of high-grade regenerated cellulose tubular dialysis membrane (Membrane Filtration Products, Inc., Seguin, Texas) with an outer protective LDPE mesh (Figure 2.4). The membranes have a nominal molecular-weight cutoff of 8,000 daltons, or about 0.0018 micron pore size, and a flat width of about 3 inches. The diameter of the filled sampler is about 1 inch and the length is about 13 inches, with a capacity of approximately 400 mL. A potential disadvantage of this sampler is that it may begin to biodegrade in some groundwater systems (Vroblesky and Pravecek, 2002); however, the ability of the samplers to produce chemical concentrations comparable to other methods in previous investigations indicates that, during short-term deployment, the susceptibility of the cellulose membrane to biodegradation does not significantly affect the sampler's usefulness in at least some groundwater environments.

Ehlke *et al*. (2004) found that VOC concentrations in RCSs equilibrated within 3 days and iron and bromide concentrations equilibrated within 3 to 7 days. In an unpublished study, Vroblesky (personal communication) found that VOC and chloride concentrations had reached equilibrium by the first sampling event at 8 days. Vroblesky *et al*. (2002) state that concentrations of inorganic constituents in RCSs equilibrated within 20.5 to 92 hours.

FIGURE 2.4
STANDARD RCS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

2.2 GRAB SAMPLERS

In contrast to the diffusion samplers, grab sampling devices represent more of an equilibrated instantaneous "snap-shot" in time of groundwater conditions. For these devices, the sampler is deployed in a well and is left there until groundwater conditions have re-equilibrated. At that time the groundwater is captured by the device, and the resulting sample is submitted to the laboratory for analysis.

2.2.1 SNAP SAMPLER™

The Snap Sampler™ (patent pending) was developed by ProHydro, Inc. and was initially designed to collect a representative VOC sample *in situ* without the need for purging. Samples collected with the Snap Sampler™ can be analyzed for more than VOCs. Utilizing minimum sample volume requirements, this sampler can also be used for analyzing a larger number of physical and/or chemical water quality parameters.

The Snap Sampler™ employs standard-sized 40 mL glass volatile organics analysis (VOA) vials with double end-openings (Figure 2.5). Specialty Teflon® end closure caps seal water within the Snap Sampler™ vial with an internal closure spring. The closure spring is made of perfluoroalkoxy (PFA Teflon®)-coated stainless steel. To deploy the sampling device, the VOA vial is placed inside the Snap Sampler™, and the end closure caps are attached to the sampler's trigger mechanism in an open position. Both ends of the VOA vial are open to the well environment during the deployment period.

FIGURE 2.5
STANDARD SNAP SAMPLER™
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Up to three Snap Samplers™ can be connected in series with a single suspension/trigger cable. The suspension/trigger cable consists of a 1/32-inch-diameter stainless steel wire rope within ¼-inch HDPE tubing. The HDPE tubing attaches to the samplers and the wire rope attaches to the release mechanism of the sampler. The samplers are lowered into the well to a predetermined depth using the suspension/trigger cable. The suspension/trigger cable is secured at the surface at a well-head docking station that does not interfere with well-head locks or water level measuring devices.

The Snap Sampler™ is left for an appropriate length of time to allow the well to return to equilibrium with the surrounding groundwater. When ready to collect samples, the internal trigger cable is manually pulled at the wellhead to activate the sampler release mechanism. The trigger releases the vial caps, which close onto the VOA vial by action of the internal closure spring. The vial caps and spring seal the groundwater within the sampling container.

The samplers are then retrieved from the well, VOA bottles are removed from the Snap Sampler™, preservative is added (if necessary) using a method that does not require the sample bottle to be uncapped (Parsons, 2004a [SOP can be accessed via vendor website at www.snapsampler.com]), and end caps are secured with standard VOA vial screw caps. The VOA vials can be used with standard laboratory autosampling equipment designed for 40 mL vials. From the well to the autosampler, water samples are never exposed to ambient air. A 125-ml sample bottle is currently in development to accommodate larger volume needs. Other sampler and bottle material compositions are available or are being developed to accommodate different sampling needs. For example, a fully non-metallic sampler is now available for metals sampling.

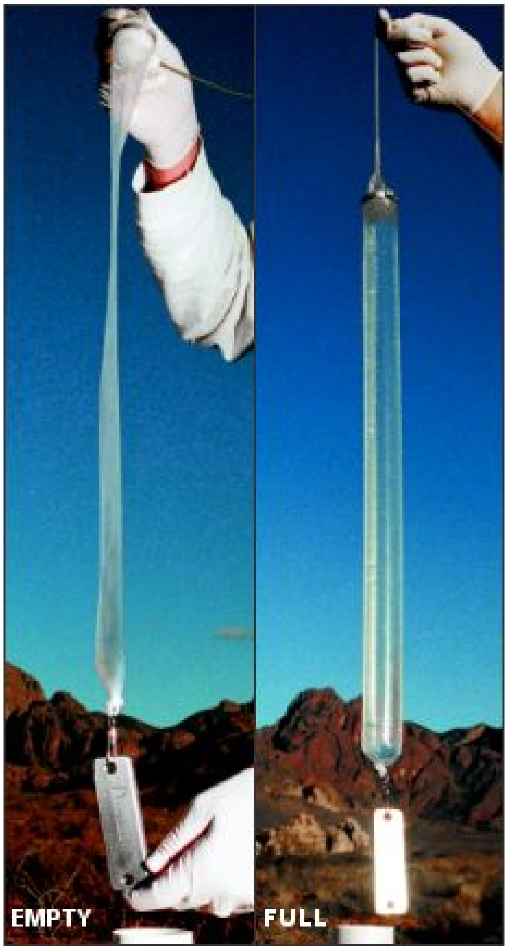
The diameter of the sampler apparatus used at McClellan was 1.6 inches. The length of the device was approximately 10 inches with a single sampler and vial, 17 inches with two samplers and two vials, and 23 inches with three samplers and three vials. The longest distance between the end openings of the three-vial configuration was 17 inches.

The current configuration uses a new connector that changes these dimensions slightly as follow: diameter = 1.66 inches, length = 8 inches with a single sampler and vial, 16 inches with two samplers and two vials, and 24 inches with three samplers and three vials. The longest distance between the end openings of the current three-vial configuration is 19 inches.

2.2.2 HYDRASLEEVE® SAMPLER

The HydraSleeve® sampler (US patents #6,481,300 and #6,837,120), manufactured by GeoInsight (www.hydrasleeve.com), is designed to collect a representative sample for most physical and chemical parameters without purging the well. It collects a water sample from a defined interval within the well screen without mixing fluid from other intervals. Physically, it is a section of lay-flat polyethylene tubing, sealed at the bottom end, and built with a polyethylene reed-valve at the top end (Figure 2.6).

FIGURE 2.6
STANDARD HYDRASLEEVE®
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA



The empty sampler is weighted at the bottom, attached to a line, and then lowered to a predetermined depth within the well screen. It is typically left in the well for a period of time to allow the well to re-equilibrate following sampler deployment. Once the well has re-equilibrated, the sampler can be activated for sample collection. Prior to activation, the sampler remains in a collapsed (i.e., empty) state and therefore takes up minimal space within the well. To activate, the sampler is pulled up a distance equal to 1 to 2 times the sampler length (2.5 to 5 feet for a 30-inch-long sampler). As the sampler rises through the water column, the reed valve opens, allowing the sampler to "core" the water column through which it is being raised. Once full, the reed valve closes, which prohibits any more water from entering the sampler. An alternate approach to activating the sampler is to raise and lower it multiple times over a distance equal to the sampler length. However, this approach is less attractive because the raising and lowering of the sampler can result in increased agitation of the water in the well and higher turbidity levels in the sample.

The 24- to 30-inch-long sampler can be purchased in either 1.5- or 2.5-inch diameter models; the 30-inch sampler has volumes of 1,000 mL and 2,500 mL for these diameters, respectively.

2.3 CONVENTIONAL SAMPLING METHODS

One of the scoping guidelines described in Section 1.5 was to have results from at least one other traditional sampling method that could serve as a "baseline" for comparison purposes to the diffusion and grab sampling technologies. In order to address this scoping guideline, conventional sampling methods used as "baseline" measurements were:

1. Sampling following low-flow/minimal drawdown purging , and
2. Sampling following conventional purging of at least three well-casing volumes of water and stabilization of water quality parameters.

The objective of low-flow sampling is to remove a small volume of water at a low flow rate from a small portion of the screened interval of a well without mixing water among vertical zones. Ideally, by placing the inflow port of a pump at a prescribed depth within the screened interval of a well, and by withdrawing water at a slow rate, groundwater will be drawn from the aquifer into the well only in the immediate vicinity of the pump. This theoretically depth-discrete sampling allows for vertical definition of contamination in the aquifer. In practice, however, when a low-flow sample is collected, determining the portion of the screened interval of the aquifer that contributed water to the sample can be problematic.

Groundwater sampling using the three-volume purge method involves removing a large volume of water (three to five well-casing volumes) from the well over a short time. The objective of this method is to remove all stagnant water present within the well casing, as well as groundwater present in the surrounding well filter pack. Theoretically, by removing this water quickly, the "stagnant" water that resided in the well and filter pack will be replaced with "fresh" groundwater from the surrounding formation with minimal mixing. The "fresh" groundwater that is then sampled is considered to be representative of the local groundwater. Rapid drawdown of the water level in a well is not uncommon, and wells are often purged dry using this method.

Conventional sampling at McClellan that is part of regularly scheduled LTM is performed using both low-flow and three-volume purge techniques. Low-flow sampling is only performed at wells in which dedicated bladder pumps have been installed, while three-volume sampling is performed using submersible pumps that are moved from well to well. McClellan is in the process of installing dedicated bladder pumps in all of their regularly sampled wells so that all future conventional sampling will be performed using the low-flow technique.

In order to maximize consistency and comparability between the historical conventional sampling record for McClellan and the conventional sampling performed as part of this demonstration, similar procedures were followed to the extent possible. However, as described in the Work Plan (Parsons, 2004a) the presence of dedicated pumps in a well automatically excluded that well for use in this demonstration. Therefore, the low-flow sampling that was performed during this demonstration did not strictly adhere to the SOP for low-flow sampling provided in the McClellan QAPP (URS, 2003).

A submersible pump (i.e., Grundfos RediFlo2®) and new, clean dedicated LDPE tubing were used to perform all purging and sampling of the wells. The pump intake was positioned at the midpoint of the saturated portion of the well screen, and the flow rate was controlled to minimize drawdown in the well (during low-flow purging only). Average pump rates varied from approximately 0.09 to 0.19 gallon per minute (gpm) for the low-flow purge and from approximately 0.71 to 4.0 gpm for the three-volume purge. Drawdown was monitored throughout the low-flow purge using a water-level probe. Field parameters including temperature, pH, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity also were monitored in a flow-through cell during both low-flow and three-volume purging. Once well stabilization was achieved, as demonstrated by stabilized field parameters (described in the Work Plan [Parsons, 2004a]), samples were collected. For the low-flow technique, sample bottles were filled directly from the pump discharge. For the three-volume purge, samples were collected using a bailer following completion of the purge, as specified in the McClellan QAPP (URS, 2003).

For all wells, the low-flow sample was collected first, after which time the pump rate was increased and the three-volume purge sample was collected following evacuation of the required purge volume and field parameter stabilization.

SECTION 3

FIELD ACTIVITIES AND LABORATORY ANALYTICAL APPROACH

3.1 FIELD ACTIVITIES

A total of 251 primary samples and 34 quality assurance/quality control (QA/QC) samples were collected from 20 wells at McClellan as part of this demonstration. Details of the field activities are discussed below.

3.1.1 SAMPLING STRATEGY

Concurrent deployment of multiple types of samplers at the same depth in each well is desirable to obtain comparative data. However, the 4-inch well diameter imposed a physical limitation on the number of samplers that could be concurrently deployed at the same depth in each well. Therefore, sampling occurred in three phases as described below.

- Phase 1 – During this phase, which occurred from May 17 through 21, 2004, the diffusion samplers (PDBS, RPPS, PsMS, and RCS) were deployed in the 20 selected monitoring wells at three different depths per well. No more than 3 different types of diffusion samplers were deployed in each well.
- Phase 2 – After an approximate 3-week equilibration period, the diffusion samplers deployed in Phase 1 were retrieved (from June 7 through 9, 2004). The grab samplers (Snap Sampler™ and HydraSleeve®) were subsequently deployed at the same depths as the samplers deployed in Phase 1. Only one type of grab sampler was deployed in each well; concurrent deployment of both the Snap Sampler™ and HydraSleeve® in the same 4-inch well would have made deployment and retrieval difficult and may have compromised the function of one or both of the devices..
- Phase 3 – After an approximate 1-week equilibration period, the grab samplers were retrieved (from June 14 through 17, 2004). Following this retrieval, conventional sampling (i.e., low-flow purge/sample and three-volume purge/sample) of all 20 wells was performed. Both low-flow purge/sample and three-volume purge/sample techniques were used at each well.

Table 3.1 is a summary of the types of sampling techniques that were used in each well.

TABLE 3.1
SAMPLING TECHNOLOGIES DEMONSTRATED IN EACH WELL
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well ID	**Sampling Technology Demonstrated in Each Well**							
	PDBS	**RPPS**	**PsMS**	**RCS**	**Hydra-Sleeve®**	**Snap Sampler™**	**Low-Flow Purge**	**Three-Volume Purge**
MW-1050	X	X	X		X		X	X
MW-1065	X	X		X		X	X	X
MW-136		X	X		X		X	X
MW-148	X	X	X		X		X	X
MW-173	X	X		X		X	X	X
MW-174	X	X		X		X	X	X
MW-19D		X	X		X		X	X
MW-211		X		X	X		X	X
MW-225	X	X	X		X		X	X
MW-241		X		X		X	X	X
MW-242	X	X		X		X	X	X
MW-333	X	X		X		X	X	X
MW-38D	X	X	X		X		X	X
MW-400	X	X		X		X	X	X
MW-411	X	X	X		X		X	X
MW-424	X	X	X		X		X	X
MW-427	X	X		X		X	X	X
MW-437	X	X	X		X		X	X
MW-453		X	X			X	X	X
MW-72	X	X		X		X	X	X

3.1.2 FIELD MEASUREMENTS

The depth to water was measured in each well prior to deployment during Phase 1, prior to retrievals during Phase 2, and prior to conventional sampling during Phase 3. Additionally, the total well depth was measured prior to deployment during Phase 1. Target sampler deployment depths were calculated after measuring the depth to water and the total well depth at the beginning of Phase 1, taking into consideration the reported screened interval of the well. Of the three sampling depths monitored per well, the intermediate interval was generally defined as the center of the saturated screened interval, the shallow interval was generally defined as being approximately 1 foot below the top of the saturated screened interval, and the deep interval was generally defined as being approximately 1 foot above the bottom of the open (i.e., non-buried) saturated screened interval. Table 3.2 is a summary of the depth to water measurements, the total depth measurements, the screened interval depths, and the sampling intervals for each well.

TABLE 3.2
WATER LEVEL MEASUREMENTS, WELL DETAILS, AND DEPLOYMENT DEPTHS

NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well ID	Measured Well Depth (ft btoc)[a]	Measured Well Stickup (ft ags)[b]	Measured Well Depth (ft bgs)[c]	Reported Depth to Top of Screen (ft bgs)	Reported Depth to Bottom of Screen (ft bgs)	Depth to Water (ft btoc)			No-Purge Sampler Deployment Depths[e] (ft bgs)		
						Phase 1[d]	Phase 2[d]	Phase 3[d]	Deep Interval	Middle Interval	Shallow Interval
MW-1050	173.4	-1.1	174.5	165	175	101.75	102.33	102.93	172.9	169.9	166.9
MW-1065	129.7	-0.9	130.6	121	131	111.64	NM[f]	112.54	129	126	123
MW-136	253.2	1.1	252.1	230	245	103.02	103.22	103.5	240.5	237.5	234.5
MW-148	300.7	1.9	298.8	288	298	107.15	108	108.68	296	293	290
MW-173	165.8	-0.9	166.7	156	166	114.93	NM	115.78	164.9	161.9	158.9
MW-174	218.8	-0.8	219.6	208.5	218.5	112.24	NM	113.14	217.3	214.3	211.3
MW-19D	150.1	1.0	149.1	139	149	96.48	96.52	96.66	147	144	141
MW-211	161.1	-1.4	162.5	151	161	108.5	109.18	110.09	159	156	153
MW-225	167.6	NM	167.6[g]	157.6	167.6	113.39	NM	113.5	165.6	162.6	159.6
MW-241	137.6	2.5	135.1	114	134	102	101.93	102.08	131	124	117
MW-242	137.8	2.2	135.6	120	135	104.85	104.79	104.85	132.5	127.5	122.5
MW-333	168.0	-0.3	168.3	160	170	111.58	110.35	112.49	166.9	164.1	161.4
MW-38D	122.9	2.1	120.8	120.03	130.03	99.5	99.53	99.76	120.3[h]	None[h]	None[h]
MW-400	121.4	-0.4	121.8	111	121	103.65	NM	105.1	119.4	116.4	113.4
MW-411	120.7	-0.9	121.6	102	122	92.42	92.26	92.51	118.25	112	105.75
MW-424	147.2	-0.4	147.5	137	147	104.45	NM	105.71	145	142	139
MW-427	124.0	-0.4	124.4	114	124	105.75	NM	106.48	122	119	116
MW-437	170.2	NM	170.2[g]	160	170	110.21	110.84	111.04	168	165	162
MW-453	120.0	-0.4	120.4	100	120	94.54	92.51	92.78	117	110	103
MW-72	138.9	2.7	136.2	121.03	131.03	102.53	102.47	102.2	129.03	126.03	123.03

[a] ft btoc = Feet below top of casing.

[b] ft ags = Feet above ground surface. A negative value indicates that the top of casing was below the ground surface.

[c] ft bgs = Feet below ground surface.

[d] Phase 1 measurements were made from 5/17/04 through 5/20/04.
Phase 2 measurements were made from 6/7/04 through 6/9/04.
Phase 3 measurements were made from 6/14/04 through 6/17/04.

[e] Depths shown are the midpoints of each no-purge sampler group.

[f] NM = Not measured.

[g] Well depth shown is actually ft btoc since no stickup was measured.

[h] Only one depth interval was monitored in this well due to the shortened screened interval.

Measurements of traditional well stabilization parameters were made during conventional sampling. These parameters included groundwater temperature, pH, conductivity, DO, ORP, and turbidity. These measurements along with the total volume purged, the time spent purging, and the average pump rate for each well are summarized in Table 3.3.

A maximum of three different types of diffusion samplers and one type of grab sampler were deployed in each well. The distribution of diffusion and grab samplers in each well was designed to facilitate inter-sampler comparisons while maintaining an overall deployment of RPPS in 20 wells; RCS, PsMS, HydraSleeve®, and Snap Samplers in 10 wells each; and PDBS in only those wells that were targeted for VOC analysis.

Table 3.4 is a summary of the sample dates, deployment lengths, and time lags between all sampling events.

3.2 LABORATORY ANALYTICAL APPROACH

3.2.1 TARGET COMPOUNDS

The following compounds were targeted for analysis in the priority listed below during the technology demonstration.

- 1,4 dioxane;
- Hexavalent chromium;
- McClellan target analyte list (TAL) for metals, total and/or dissolved phases depending on sample turbidity (see below and Section 4.2 of Work Plan [Parsons, 2004a]) including: aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc;
- Anions including sulfate, nitrate, and chloride; and
- VOCs (refer to Table 4.11 of the McClellan QAPP [URS, 2003] for a list of specific analytes).

With the exception of VOCs, these compounds were targeted because they are not able to be monitored using the PDBS method, but are contaminants of concern at some DoD installations. VOCs were included in the target compound list to verify that all no-purge sampling devices also would be capable of accurately monitoring for these compounds.

The final measurements of turbidity made during both types of conventional sampling were used to determine whether or not the samples should be field-filtered for TAL metals analysis using a 0.45-micron disposable filter. If the final turbidity measurement made immediately before sample collection was less than or equal to 5 Nephelometric Turbidity Units (NTUs), the samples were not filtered in the field and were submitted for total metals analysis. If the final turbidity measurement was greater than 5 NTUs, the samples were filtered according to procedures described in SOP #6 of the Work Plan (Parsons, 2004a), and were scheduled for dissolved metals analysis. All conventionally sampled wells that were analyzed for metals were field-filtered with the exception of well

TABLE 3.3
SUMMARY OF CONVENTIONAL SAMPLING FIELD PARAMETER MEASUREMENTS

NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well ID	Sampling Method	Temperature (ºC)[a/]	pH	Conductivity (µS/cm)[b/]	DO (mg/L)[c/]	ORP (mV)[d/]	Turbidity (NTU)[e/]	Total Volume Purged (gallons)	Time Spent Purging (minutes)	Average Purge Rate (gpm)[f/]	Average Purge Rate (Lpm)[g/]	Samples Field Filtered?
MW-1050	Low-Flow	19.37	7.64	264	6.29	142	15	2	19	0.11	0.40	Yes
	Three Volume	19.06	7.91	268	7.62	149.6	7	144	36	4.00	15.14	Yes
MW-1065	Low-Flow	24.20	7.20	621	7.41	353	58.7	3.5	19	0.18	0.70	Yes
	Three Volume	21.32	7.31	578	9.12	332	10	35	21	1.67	6.31	Yes
MW-136	Low-Flow	21.05	6.43	310	0.53	412	86.5	3.8	22	0.17	0.65	Yes
	Three Volume	21.04	6.34	333	7.33	467	15.3	290	88	3.30	12.47	Yes
MW-148	Low-Flow	20.88	7.00	598	4.24	364	5.5	3.3	19	0.17	0.66	Yes
	Three Volume	21.57	7.29	616	4.42	358	8.1	380	128	2.97	11.24	Yes
MW-173	Low-Flow	22.40	6.81	200	6.66	281.8	171.6	1.5	15	0.10	0.38	Yes
	Three Volume	20.84	7.51	195	7.55	229	NM[h/]	99	33	3.00	11.36	Yes
MW-174	Low-Flow	23.95	7.09	458	5.42	313	56.3	2.5	18	0.14	0.53	Yes
	Three Volume	23.12	6.83	459	5.67	432	7.8	205	61	3.36	12.72	Yes
MW-19D	Low-Flow	23.47	7.41	249	1.85	372	16.5	3	19	0.16	0.60	--[j/]
	Three Volume	21.99	6.55	239	2.52	423	4.2	97	37	2.62	9.92	--
MW-211	Low-Flow	21.08	7.16	520	7.71	339	35.2	2.5	17	0.15	0.56	Yes
	Three Volume	20.00	7.31	499	8.90	323	74.9	105	35	3.00	11.36	Yes
MW-225	Low-Flow	24.40	7.12	234	6.71	213.3	26.8	4.5	24	0.19	0.71	--
	Three Volume	22.16	7.60	257	7.12	166.6	21	105	35	3.00	11.36	--
MW-241	Low-Flow	24.23	7.29	249	6.27	356.8	49.8	2.4	19	0.13	0.48	--
	Three Volume	22.57	7.41	151	6.89	355	1.2	70	24	2.92	11.04	--
MW-242	Low-Flow	22.37	6.99	258	2.75	NM	3.8	4	30	0.13	0.50	--
	Three Volume	20.28	6.65	224	5.99	338.8	1.3	63	19	3.32	12.55	--
MW-333	Low-Flow	23.85	7.09	226	6.50	174.2	194	2.5	21	0.12	0.45	--
	Three Volume	21.51	7.09	209	9.83	207.3	86	112	30	3.73	14.13	--
MW-38D	Low-Flow	23.37	7.66	277	0.61	-134.8	180.4	2.5	20	0.13	0.47	--
	Three Volume	22.80	7.49	283	NM	77.8	140.6	21	29	0.72	2.74	--
MW-400	Low-Flow	23.89	7.26	646	7.59	352	1.1	4.5	29	0.16	0.59	No
	Three Volume	21.60	7.08	621	8.62	374	4.9	33	47	0.70	2.66	No
MW-411	Low-Flow	23.30	7.36	393	2.37	106.7	158.1	1.5	16	0.09	0.35	Yes
	Three Volume	21.01	7.49	352	5.60	159.5	54	53	22	2.41	9.12	Yes
MW-424	Low-Flow	23.96	8.87	330	6.01	55.8	59.3	3	24	0.13	0.47	Yes
	Three Volume	21.10	8.71	311	2.64	75.6	101	84	21	4.00	15.14	Yes
MW-427	Low-Flow	23.11	6.61	693	7.04	282.6	82.2	2	19	0.11	0.40	Yes
	Three Volume	21.84	7.03	683	9.81	258.7	223	33	37	0.89	3.38	Yes
MW-437	Low-Flow	21.68	6.91	202	5.91	282.8	190.5	3	19	0.16	0.60	--
	Three Volume	20.40	7.24	201	8.34	257.7	24	120	30	4.00	15.14	--
MW-453	Low-Flow	19.33	7.24	797	8.09	157.8	27	2	21	0.10	0.36	Yes
	Three Volume	18.76	7.63	668	9.05	148	7.3	56	14	4.00	15.14	Yes
MW-72	Low-Flow	25.86	7.73	551	0.95	34.5	28.9	NM	16	NA[i/]	NA	--
	Three Volume	22.01	7.36	510	2.84	68.4	10.8	69	49	1.41	5.33	--

[a/] ºC = Degrees Celsius.

[b/] µS/cm = Microsiemens per centimeter.

[c/] mg/L = Milligrams per liter.

[d/] mV = Millivolts.

[e/] NTU = Nephelometric turbidity units.

[f/] gpm = Gallons per minute.

[g/] Lpm = Liters per minute.

[h/] NM = Not measured.

[i/] NA = Not applicable.

[j/] -- = Target analyte list metals not analyzed, therefore field filtering was not required.

TABLE 3.4
SAMPLE DATES AND TIME LAGS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well	No-Purge Samplers Used						Diffusion Sampler			Grab Sampler			Conventional Sampling Date	Days Between Conventional and Diffusion Sampling	Days Between Conventional and Grab Sampling
	PDBS	RPPS	PsMS	RCS	Hydrasleeve	Snap Sampler	Deployment Date	Retrieval Date	Days Deployed	Deployment Date	Retrieval Date	Days Deployed			
MW-1050	X	X	X		X		05/21/04	06/08/04	18	06/08/04	06/15/04	7	06/17/04	9	2
MW-1065	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/15/04	6	06/17/04	8	2
MW-136		X	X		X		05/20/04	06/08/04	19	06/08/04	06/15/04	7	06/15/04	7	0
MW-148	X	X	X		X		05/21/04	06/08/04	18	06/08/04	06/15/04	7	06/16/04	8	1
MW-173	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/14/04	5	06/16/04	7	2
MW-174	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/14/04	5	06/16/04	7	2
MW-19D		X	X		X		05/19/04	06/07/04	19	06/07/04	06/15/04	8	06/15/04	8	0
MW-211		X		X	X		05/20/04	06/07/04	18	06/07/04	06/15/04	8	06/17/04	10	2
MW-225	X	X	X		X		05/19/04	06/09/04	21	06/09/04	06/15/04	6	06/16/04	7	1
MW-241		X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/15/04	8	1
MW-242	X	X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/14/04	7	0
MW-333	X	X		X		X	05/21/04	06/08/04	18	06/08/04	06/14/04	6	06/15/04	7	1
MW-38D	X	X	X		X		05/19/04	06/07/04	19	06/07/04	06/15/04	8	06/15/04	8	0
MW-400	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/16/04	7	06/17/04	8	1
MW-411	X	X	X		X		05/19/04	06/08/04	20	06/08/04	06/15/04	7	06/15/04	7	0
MW-424	X	X	X		X		05/19/04	06/09/04	21	06/09/04	06/16/04	7	06/17/04	8	1
MW-427	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/15/04	6	06/16/04	7	1
MW-437	X	X	X		X		05/20/04	06/08/04	19	06/08/04	06/15/04	7	06/16/04	8	1
MW-453		X	X			X	05/19/04	06/08/04	20	06/08/04	06/14/04	6	06/17/04	9	3
MW-72	X	X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/14/04	7	0
Minimum									17			5		7	0
Maximum									21			8		10	3
Median									19			7		8	1

MW-400 where the measured turbidity was less than 5 NTUs. Additionally, all metals samples collected using the HydraSleeve® were field-filtered. Samples for hexavalent chromium analysis were not field-filtered.

3.2.2 LABORATORIES

Two analytical laboratories were used during this demonstration to perform all of the required analyses. Columbia Analytical Services, Inc. (CAS) in Kelso, Washington performed the metals and 1,4 dioxane analyses. Sequoia Analytical (Sequoia), based in Sacramento, California performed the hexavalent chromium, anion, and VOC analyses. Sequoia used two different facilities to perform the requested analyses; hexavalent chromium and anions were analyzed in their Morgan Hill, California facility while VOCs were analyzed in their Petaluma, California facility.

The maximum holding time permitted for hexavalent chromium is 24 hours. Therefore, samples were sent twice per day (once at approximately noon, and again at approximately 5 pm) to Sequoia using a hand-delivery courier. Samples were shipped daily each afternoon to CAS via overnight express courier.

3.2.3 SAMPLE VOLUME

As described in the Work Plan (Parsons, 2004a), the diffusion and grab samplers do not collect large volumes of groundwater (relative to conventional sampling methods), and the available sample volume does not always fulfill normal laboratory and/or analytical method recommendations. This characteristic is not necessarily a critical limitation since most analytical methods do not actually require the larger sample volumes recommended in standard analytical procedures. An ITRC Diffusion Sampler subteam has estimated the minimum sample volumes required for common environmental analytical methods; details are available on the ITRC diffusion sampling website at http://64.203.146.40/news.asp#41. Prior coordination with the analytical laboratories enabled use of smaller sample volumes to perform the required analytical methods while still maintaining required detection limits. Table 3.5 is a summary of the approximate maximum volume capacities of each type of no-purge sampling device used in this study per sample depth (some sampling devices required more than one sampler per depth interval). The volumes listed in Table 3.5 are the maximum obtainable with the configuration used at McClellan; larger volumes can potentially be obtained in some cases by reconfiguring the samplers (e.g., using more PsMS canisters). It should be noted that a larger-volume Snap Sampler™ and HydraSleeve® are now available. Table 3.6 summarizes the minimum sample volume requirements (per analysis) specified by the analytical laboratories.

Groundwater samples from each well were analyzed for only a subset of the target analyte list. The minimum sample volumes shown in Table 3.6 were used for diffusion, grab, and low-flow samples to maintain consistency and to facilitate comparison of the results. However, in order to maintain consistency between the three-volume purge method historically used for these wells as part of LTM and the conventional samples collected as part of this demonstration, normal sample volumes specified in the McClellan QAPP (URS, 2003) were collected for the three-volume purge method.

TABLE 3.5
VOLUMETRIC CAPACITIES OF SAMPLING DEVICES
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Sampling Device	Volumetric Capacity (mL)
PDBS	350 (1 sampler)
RPPS	300 (2 samplers)
PsMS	216 (2 samplers)
RCS	400 (1 sampler)
Snap Sampler™	120 (3 vials)
HydraSleeve®	2,000 (1 sampler)

TABLE 3.6
MINIMUM VOLUME REQUIREMENTS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Analyte	Analytical Method(s)	Minimum Volume Required (mL)
Hexavalent chromium	SW7199	5
Metals	SW6020, SW6010, SW7740	25
1,4 dioxane	SW8270C	100
Anions	E300.0	5
VOCs	SW8260B	20

One or more additional sets of sample bottles were filled and submitted to the analytical laboratory along with the primary sample whenever sufficient sample volume was available. This practice allowed the laboratory to reanalyze samples as necessary due to the need for sample dilution or other circumstances.

3.3 DEVIATIONS FROM WORK PLAN

The field activities generally occurred in accordance with the Work Plan (Parsons, 2004a). However, the following notable deviations occurred during this evaluation.

- While measuring the total depth of MW-1031, the depth sounding device continually became caught on the inside of the well. Due to concerns of having the no-purge samplers stuck or damaged inside the well during deployment and/or retrieval, MW-1031 was replaced with the first alternate well (MW-424) listed in the Work Plan (Parsons, 2004a).
- Upon retrieval of the HydraSleeve® samplers from well MW-148, a knot was observed in the rope used for deployment approximately 10 to 30 feet above the top of the upper (i.e., shallow) sampler. Approximately 10.8 feet of rope was tangled as part of this knot, which presumably meant that all HydraSleeve® samplers in this well were actually deployed approximately 10.8 feet higher in the well than anticipated. Additionally, upon retrieval the deepest HydraSleeve® sampler from this well had a hole in it and no water was recovered. Because of these issues, only the intermediate depth sampler was sent to the laboratory for analysis.

- The trigger mechanism of the Snap™ Sampler was not pulled hard enough at two wells, resulting in no Snap™ Samples being collected from well MW-242 and no deep Snap Sample being collected from well MW-427.
- In order to evaluate the ability of PDBS to monitor 1,4 dioxane, this analysis was requested for one PDBS during the demonstration (the shallow PDBS deployed in well MW-72).
- The measured total depth in well MW-38D was 120.8 ft bgs (Table 3.2). The reported values for the top and bottom of the screened interval for this well were 120.03 and 130.03 ft bgs, respectively. Based on these values, only approximately 0.8 foot of screen was open in this well. Accordingly, only one depth interval was monitored (defined as the deep interval) at 120.3 ft bgs.
- The water level indicator used during the Phase 2 activities malfunctioned during the afternoon of June 8, 2004. Accordingly, no water level measurements were obtained for the last 1.5 days of Phase 2 activities.
- Hexavalent chromium was analyzed using US Environmental Protection Agency (USEPA) Method SW7199 as opposed to SW7196M as described in the Work Plan (Parsons, 2004a). Use of SW7199 permitted a lower detection limit than would have been possible with SW7196M.
- Metals were analyzed using USEPA Methods SW6010, SW6020, and SW7740 as opposed to only SW6020 as described in the Work Plan (Parsons, 2004a).
- Typically, at least two 20-mL VOA vials were shipped to Sequoia for VOC analysis. The expectation (based on prior discussions with the laboratory) was that Sequoia would use one sample bottle for the initial analysis and would use any additional sample bottles as back-up samples in the event that re-analysis was necessary (e.g., dilutions). However, for most analyses Sequoia composited the two 20-mL VOA vials into one 40-mL VOA vial for analysis using their autosampler. Parsons discussed this issue with Sequoia after realizing that the procedure was being used, and Sequoia clarified that the procedure that was used was consistent with USEPA guidance. Nonetheless, the potential for volatilization of VOCs during the compositing process is a potential concern.
- Due to a field oversight, hexavalent chromium was not analyzed in either the Low-Flow or the three-Volume samples collected from wells MW-38D and MW-424.

3.4 QA/QC SAMPLE COLLECTION

A total of 34 samples were collected for QA/QC purposes. The number and type of each of these samples is summarized in Table 3.7. Generally QA/QC sample collection followed the schedule described in the Work Plan (Parsons, 2004a). However, some variances did occur as described below.

Sequoia did not provide trip blank samples as part of the Phase 2 bottle order. However, one trip blank sample was provided via courier by Sequoia on June 9, 2004. This was the only trip blank sample collected during the Phase 2 activities. This sample was sent to Sequoia along with the daily shipment of VOC samples on June 9, 2004. However, Sequoia did not analyze this sample. No explanation was available from Sequoia as to why this sample was not analyzed. Trip blank samples were provided by Sequoia for the Phase 3 activities, and one of these samples was shipped along with each

TABLE 3.7
QA/QC SAMPLES COLLECTED
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sample Type	PDBS	RPPS	PsMS	RCS	Hydra-Sleeve®	Snap Sampler™	Low-Flow	Three-Volume Purge
Field Duplicate	2	0	0	1	0	0	4[a/]	4[a/]
Matrix Spike/Matrix Spike Duplicate	0	0	0	0	0	0	1[b/]	1[b/]
Equipment Rinseate	1	1	1	1	1	1	1 from pump and tubing	2 Total: -1 from bailer only -1 from bailer and filter
Source Water Blank[c/]	1				NA[d/]	NA[d/]	NA[d/]	NA[d/]
Purified Water[e/]	1							
Trip Blank	7 Total: 1 during Phase 2 which was never analyzed 1 per cooler containing VOC samples collected during Phase 3							

[a/] Although four samples were collected with the intention of being used as field duplicates, a fifth field duplicate sample was available for the analyses performed by Sequoia (see Note [b/] below).

[b/] These samples were designated for MS/MSD analyses on the chains of custody. However, Sequoia treated them as primary samples and did not spike them. They therefore are considered field duplicate samples for analyses performed by Sequoia only. Although no other samples were designated by the field scientists as MS/MSD samples, both Sequoia and CAS chose other samples at random upon which to perform MS/MSD analyses (see Appendix A).

[c/] Source water blank was comprised of the water used to fill the diffusion samplers prior to deployment.

[d/] NA = not applicable.

[e/] Purified water blank was comprised of the water used for decontamination.

cooler containing samples intended for VOC analysis. As a result of the lack of trip blanks during Phase 2, the degree to which low-level VOC detections may be attributable to cross-contamination during sample shipping and handling cannot be fully confirmed.

Two of the samples collected with the intent of being used by the laboratories as matrix spike/matrix spike duplicate (MS/MSD) samples were not treated as MS/MSD samples by Sequoia although they were by CAS. Instead, Sequoia analyzed these samples as primary samples. They are therefore considered duplicate samples for QA/QC purposes. These samples were MW173-3VOL-MS/MSD and MW225-MICRO-MS/MSD. Despite this oversight, other samples were selected at random by Sequoia for MS/MSD analysis (see Appendix A). In the instances where field samples designated as MS/MSDs were not analyzed as such, measurements of accuracy and analytical precision based on MS/MSD results were not developed for samples collected using a given sampling method.

In the Work Plan (Parsons, 2004a), two field duplicates and two MS/MSD samples were scheduled for collection with the HydraSleeve®. However, due to an oversight, no field duplicates or MS/MSD samples for this sampler type were collected. Therefore, information regarding precision of the HydraSleeve® sampling process based on MS/MSD results and the impact of potential matrix effects on the analytical testing is not available.

A total of four field duplicate samples were collected for both the low-flow and three-volume purge sampling methods while only two were scheduled according to the Work Plan (Parsons, 2004a).

Although only one equipment rinseate was scheduled for the three-volume purge method (Parsons, 2004a), two were actually collected; one from the bailer only, and another from both the bailer and the in-line filter.

SECTION 4

SAMPLING RESULTS AND COMPARISON

4.1 DATA PRESENTATION

Field measurements collected during this demonstration are summarized in Tables 3.2 and 3.3. Laboratory analytical results are included on CD as an attachment to this report.

4.2 DATA VALIDATION

A project-specific “Level III” data validation protocol was performed, which evaluated sample data and QC data and results summarized on AFCEE reporting forms. In performing the data validation, it was assumed that the laboratory’s documentation was acceptable and that the data reported by the laboratory were an accurate representation of the raw data. The raw data were not reviewed. A complete review of the applicable data was performed, and the project-specific QAPP and the McClellan QAPP 5.0 were used as the primary tools in the validation of the data.

The data quality assessment report (Appendix A) is based on the reviewed information, and on the data quality specifications of the project QAPP, as well as Sections 1-17 of the McClellan AFB QAPP 5.0 and the appended SOP McAFB-028 (“Data Review Procedures”) and SOP McAFB-029 (“Data Validation Standard Operating Procedures”).

In accordance with the Work Plan (Parsons, 2004a) and as described in Section 3.4, QA/QC samples were collected during this demonstration. These samples included field duplicate, MS/MSD, equipment rinseate, source water blank, purified water, and trip blank samples. A brief summary of the data validation results is provided in the following paragraphs, and more complete details are presented in Appendix A.

- Accuracy is considered acceptable for all VOC, 1,4 dioxane, and anion results, all but one hexavalent chromium result, and all metals results with the exception of the aluminum result in several samples.
- Overall precision (sampling and analysis) is considered to be acceptable for all parameters, recognizing that, as shown in Table 3.7, a field duplicate HydraSleeve® sample was not collected. Therefore, information regarding precision of the HydraSleeve® sampling process is not available.
- Analytical precision is considered to be acceptable, recognizing that in the instances where project samples were not analyzed as MS/MSDs, measurements of accuracy and analytical precision based on MS/MSD results were not developed for samples collected using a given sampling technology.
- Representativeness is considered to be acceptable for all parameters, with the exception of many of the extremely low (below or near the practical quantitation limit [PQL]) results for VOCs, anions, and metals that have been qualified as

undetected (“U”) due to associated contamination of laboratory method blanks or field blanks.

- Completeness is considered to be acceptable for all parameters.

Some data quality issues were noted either in the laboratory case narratives or during the data validation process. Despite these issues, nearly all of the validated data were deemed usable for the intended purposes (only one result was rejected) based on this validation. The reader is directed to Appendix A for a detailed discussion of the data validation results.

4.3 WELL-SPECIFIC DATA PLOTS

Figures were prepared that present the concentrations of selected analytes in each well, as reported for each sampling method used and for each sampling depth (shallow, intermediate, and deep). These figures are included in Appendix B. Graphs were prepared for one VOC of concern (trichloroethene [TCE]), one anion (sulfate), one reduction-oxidation (redox)-sensitive metal (iron), one metal that is less redox-sensitive (zinc), 1,4 dioxane, and hexavalent chromium. Results for the three-volume purge are shown using a vertical line across all depths since that method is not depth specific. Results for the low-flow purge are shown as a single point located at the intermediate depth, despite uncertainty about the depth-discrete nature of a low-flow sample. When a low-flow sample is collected, determining the portion of the screened interval of the aquifer that contributed water to the sample can be problematic. As noted in Section 4.4, for instances where more than one value was available per comparison, the maximum value was used in the sampling results comparison.

4.4 SAMPLING RESULTS COMPARISON

Numerous potential methods of data evaluation are possible due to the relatively large amount of analytical data and number of comparisons. For this report, three different types of evaluation processes were used to compare the data sets:

- Conventional statistical methods,
- Other quantitative comparative tools, and
- Holistic qualitative data evaluation.

Each of these processes was applied with the objective of identifying general trends or tendencies present in the data sets. After all of the processes were applied, overall conclusions related to sampler performance were made. In this comparative analysis, the results for each sampler type were compared to the corresponding results (i.e., same well, same depth, same analyte) for each of the other sampling methods. Additionally, the analytical data set was subdivided into the following six categories for comparison purposes:

1. All data combined,
2. 1,4 dioxane,
3. Anions,
4. Hexavalent chromium,
5. Metals, and
6. VOCs.

Each sampler-to-sampler comparison was performed for each of the analytical subgroups listed above, resulting in a total of 113 dataset comparisons. The quantitative evaluation processes described in Sections 4.4.1 and 4.4.2 (Conventional Statistical Methods and Other Quantitative Comparative Tools, respectively) were applied to each of these 113 comparison instances. The results of these quantitative comparisons were then considered using a holistic qualitative review to derive final conclusions about each specific comparison.

Prior to applying the statistical analysis tools, the datasets used for comparison were "pared down" through the application of several logical filters. These filters are described below.

- Instances where both results being compared were not detected (e.g., TCE was not detected in both low-flow purge and PDB samples) were excluded from the data set.
- If a result was qualified as non-detect (U) based on data validation only, it was excluded from the comparative analyses. This alleviates any concerns about skewing the dataset comparisons due to biases that may be caused by laboratory or field contamination.
- One result was rejected based on the data validation; this value was not used in the statistical analyses.
- For instances where more than one value was available per comparison (i.e., multi-depth sampling versus single-point sampling, primary and duplicate samples), the maximum value was used in the statistical analyses.
- For instances where a result was not detected (ND) at the method detection limit (MDL) using one sampling method, and the corresponding result using the other sampling method was a detected value, a value of one-half of the MDL was used for the ND measurement in the statistical analyses. This permitted use of a log-log scale to plot results, whereas if a value of zero had been assigned to the result instead, it would not plot on that type of scale. One exception to this filter was applied however. In circumstances where one result was ND and the other result being compared was detected but had a lower MDL, the comparison was excluded from the statistical analyses. This prevented the comparison from being biased, because one-half of the MDL for the non-detected analyte may have been greater than the detected result.
- One PDB sample was analyzed for 1,4 dioxane to see if that compound would diffuse through the membrane. Although 1,4 dioxane was detected in other samples from the same well, it was not detected in the PDB sample. This indicates that the PDBS method is not suitable for monitoring 1,4 dioxane. Therefore, the PDBS results for 1,4 dioxane were excluded from the statistical analyses.

Tables 4.1 through 4.6 show the number of data pairs that were available for each comparison after all filters had been applied to the data set. For the quantitative evaluation processes, a lower confidence or meaning was ascribed to comparisons with fewer data pairs. In Tables 4.1 through 4.6, instances where less than 10 data pairs were available for a particular comparison were highlighted in red in the "Number of Comparisons" column.

TABLE 4.1

STATISTICAL SUMMARY - ALL DATA

NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a/]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f/]		
						Sign[b/]	Wilcoxon[c/]	Median RPD[d/]	X-Y Scatter Slope (R^2)[e/]	Sampler A		Sampler B
Low-Flow	3-Volume	379	190	174	15	57% (48%)	47%	1.0	0.99 (0.95)	**Low-Flow**	=	**3-Volume**
Low-Flow	HydraSleeve®	175	82	85	8	12% (51%)	20%	0.0	0.96 (0.94)	**Low-Flow**	=	**HydraSleeve®**
Low-Flow	PDBS	92	31	57	4	99% (65%)	100%	-22.0	1.41 (0.79)	**Low-Flow**	<	**PDBS**
Low-Flow	PSMS	171	92	74	5	81% (45%)	51%	2.8	0.95 (0.97)	**Low-Flow**	=	**PSMS**
Low-Flow	RCS	168	93	69	6	93% (43%)	79%	5.3	0.93 (0.97)	**Low-Flow**	=	**RCS**
Low-Flow	RPPS	336	178	140	18	96% (44%)	73%	3.5	0.94 (0.98)	**Low-Flow**	=	**RPPS**
Low-Flow	Snap Sampler™	52	7	41	4	100% (85%)	100%	-21.7	1.22 (0.99)	**Low-Flow**	<	**Snap Sampler™**
3-Volume	HydraSleeve®	180	79	93	8	68% (54%)	83%	-1.3	1.04 (0.98)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PDBS	99	50	49	0	0% (49%)	53%	5.1	0.76 (0.58)	**3-Volume**	=	**PDBS**
3-Volume	PSMS	173	82	89	2	35% (52%)	45%	-1.2	1.02 (0.97)	**3-Volume**	=	**PSMS**
3-Volume	RCS	168	104	61	3	100% (37%)	100%	10.6	0.85 (0.98)	**3-Volume**	>	**RCS**
3-Volume	RPPS	338	178	148	12	89% (45%)	81%	2.4	0.92 (0.96)	**3-Volume**	=	**RPPS**
3-Volume	Snap Sampler™	53	15	33	5	99% (69%)	94%	-6.9	1.08 (0.99)	**3-Volume**	<	**Snap Sampler™**
HydraSleeve®	PDBS	95	51	40	4	71% (44%)	73%	12.8	0.98 (0.39)	**HydraSleeve®**	=	**PDBS**
HydraSleeve®	PSMS	359	186	151	22	94% (45%)	95%	1.8	0.91 (0.93)	**HydraSleeve®**	=	**PSMS**
HydraSleeve®	RCS	49	35	14	0	100% (29%)	99%	7.9	1.00 (1.00)	**HydraSleeve®**	>	**RCS**
HydraSleeve®	RPPS	413	213	174	26	95% (45%)	91%	0.9	0.94 (0.98)	**HydraSleeve®**	=	**RPPS**
PDBS	PSMS	120	59	55	6	22% (48%)	92%	0.0	0.41 (0.3)	**PDBS**	=	**PSMS**
PDBS	RCS	122	80	30	12	100% (27%)	100%	7.7	0.90 (0.96)	**PDBS**	>	**RCS**
PDBS	RPPS	232	146	65	21	100% (31%)	100%	11.6	0.81 (0.71)	**PDBS**	>	**RPPS**
PDBS	Snap Sampler™	72	9	61	2	100% (87%)	100%	-21.7	1.27 (0.95)	**PDBS**	<	**Snap Sampler™**
PSMS	RPPS	471	234	198	39	91% (46%)	96%	0.0	0.99 (0.98)	**PSMS**	=	**RPPS**
PSMS	Snap Sampler™	3	1	2	0	0% (67%)	71%	-27.3	1.20 (-16.2)	**PSMS**	<	**Snap Sampler™**
RCS	RPPS	457	177	232	48	99% (57%)	85%	-0.7	1.00 (1.00)	**RCS**	=	**RPPS**
RCS	Snap Sampler™	132	9	113	10	100% (93%)	100%	-26.3	1.13 (0.96)	**RCS**	<	**Snap Sampler™**
RPPS	Snap Sampler™	134	17	107	10	100% (86%)	100%	-17.0	1.11 (0.96)	**RPPS**	<	**Snap Sampler™**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.2

STATISTICAL SUMMARY - 1,4 DIOXANE

NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a/]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f/]		
						Sign[b/]	Wilcoxon[c/]	Median RPD[d/]	X-Y Scatter Slope (R^2)[e/]	Sampler A		Sampler B
Low-Flow	3-Volume	7	3	4	0	0% (57%)	50%	-1.5	1.41 (0.97)	**Low-Flow**	=	**3-Volume**
Low-Flow	HydraSleeve®	3	1	2	0	0% (67%)	41%	0.0	1.11 (1.00)	**Low-Flow**	=	**HydraSleeve®**
Low-Flow	PSMS	4	3	1	0	38% (25%)	73%	7.7	0.94 (0.99)	**Low-Flow**	=	**PSMS**
Low-Flow	RCS	3	0	3	0	75% (100%)	89%	-7.4	1.11 (1.00)	**Low-Flow**	<	**RCS**
Low-Flow	RPPS	7	5	2	0	55% (29%)	82%	6.1	0.92 (0.99)	**Low-Flow**	=	**RPPS**
Low-Flow	Snap Sampler™	3	0	3	0	75% (100%)	89%	-20.7	1.26 (1.00)	**Low-Flow**	<	**Snap Sampler™**
3-Volume	HydraSleeve®	3	1	2	0	0% (67%)	71%	-5.4	1.05 (1.00)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PSMS	4	2	2	0	38% (50%)	53%	5.2	0.90 (0.99)	**3-Volume**	=	**PSMS**
3-Volume	RCS	3	2	1	0	0% (33%)	71%	30.3	0.74 (0.99)	**3-Volume**	=	**RCS**
3-Volume	RPPS	7	5	2	0	55% (29%)	82%	28.6	0.64 (0.99)	**3-Volume**	>	**RPPS**
3-Volume	Snap Sampler™	3	2	1	0	0% (33%)	71%	17.1	0.84 (0.99)	**3-Volume**	=	**Snap Sampler™**
HydraSleeve®	PSMS	6	6	0	0	96% (0%)	97%	27.6	0.83 (1.00)	**HydraSleeve®**	>	**PSMS**
HydraSleeve®	RPPS	7	6	1	0	87% (14%)	96%	25.0	0.69 (0.99)	**HydraSleeve®**	>	**RPPS**
PSMS	RPPS	9	4	3	2	0% (43%)	69%	0.0	0.85 (0.97)	**PSMS**	=	**RPPS**
PSMS	Snap Sampler™	3	1	2	0	0% (67%)	71%	-27.3	1.20 (-16.2)	**PSMS**	<	**Snap Sampler™**
RCS	RPPS	9	4	4	1	28% (50%)	6%	0.0	0.90 (0.95)	**RCS**	=	**RPPS**
RCS	Snap Sampler™	6	0	6	0	96% (100%)	97%	-21.8	1.35 (0.86)	**RCS**	<	**Snap Sampler™**
RPPS	Snap Sampler™	9	0	9	0	99% (100%)	99%	-28.6	1.50 (0.95)	**RPPS**	<	**Snap Sampler™**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.3
STATISTICAL SUMMARY - ANIONS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a/]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f/]		
						Sign[b/]	Wilcoxon[c/]	Median RPD[d/]	X-Y Scatter Slope (R^2)[e/]	Sampler A		Sampler B
Low-Flow	3-Volume	42	11	20	11	85% (65%)	94%	0.0	1.06 (0.98)	**Low-Flow**	=	**3-Volume**
Low-Flow	HydraSleeve®	18	6	7	5	0% (54%)	45%	-9.5	1.06 (0.96)	**Low-Flow**	=	**HydraSleeve®**
Low-Flow	PSMS	16	3	12	1	96% (80%)	98%	-6.2	1.07 (0.99)	**Low-Flow**	=	**PSMS**
Low-Flow	RCS	24	12	7	5	64% (37%)	3%	0.7	1.00 (1.00)	**Low-Flow**	=	**RCS**
Low-Flow	RPPS	41	13	15	13	15% (54%)	85%	0.0	1.01 (0.99)	**Low-Flow**	=	**RPPS**
Low-Flow	Snap Sampler™	19	3	13	3	98% (81%)	99%	-5.1	1.22 (0.99)	**Low-Flow**	<	**Snap Sampler™**
3-Volume	HydraSleeve®	18	6	7	5	0% (54%)	42%	0.0	1.09 (0.94)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PSMS	17	4	11	2	88% (73%)	76%	-8.0	1.02 (0.93)	**3-Volume**	=	**PSMS**
3-Volume	RCS	24	16	6	2	94% (27%)	64%	6.7	0.88 (0.99)	**3-Volume**	=	**RCS**
3-Volume	RPPS	42	19	13	10	62% (41%)	51%	0.0	0.92 (0.96)	**3-Volume**	=	**RPPS**
3-Volume	Snap Sampler™	19	5	9	5	58% (64%)	90%	0.0	1.08 (0.99)	**3-Volume**	=	**Snap Sampler™**
HydraSleeve®	PSMS	44	9	21	14	96% (70%)	75%	0.0	0.86 (0.77)	**HydraSleeve®**	=	**PSMS**
HydraSleeve®	RPPS	49	19	19	11	13% (50%)	60%	0.0	0.94 (0.97)	**HydraSleeve®**	=	**RPPS**
PSMS	RPPS	50	32	4	14	100% (11%)	100%	6.3	0.98 (0.87)	**PSMS**	=	**RPPS**
RCS	RPPS	70	14	33	23	99% (70%)	99%	0.0	1.01 (1.00)	**RCS**	=	**RPPS**
RCS	Snap Sampler™	57	5	43	9	100% (90%)	100%	-10.0	1.13 (0.94)	**RCS**	<	**Snap Sampler™**
RPPS	Snap Sampler™	59	11	40	8	100% (78%)	99%	-6.5	1.11 (0.95)	**RPPS**	<	**Snap Sampler™**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.4
STATISTICAL SUMMARY - HEXAVALENT CHROMIUM
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

						Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f/]		
Sampler A	**Sampler B**	**Number of Comparisons[a/]**	**Number of Instances Where Sampler A > B**	**Number of Instances Where Sampler A < B**	**Number of Instances Where Sampler A = B**	**Sign[b/]**	**Wilcoxon[c/]**	**Median RPD[d/]**	**X-Y Scatter Slope (R^2)[e/]**	**Sampler A**		**Sampler B**
Low-Flow	3-Volume	13	1	12	0	99% (92%)	100%	-42.0	1.39 (0.14)	**Low-Flow**	<	**3-Volume**
Low-Flow	HydraSleeve®	7	1	6	0	87% (86%)	96%	-95.1	2.49 (0.46)	**Low-Flow**	<	**HydraSleeve®**
Low-Flow	PSMS	5	1	4	0	63% (80%)	92%	-34.5	1.35 (-2.03)	**Low-Flow**	<	**PSMS**
Low-Flow	RCS	8	0	7	1	98% (100%)	98%	-47.0	1.32 (-3.66)	**Low-Flow**	<	**RCS**
Low-Flow	RPPS	14	1	12	1	99% (92%)	100%	-52.6	1.46 (-0.38)	**Low-Flow**	<	**RPPS**
3-Volume	HydraSleeve®	7	2	5	0	55% (71%)	69%	-32.3	1.43 (0.43)	**3-Volume**	<	**HydraSleeve®**
3-Volume	PSMS	5	3	2	0	0% (40%)	11%	16.2	0.83 (-1.49)	**3-Volume**	=	**PSMS**
3-Volume	RCS	8	2	6	0	71% (75%)	84%	-12.3	1.05 (-0.05)	**3-Volume**	=	**RCS**
3-Volume	RPPS	14	4	10	0	82% (71%)	86%	-20.0	1.05 (0.10)	**3-Volume**	<	**RPPS**
HydraSleeve®	PSMS	16	9	7	0	20% (44%)	83%	12.7	0.57 (0.12)	**HydraSleeve®**	=	**PSMS**
HydraSleeve®	RCS	3	3	0	0	75% (0%)	89%	47.8	0.62 (-1.90)	**HydraSleeve®**	>	**RCS**
HydraSleeve®	RPPS	18	9	8	1	0% (47%)	90%	9.1	0.79 (0.77)	**HydraSleeve®**	=	**RPPS**
PSMS	RPPS	21	8	9	4	0% (53%)	51%	0.0	1.06 (0.66)	**PSMS**	=	**RPPS**
RCS	RPPS	24	6	14	4	88% (70%)	99%	-7.4	1.06 (0.51)	**RCS**	<	**RPPS**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.5
STATISTICAL SUMMARY - METALS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a/]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f/]		
						Sign[b/]	Wilcoxon[c/]	Median RPD[d/]	X-Y Scatter Slope (R^2)[e/]	Sampler A		Sampler B
Low-Flow	3-Volume	230	150	76	4	100% (34%)	100%	18.9	0.96 (0.93)	**Low-Flow**	>	**3-Volume**
Low-Flow	HydraSleeve®	107	68	37	2	100% (35%)	98%	26.9	0.91 (0.93)	**Low-Flow**	>	**HydraSleeve®**
Low-Flow	PSMS	104	66	35	3	100% (35%)	98%	9.2	0.92 (0.97)	**Low-Flow**	>	**PSMS**
Low-Flow	RCS	92	62	30	0	100% (33%)	92%	26.1	0.90 (0.95)	**Low-Flow**	>	**RCS**
Low-Flow	RPPS	198	121	75	2	100% (38%)	93%	8.0	0.91 (0.97)	**Low-Flow**	>	**RPPS**
3-Volume	HydraSleeve®	108	52	55	1	15% (51%)	65%	-0.6	1.01 (0.99)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PSMS	100	48	52	0	24% (52%)	34%	-1.2	1.02 (0.97)	**3-Volume**	=	**PSMS**
3-Volume	RCS	90	56	34	0	97% (38%)	95%	11.3	0.83 (0.97)	**3-Volume**	>	**RCS**
3-Volume	RPPS	192	94	98	0	17% (51%)	23%	-1.8	0.92 (0.96)	**3-Volume**	=	**RPPS**
HydraSleeve®	PSMS	203	109	88	6	85% (45%)	97%	1.8	0.94 (0.97)	**HydraSleeve®**	=	**PSMS**
HydraSleeve®	RCS	46	32	14	0	99% (30%)	98%	7.5	1.00 (1.00)	**HydraSleeve®**	>	**RCS**
HydraSleeve®	RPPS	256	121	125	10	15% (51%)	13%	1.0	0.94 (0.98)	**HydraSleeve®**	=	**RPPS**
PSMS	RPPS	288	133	146	9	53% (52%)	31%	-0.5	0.99 (1.00)	**PSMS**	=	**RPPS**
RCS	RPPS	243	98	137	8	99% (58%)	7%	-1.8	0.99 (1.00)	**RCS**	<	**RPPS**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
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TABLE 4.6
STATISTICAL SUMMARY - VOCs
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

						Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f]		
Sampler A	**Sampler B**	**Number of Comparisons[a]**	**Number of Instances Where Sampler A > B**	**Number of Instances Where Sampler A < B**	**Number of Instances Where Sampler A = B**	**Sign[b]**	**Wilcoxon[c]**	**Median RPD[d]**	**X-Y Scatter Slope (R^2)[e]**	**Sampler A**		**Sampler B**
Low-Flow	3-Volume	87	25	62	0	100% (71%)	100%	-33.7	1.52 (0.76)	**Low-Flow**	<	**3-Volume**
Low-Flow	HydraSleeve®	40	6	33	1	100% (85%)	100%	-23.4	1.20 (0.96)	**Low-Flow**	<	**HydraSleeve®**
Low-Flow	PDBS	92	31	57	4	99% (65%)	100%	-22.0	1.41 (0.79)	**Low-Flow**	<	**PDBS**
Low-Flow	PSMS	42	19	22	1	25% (54%)	57%	-8.7	0.99 (0.77)	**Low-Flow**	=	**PSMS**
Low-Flow	RCS	41	19	22	0	25% (54%)	54%	-6.9	1.22 (0.96)	**Low-Flow**	=	**RCS**
Low-Flow	RPPS	76	38	36	2	9% (49%)	38%	1.8	1.16 (0.91)	**Low-Flow**	=	**RPPS**
Low-Flow	Snap Sampler™	30	4	25	1	100% (86%)	100%	-53.3	1.77 (0.99)	**Low-Flow**	<	**Snap Sampler™**
3-Volume	HydraSleeve®	44	18	24	2	56% (57%)	42%	-15.7	0.59 (0.50)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PDBS	99	50	49	0	0% (49%)	53%	5.1	0.76 (0.58)	**3-Volume**	=	**PDBS**
3-Volume	PSMS	47	25	22	0	23% (47%)	80%	23.3	0.46 (0.33)	**3-Volume**	>	**PSMS**
3-Volume	RCS	43	28	14	1	96% (33%)	99%	20.6	0.63 (0.75)	**3-Volume**	>	**RCS**
3-Volume	RPPS	83	56	25	2	100% (31%)	100%	35.5	0.63 (0.70)	**3-Volume**	>	**RPPS**
3-Volume	Snap Sampler™	31	8	23	0	99% (74%)	96%	-17.0	1.04 (0.90)	**3-Volume**	<	**Snap Sampler™**
HydraSleeve®	PDBS	95	51	40	4	71% (44%)	73%	12.8	0.98 (0.39)	**HydraSleeve®**	=	**PDBS**
HydraSleeve®	PSMS	90	53	35	2	93% (40%)	99%	21.1	0.90 (0.81)	**HydraSleeve®**	>	**PSMS**
HydraSleeve®	RPPS	83	58	21	4	100% (27%)	100%	42.1	1.16 (0.56)	**HydraSleeve®**	>	**RPPS**
PDBS	PSMS	120	59	55	6	22% (48%)	92%	0.0	0.41 (0.30)	**PDBS**	=	**PSMS**
PDBS	RCS	122	80	30	12	100% (27%)	100%	7.7	0.90 (0.96)	**PDBS**	>	**RCS**
PDBS	RPPS	232	146	65	21	100% (31%)	100%	11.6	0.81 (0.71)	**PDBS**	>	**RPPS**
PDBS	Snap Sampler™	72	9	61	2	100% (87%)	100%	-21.7	1.27 (0.95)	**PDBS**	<	**Snap Sampler™**
PSMS	RPPS	103	57	36	10	96% (39%)	99%	5.9	1.05 (0.35)	**PSMS**	=	**RPPS**
RCS	RPPS	111	55	44	12	69% (44%)	96%	0.0	0.96 (0.97)	**RCS**	=	**RPPS**
RCS	Snap Sampler™	69	4	64	1	100% (94%)	100%	-39.5	1.38 (0.93)	**RCS**	<	**Snap Sampler™**
RPPS	Snap Sampler™	66	6	58	2	100% (91%)	100%	-37.0	1.40 (0.88)	**RPPS**	<	**Snap Sampler™**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
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4.4.1 CONVENTIONAL STATISTICAL ANALYSES

The distribution of the data was evaluated in order select the most appropriate statistical methods to apply to the data. Conventional statistical methods were then selected and used to evaluate the data sets that were being compared.

4.4.1.1 DATA DISTRIBUTION

Each of the data sets was tested for normality in order to determine whether parametric or non-parametric statistical tests were appropriate for the data analysis. The Shapiro-Wilk's W test was used to determine data distribution. Several groupings of data were evaluated for normality as described below.

Initially, data sets for each of the eight different sampling methods were tested for each of the six different compound groupings (all data combined, 1,4 dioxane only, anions only, hexavalent chromium only, metals only, and VOCs only). Data used for normality testing in this application included both primary and field duplicate sample results; results that were not detected or rejected during data validation were excluded.

Additionally, since the difference between two sampling methods was the end-use of the data for comparison purposes, the Shapiro-Wilk's W test also was applied to the populations of differences between two sampling methods being compared. Data used for this variance of normality testing were taken from the "pared-down" data sets described in Section 4.4. As an example of this variance of normality testing, each time there was an available comparison between two sampling methods (e.g., all VOC concentrations at the shallow sample depth in well MW-1065 obtained using the PDBS and RCS sampling methods), the difference between those two concentrations was calculated. After the differences were calculated for all possible comparisons of analytical results obtained using those two sampling methods, the Shapiro-Wilk's W test was then applied to that population (e.g., PDBS versus RCS for VOCs only). The results of all normality tests are included in Appendix C.

Tests for normality failed (i.e., data sets are not normally distributed) for almost all of the data subsets evaluated. Some exceptions were noted (see Appendix C) but were due mostly to small sample populations (e.g., 1,4 dioxane in the difference between PsMS and RPPS results). The overall lack of normally-distributed data sets supports the use of nonparametric statistical tools as described below.

4.4.1.2 WILCOXON MATCHED-PAIRS SIGNED RANKS TEST

The Wilcoxon Matched-Pairs Signed Ranks Test (Wilcoxon test) was applied to determine if two dependent variables (e.g., RPPS and HydraSleeve® analytical results) represent two different populations. The Wilcoxon test is a nonparametric procedure used in hypothesis testing when one or more of the assumptions of the students paired t-test (e.g., normal population distributions) are violated. The Wilcoxon test determines if the median of the differences between the pairs of data (e.g., the RPPS measurement and the HydraSleeve® measurement for a given well [θ_D]) is equal to zero. If a significant difference is obtained, it indicates that there is a high likelihood that the two data sets represent different populations.

A test statistic (the Wilcoxon T statistic) is calculated and associated with a p-value (and corresponding confidence level). For example, a Wilcoxon T statistic that resulted in a p-value of 0.03 would correspond to a confidence level of 97 percent that the two samples represent two different populations.

Tables 4.1 through 4.6 include summaries of the results of the Wilcoxon test analyses. Values presented in these tables are the confidence level (i.e., 1 minus the p-value) that the two sampling methods represent different populations. For this analysis, if the confidence was greater than or equal to 90 percent, the two populations were deemed to be different at a statistically significant level, and are highlighted in yellow.

4.4.1.3 SIGN TEST

The sign test is a nonparametric alternative to the students paired t-test for dependent samples. The test is applicable to situations where the researcher has two measures (e.g., under two conditions) for each subject and wants to establish whether or not the two measurements (or conditions) are different.

The only assumption required by this test is that the underlying distribution of the variable of interest is continuous; no assumptions about the nature or shape of the underlying distribution are required. The test simply computes the number of times (across subjects) that the value of the first variable (*A*) is larger than that of the second variable (*B*). Under the null hypothesis, which states that the two variables are not different from each other, this is expected to be the case about 50 percent of the time. Based on the number of observed cases where A is greater than B, a p-value and associated confidence level can be calculated for the data set.

Tables 4.1 through 4.6 include summaries of the results of the sign test analyses. Values presented in these tables are the confidence that the two sampling methods represent different populations. For this analysis, if the confidence was greater than or equal to 90 percent, the two populations were deemed to be different at a statistically significant level, and are highlighted in yellow. The results of the sign test also indicate the percentage of times that non-equal values are greater than or less than the comparative set of values (i.e., the percent of times that values in population A were greater than values in population B). These values also are shown in Tables 4.1 through 4.6.

4.4.2 OTHER QUANTITATIVE COMPARATIVE TOOLS

In addition to the traditional statistical tools discussed in Section 4.4.1, two other quantitative tools were used to compare the various combinations of data sets.

4.4.2.1 LINEAR REGRESSION

The results for each sampling method were plotted against the corresponding results for each of the other sampling methods using X-Y scatter plots. Best-fit linear trend lines were then fitted to these data sets, and the slope and goodness-of-fit (R^2) value for each line was calculated. Best-fit linear trend lines were fitted to each of the subgroups of compounds/analytes listed in Section 4.4. These plots are included in Appendix D.

Slopes that are close to 1 suggest that the average correlation between both sampling devices being compared approaches a 1 to 1 ratio, whereas higher or lower slopes suggest that one sampling method is more likely to result in higher or lower concentrations than the other method. Likewise, the closer the R^2 value is to 1, the better the fit of the data to the trend line, and the lower the degree of scatter of data about the best-fit linear trend line.

Tables 4.1 through 4.6 include summaries of the slope and R^2 values for each of the figures discussed above. The slope and R^2 values shown in Tables 4.1 through 4.6 are highlighted in yellow to indicate when the two populations being compared were deemed to not be similar to each other based on the magnitude of the slope. The following guidelines were followed when applying highlighting to these values:

Slope Guidelines

- If the slope was between 0.90 and 1.10, the two sets of sampling results were deemed to be similar.
- If the slope was equal to or greater than 1.10, the sampling device represented on the Y-axis of the plot was deemed to be more likely to return a higher-magnitude result than the sampling device represented on the X-axis.
- If the slope was equal to or less than 0.90, the sampling device represented on the X-axis of the plot was deemed to be more likely to return a higher-magnitude result than the sampling device represented on the Y-axis.

R^2 Guidelines

- If the R^2 value was greater than or equal to 0.90, the degree of scatter of the data relative to the best-fit linear trend line was deemed to be low; therefore the observation made based on the slope was considered more meaningful.
- If the R^2 value was less than 0.90, the degree of scatter of the data relative to the best-fit linear trend line was deemed to be significant; therefore the observation made based on the slope was considered less meaningful.

The threshold values described above were selected somewhat arbitrarily, but also were based on a qualitative review of the data as described in Section 4.4.3. The guidelines established for R^2 values were used primarily in the qualitative evaluation.

4.4.2.2 MEDIAN RPD

Another quantitative analysis tool applied to the data sets is referred to as the median relative percent difference (RPD). The first step in this analysis is to calculate the RPD of each data pair using the following equation:

$$RPD = 100*[(A-B)/\{(A+B)/2\}]$$

Where:

A = Result from sampling method A; and

B = Result from sampling method B.

A positive RPD indicates that the result from sampling method A is higher than the result from sampling method B, while a negative RPD indicates the opposite. RPDs close to zero generally indicate that results from both sampling methods were similar.

Once all the RPDs were calculated, the median of the RPDs for each data comparison group was calculated by ranking the RPD values from lowest to highest and choosing the middle value of the ranked set of calculated RPDs. If the number of RPD values was even, then the median was selected as the mean RPD of the middle two values. This median RPD was then used as an indicator of the comparability of the two sampling methods for each compound/analyte subset. A positive value for the median RPD indicated that sampling method A results were more frequently higher than sampling method B results (the reverse is true for negative values). Additionally, the closer the median RPD was to zero, the more likely the two sampling methods returned similar results (essentially, for every time sampling method A was greater than sampling method B, there were an equal number of times where sampling method B was greater than sampling method A). Conversely, if the median RPD was much greater than or less than zero, the more likely one sampling method was to return results that were significantly greater than the other method. For this analysis, a median RPD that was either greater than or equal to 10 or less than or equal to -10 was considered to indicate that one method was more likely to return a meaningfully higher (or lower) concentration than the other sampling method compared. Median RPD values between 10 and -10 were considered to indicate that both sampling methods returned similar concentrations. As with the guideline values described for the linear regression analysis, these values were selected somewhat arbitrarily, but also were based on a qualitative review of the data as described in Section 4.4.3.

Tables 4.1 through 4.6 include summaries of the results of the median RPD analysis. RPD results greater than or less than 10 are highlighted in yellow.

4.4.3 HOLISTIC QUALITATIVE ASSESSMENT

Each of the statistical analyses described above was applied to the 113 possible comparison combinations. Of the 113 possible comparison combinations, 26 (23 percent) had sufficiently small populations (i.e., fewer than 10 data pairs) that the results of the statistical analyses are not considered to be particularly meaningful.

Of the remaining 87 combinations, there were 41 instances where both the conventional statistical and other quantitative comparison tests resulted in consistent observations. Conversely, there were 46 instances where the results of each of these tests were not internally consistent.

If the results of each of the four quantitative comparisons were consistent for a particular comparison (as shown in Tables 4.1 through 4.6 by having consistent highlighting of all four comparative test results), the resulting observation was validated and deemed correct without further review. The resulting observation is shown in Tables 4.1 through 4.6 under the column titled “Holistic Conclusion”.

For those instances where the results of the four quantitative analyses varied, the results of the two populations being compared were scrutinized qualitatively, and a general conclusion regarding the comparison was made based not only on the results of the statistical analyses, but also on professional judgment. For example, some of the following criteria were considered during the holistic qualitative evaluation.

- The paired data sets were reviewed to identify whether outlier points may have contributed to anomalous comparison results.
- The R^2 value calculated as part of the linear regression was reviewed to evaluate the degree of confidence in the linear regression results.
- The median RPD and linear regression results were compared to the threshold values derived for those comparative methods (i.e., 10 and -10 for median RPD and 0.90 to 1.10 for linear regression slope) to determine if the results were close to those values.

A discussion of the comparison results is presented in Section 6. However, if the reader is interested in better understanding the comparison results for particular analytes and/or sampling methods, they are encouraged to perform a detailed review of all of the comparison results presented in Tables 4.2 through 4.6 rather than limiting their review to the holistic conclusions. For example, the holistic conclusion for comparison of VOC concentrations obtained using the three-volume purge and HydraSleeve® methods is that these methods provided essentially equivalent results. The orange highlight indicates a lower degree of confidence in this conclusion because the results of all of the comparison tests were not internally consistent. Further inspection of the comparison results shown in Table 4.6 indicates that the Sign and Wilcoxon tests both indicated that the two data sets are statistically similar. However, the RPD and X-Y Scatter Slope/R^2 tests both indicate differences in the data sets. The slope result (0.59) indicates that the VOC concentrations obtained using the 3-volume purge method tended to be higher than the concentrations obtained using the HydraSleeve®. However, the relatively low R^2 value (0.50) indicates a high degree of scatter about the best-fit trend line and a correspondingly low confidence that the slope value is accurate and meaningful. Therefore, some comparisons termed "equal" in the holistic sense are more equal than others (i.e., "equal" defines a range of conditions rather than one specific condition).

The combined (i.e., "all data") results presented in Table 4.1 are solely for illustration purposes as a way to provide a summary analysis of the entire evaluation. However, these summary data may be misleading when compared with the results for the individual analytes or analyte groups presented in Tables 4.2 through 4.6. Tables 4.2 through 4.6 should be used to evaluate a particular sampling method's utility for a specific analyte or analyte group.

SECTION 5

COST ANALYSIS

In addition to the technical capability of a specific sampling method to monitor the medium in question, the potential cost of using any type of sampling method is a significant consideration when devising a sampling strategy. Accordingly, one of the objectives of this demonstration is to evaluate and compare the costs of each different sampling method demonstrated.

Due to the nature of the demonstration performed at McClellan (i.e., deployment and retrieval of multiple sampler types in the same well concurrently), some elements of the cost analysis such as labor costs are difficult to determine based on the actual dollars and hours expended for the demonstration, and must be estimated using professional judgment. To compare the costs of the eight sampling techniques used in this demonstration, the annual cost per well sampled for a given LTM scenario was estimated for each technique. Because other factors in addition to cost are considered in selecting an appropriate groundwater sampling method, it is assumed that each method is technically appropriate and can collect the necessary volume of water required for the target analyses. The following assumptions and expenses were considered in the development of a cost analysis for each different sampling method:

- Only one sample depth per well was assumed for LTM as opposed to the three sample depths scoped in the McClellan demonstration.
- Some of the diffusion and grab sampling devices require more time than others to deploy and retrieve. For LTM using these samplers, it is assumed that new samplers are deployed at the time of sample collection so that only one mobilization is required. A combination of field notes from the McClellan sampling events and professional judgment were used to estimate labor requirements for each of the different sampling methods.
- Each sampling method evaluated requires varying lengths of time at the outset of the LTM program for initial setup (e.g., installing dedicated systems and building sampler strings). This cost analysis does not include those initial setup costs for any of the evaluated methods.
- Some of the sampling methods require a one-time capital expenditure for equipment that is re-used throughout LTM (e.g., dedicated pump, Snap Sampler™ equipment, stainless steel weights). For the cost analysis, the one-time expenditures are amortized over the assumed 20-year duration of the LTM program.
- The LTM program was assumed to be comprised of 20 4-inch-diameter wells sampled semi-annually. Each well was assumed to be 50 feet deep, and the

bottom 10 feet of each well was assumed to comprise the screened interval. Depth to groundwater at all wells was assumed to be 15 feet.

- All sampling was assumed to be performed by a two-person field crew.
- Since water level measurements would be made regardless of which sampling method was used, costs for this task were not included in the cost analysis.
- Although field filtration of samples was performed in some instances during the McClellan demonstration, this task was not built into the cost analysis.
- Conventional sampling was assumed to be performed in a manner consistent with current practices at McClellan. The low-flow method was assumed to be performed using pumps and tubing that are dedicated to each well. The three-volume purge method was assumed to be performed using non-dedicated pumps and tubing and disposable bailers.
- In order to estimate the labor requirements for conventional sampling, the following assumptions were made:
  - Average low-flow and three-volume purge rates used during this demonstration (summarized in Table 3.3) were used to develop the cost estimates for these methods.
  - For the low-flow method, the average purge volume used during this demonstration (Table 3.3) was assumed.
  - For the three-volume purge method, a per-well purge volume of approximately 69 gallons was assumed, which is approximately three times the volume of water contained in a 4-inch well casing with 35 feet of water.
- Costs associated with disposal and/or management of investigation-derived waste (IDW) at some sites can vary widely depending on the approach used. For this cost analysis, no additional costs were assumed for treatment of IDW since McClellan uses an on-base treatment plant. However, labor and equipment costs to collect and transfer the IDW to the treatment plant were included in the cost analysis. As a qualitative consideration not captured in this cost analysis, IDW disposal and treatment can be significant at some sites where waste water generated must be disposed of off-site. The three-volume purge method would typically be expected to have the highest IDW disposal costs.
- Field mobilization/demobilization costs were assumed to be equal for all methods and therefore were not included in the cost analysis.
- Prices for commercially available products were obtained from product distributors or vendors.
- Three Snap Samplers™ were assumed to be used per well for LTM due to the relatively small volume of a single sampler (40 ml). Depending on the specific sample volume needs, use of a lesser number of Snap Samplers™ may be possible, resulting in a lower cost per sample than calculated for this cost analysis.
- For the RPPS, PsMS, and RCS, which are not commercially available, a retail price was estimated. This price was derived by summing the purchase cost of each individual component of the samplers used for the McClellan demonstration and

factoring in a profit of 400 percent (i.e., multiplying the materials cost by a factor of 4).

- Many of the common sampling supplies (e.g., nitrile gloves, plastic sheeting, sample containers) were assumed to be equal in cost regardless of the sampling method and were not included.
- Sales taxes were not included in the cost analysis.
- Labor is broken out by task in the cost analysis. Estimates of labor required for each task are based on field experience and professional judgment.
- A labor rate of $60 per hour was assumed for a field scientist.
- Laboratory analytical expenses were assumed to be equal regardless of sampling method and therefore are not included in the analysis.

Table 5.1 is a detailed account of the various costs that were considered in this analysis. Table 5.2 is a summary of the calculated per-well-per-event sampling costs using each of the eight methods. The results of this analysis indicate that conventional sampling is more expensive than any of the diffusion and grab sampling techniques. The PDBS and HydraSleeve® were the least expensive sampling methods, with the primary cost difference between the two being the time required to refill a new PDBS that is not necessary when using the HydraSleeve®.

The Snap Sampler™ was more expensive than the other no-purge samplers, but it still was substantially less then the purge methods. The initial purchase of the device and the recurring costs for the specialized sample bottles make the Snap Samplers™ more expensive than the other no-purge sampling devices. However, the Snap Sampler™ is less expensive than both conventional sampling methods. Because the Snap Sampler™ is untested in long-term use, it is difficult to estimate a realistic life expectancy for the device. The manufacturer of the Snap Sampler™ (ProHydro, Inc.) states that the Snap Sampler™ itself seems likely to have an extended life, and that replacing trigger linkage parts or other maintenance may be needed rather than full replacement of the samplers. For the cost calculation we assumed replacement parts and maintenance would be equivalent to replacing 1/3 of the sampler cost over the course of the program. It should be noted that the cost analysis assumed a three-vial configuration as was used at McClellan. In some applications, use of a two-vial configuration would be sufficient, which would reduce the cost of using the Snap Sampler method™ from that shown in Tables 5.1 and 5.2.

The cost for use of the RPPS was relatively high compared to other diffusion samplers and the HydraSleeve® primarily due to the labor required to prepare new samplers for deployment. Specifically, a significant amount of time was taken in purging the samplers of residual air. If the sampler is ever developed commercially, it is reasonable to expect that the degassing could be done more cheaply and efficiently prior to delivery.

If so, the cost to use the RPPS would be significantly reduced, potentially to the point where is would be comparable to the PDBS and RCS costs.

Similar to the RPPS, although to lesser degrees, the PsMS and RCS also were relatively time consuming to construct. Although this resulted in higher costs for the McClellan cost analysis, optimized designs and commercial availability would likely

TABLE 5.1
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

3-VOLUME PURGE

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Sampling Pump (Submersible Electric)	$ 300.00	week	--	1	40	$ 15.00
Pump Tubing	$ 0.50	foot	0.5	100	4000	$ 2.50
Tubing Reel	$ 100.00	each	5	1	4	$ 0.50
Controller	$ 150.00	week	--	1	40	$ 7.50
Generator (3,800 watt)	$ 200.00	week	--	1	40	$ 10.00
Field Meters + Flow-thru Cell	$ 300.00	week	--	1	40	$ 15.00
Field Meter Calibration Solutions	$ 50.00	each	0.5	1	40	$ 2.50
Truck Rental	$ 200.00	week	--	1	40	$ 10.00
500-Gallon IDW Poly Tank and Trailer	$ 3,000.00	each	20	1	1	$ 3.75
Teflon® Bailer (1.5" x 36" disposable)	$ 15.00	each	0.5	20	800	$ 15.00
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	0.5	1000	40000	$ 1.00
					Subtotal	**$ 82.75**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	20	40	$ 40.00
Purge Time	$ 1.00	minute	2	25	50	$ 50.00
Sample Collection	$ 1.00	minute	2	10	20	$ 20.00
Decontamination	$ 1.00	minute	2	15	30	$ 30.00
IDW Transfer to Treatment Plant	$ 1.00	minute	2	6	12	$ 12.00
					Subtotal	**$ 152.00**
					TOTAL COST	**$ 234.75**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

LOW-FLOW PURGE

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Sampling Pump (Submersible Electric)	$ 1,200	each	10	20	40	$ 60.00
Pump Tubing (dedicated)	$ 0.50	foot	5	900	3600	$ 2.25
Controller	$ 150.00	week	--	1	40	$ 7.50
Generator (3,800 watt)	$ 200.00	week	--	1	40	$ 10.00
Field Meters + Flow-thru Cell	$ 300.00	week	--	1	40	$ 15.00
Field Meter Calibration Solutions	$ 50.00	each	0.5	1	40	$ 2.50
55-Gallon Drums	$ 50.00	each	10	2	4	$ 0.25
Truck Rental	$ 200.00	week	--	1	40	$ 10.00

Subtotal **$ 107.50**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	10	20	$ 20.00
Purge Time	$ 1.00	minute	2	20	40	$ 40.00
Sample Collection	$ 1.00	minute	2	10	20	$ 20.00
Decontamination	$ 1.00	minute	2	5	10	$ 10.00
IDW Transfer to Treatment Plant	$ 1.00	minute	2	1.5	3	$ 3.00

Subtotal **$ 93.00**

TOTAL COST $ 200.50

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

SNAP SAMPLER™

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Samplers	$ 185.00	each	20	60	60	$ 13.88
Sampler Bottles (3 per sample)	$ 16.00	each	0.5	60	2400	$ 48.00
Docking Stations	$ 35.00	each	20	20	20	$ 0.88
Trigger Line	$ 1.25	foot	20	900	900	$ 1.41
Trigger with reel	$ 40.00	each	20	20	20	$ 1.00
Sampler Equipment Maintenance	$ 60.00	year	--	--	20	$ 1.50
					Subtotal	**$ 66.66**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	10	20	$ 20.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Removal	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Preservation/Prep	$ 1.00	minute	2	7	14	$ 14.00
Sample Bottle Replacement	$ 1.00	minute	2	8	16	$ 16.00
Decontamination	$ 1.00	minute	2	2	4	$ 4.00
					Subtotal	**$ 78.00**
					TOTAL COST	**$ 144.66**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

PDBS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 16.50	each	0.5	20	800	$ 16.50
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 17.76**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Filling and Replacement	$ 1.00	minute	2	6	12	$ 12.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 50.00**
					TOTAL COST	**$ 67.76**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

HYDRASLEEVE®

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 20.00	each	0.5	20	800	$ 20.00
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 21.01**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Replacement	$ 1.00	minute	2	2	4	$ 4.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 42.00**
					TOTAL COST	**$ 63.01**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

RPPS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 33.40	each	0.5	20	800	$ 33.40
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 34.66**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	10	20	$ 20.00
Sampler Filling and Replacement	$ 1.00	minute	2	20	40	$ 40.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 86.00**
					TOTAL COST	**$ 120.66**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

PsMS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 40.00	each	0.5	20	800	$ 40.00
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 41.26**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	8	16	$ 16.00
Sampler Filling and Replacement	$ 1.00	minute	2	14	28	$ 28.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 70.00**
					TOTAL COST	**$ 111.26**

TABLE 5.1 (Concluded)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

RCS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 32.60	each	0.5	20	800	$ 32.60
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 33.86**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Filling and Replacement	$ 1.00	minute	2	12	24	$ 24.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 62.00**
					TOTAL COST	**$ 95.86**

[a/] Assumes that 20 wells are sampled semi-annually for 20 years. See Section 5 for additional details.

TABLE 5.2
SUMMARY OF COST ANALYSIS RESULTS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampling Method	Per Well, Per Event Cost
3-Volume Purge	\$235
Low-Flow Purge	\$200
Snap Sampler™	\$145[a/]
RPPS	\$121
PsMS	\$111
RCS	\$96
PDBS	\$68
HydraSleeve®	\$63

a/ Assumes use of 3 samplers per well per sampling event.

reduce the construction time needed for both devices and would therefore reduce the overall cost of using them.

Of important note is that this cost analysis did not consider various more subtle aspects of using each of the sampling methods evaluated. For example, fewer QA/QC samples are typically necessary for the diffusion and grab sampling devices compared to conventional methods. This is due in part to the fact that it generally takes longer to sample a given number of wells using conventional methods than using diffusion and grab methods, and that conventional methods may require equipment decontamination. For these reasons, it is presumed that more trip blank and equipment rinseate blank samples would be required for conventional sampling compared to the alternate approaches. In addition, collection of MS/MSD samples may not be required using diffusion sampling given that turbidity would not migrate through the walls of these samplers. Snap Samplers™ are sealed shut while still in the well; therefore, collection of ambient field blanks should not be necessary when using this device (compared to other methods where the sample is transferred into sample bottles above-ground).

Additionally, this cost analysis does not consider the costs required to actually convert from one sampling method to another. Switching from one sampling method to another would probably require approval from one or more regulatory agencies, which could be simple or more complicated, depending on the specific circumstances (e.g., federal or state regulatory requirements, degree of technology “acceptance”). Converting from one sampling method to another also would probably require modification of some site-specific documents (e.g., QAPP, Record of Decision, Sampling and Analysis Plan). In some instances, additional field demonstrations may also be required in which side-by-side comparisons of the results of the proposed sampling method to contemporaneous or historical results of the current sampling method would be performed.

In summary, the cost analysis described above provides a general comparison of the per-well-per-event costs of each of the eight sampling methods demonstrated at McClellan; these costs can be used as an initial screening tool when trying to identify a candidate alternative sampling technology. Accordingly, prior to conversion from one sampling method to another, a more complete cost analysis that takes into account all site-specific cost factors should be performed.

SECTION 6

DISCUSSION

As described in Sections 1.1 and 2.3, one of the objectives of this demonstration was to include one or more "baseline" sampling methods to provide data against which the results of the alternative diffusion and grab samplers can be compared. This was achieved by incorporating the conventional methods (three-volume purge and low-flow purge) into the demonstration. However, these methods utilize inherently different sampling concepts than both the diffusion and grab sampling methods. Most notably, the conventional sampling methods induce groundwater flow into the well by creating an increased hydraulic gradient around the well resulting from the purge. Conversely, the alternative sampling methods rely solely on the natural flow of groundwater through the well. These methods might be expected to provide differing results since they are monitoring different flow conditions and potentially also different volumes of the aquifer. Furthermore, even results from the two conventional methods are expected to vary given the differences in purge volume and rate and the fact that low-flow samples are considered by some to be representative of a more discrete sample interval than samples obtained using a three-volume purge. Accordingly, although they represent "baseline" data in the sense that they are the commonly-used sampling methods that are generally accepted by the regulatory community, they do not necessarily represent the *correct* answer (only a *different* answer).

Because there are many different ways to evaluate a data set as large and robust as the one collected during this demonstration, it is difficult to derive sweeping conclusions about the relative performance of one device compared to all the others. If all methods were measuring the same thing, comparison of the performance of one method to another would be more straightforward. However, in this demonstration, the purge and no-purge sampling methods actually might have measured different things (as described above). Accordingly, the performance of one sampling method relative to another is more difficult to quantify. Nonetheless, the sampling results were compared as described in Section 4.

Sampling method- and analyte-specific conclusions and observations are summarized in the following subsections. These conclusions and observations were derived entirely from the 'holistic conclusions' presented in Tables 4.2 through 4.6. The holistic conclusions are necessarily 'broad-brush' and generalized and were assigned varying degrees of confidence depending on whether all of the quantitative comparisons performed resulted in the same observation. For example, the holistic conclusion that low-flow anion concentrations are less than Snap Sampler™ anion concentrations does not mean that this is always the case. The results of all four comparative tests did not consistently indicate this conclusion; however, the weight of evidence indicated that this was true more often than not. The reader is encouraged to study the more detailed information presented in Section 4 (Tables 4.2 through 4.6) prior to making final decisions on use of the various samplers tested at McClellan. The summary data presented in Table 4.1 may be misleading when compared with the results for the individual analytes or analyte groups presented in Tables 4.2 through 4.6, and should not be used to evaluate a particular sampling method's utility for a specific analyte or analyte group.

It should be noted that sampling results were quantitatively compared using groupings of analytes rather than specific analytes (e.g., all metals rather than individual metals such as aluminum and zinc, and all VOCs rather than specific VOCs such as TCE). Pooling data for a multitude of analytes provides a general basis for comparison, but the comparison results may not be representative of how each of the individual analytes compared. For example, a more extensive study is being performed by URS that is comparing individual and pooled metals results obtained from more than 250 McClellan wells using both low-flow and three-volume purge methods, and the results of this comparison obtained to date do not agree with the results presented in this report (source: written communication from J. Rogalla [URS]). Therefore, the comparison results presented in this report may not definitively determine comparability among the different sampling methods.

6.1 SUMMARY OF RESULTS BY SAMPLING METHOD

6.1.1 LOW-FLOW PURGE

Generally, results of the low-flow purge are equal to or lower in concentration than corresponding results from most of the other sampling methods. The only notable exception to this observation is with metals (not including hexavalent chromium), where the low-flow purge method typically produced higher concentrations than all of the other sampling methods (Table 4.5). Low-flow results for hexavalent chromium tended to be lower than results obtained using other methods (Table 4.4). Although it is not entirely evident why these trends occurred, the following explanations are proposed.

The three-volume purge samples were collected from a bailer after the purge was complete, while the low-flow samples were collected directly from the pump discharge. As shown in Table 3.3, the final water temperature in the low-flow purge sample was usually higher than for the three-volume purge samples. The temperature differences ranged from 0.01 to 3.8 degrees Celsius (ºC) with a mean value of 1.7 ºC . This may have resulted from the heat generated by the pump motor and impeller, and could at least partially explain why the VOC concentrations in the low-flow purge samples are frequently lower than the concentrations of the same analytes derived using other sampling methods (i.e., a higher water temperature could result in a higher volatilization rate and correspondingly lower concentrations of VOCs in the sample).

In this particular case study, the final turbidity in the low-flow purge water was generally higher than it was in the three-volume purge water (Table 3.3). This indicates that more particulates were present in the low-flow water than in the three-volume water, and could explain why metals concentrations were usually higher in the low-flow purge samples. While the reasons for this are unclear, it may be due at least in part to the fact that the low-flow purge was performed prior to the three-volume purge and shortly after the sampling pump had been introduced into the well (disturbing the water column and potentially increasing turbidity levels in the well). However, in almost every instance conventional and grab samples collected for metals analysis were field filtered with a new 0.45-micron filter to remove particulates. One hypothesis is that elevated quantities of colloidal metals were present in the low-flow samples that passed through the filters. The use of dedicated pumps, rather than newly decontaminated submersible equipment, may result in lower turbidity results during purging, possibly eliminating the need for filtration to remove particulates.

From a cost perspective, the low-flow purge method was the second most expensive method demonstrated (Section 5).

6.1.2 THREE-VOLUME PURGE

From a "performance" perspective, concentrations in samples collected using the three-volume purge technique were generally equal to or greater than corresponding concentrations in other sampling devices. Four exceptions to this trend were noted, including VOC concentrations in the Snap Sampler™, metals concentrations in the low-flow samples, and hexavalent chromium concentrations in the Hydrasleeve® and RPPS samples. In each of these instances, the three-volume purge concentrations tended to be lower. Overall, of the two conventional sampling methods demonstrated, the three-volume purge method produced results that were the most similar to the results for the diffusion and grab sampling devices.

Based on the cost analysis (Section 5), the three-volume purge method was the most expensive method demonstrated. It should be noted that if the cost analysis had assumed use of dedicated pumps for the three-volume purge (similar to what was assumed for the low-flow purge method), the estimated costs of the three-volume and low-flow purge methods would have been more similar.

6.1.3 HYDRASLEEVE®

For VOC concentrations, the HydraSleeve® was most comparable to the three-volume purge and the PDBS. Samples obtained using this device usually had higher concentrations of VOCs relative to the low-flow purge, PsMS, and RPPS methods. For metals, it was comparable to the three-volume purge, PsMS, and RPPS. HydraSleeve® samples typically contained higher concentrations of metals than the RCS and lower concentrations of metals than the low-flow purge samples. For anions, the HydraSleeve® was comparable to all other sampling methods against which it was compared. For hexavalent chromium, the HydraSleeve® was most comparable to the PsMS and RPPS, and was greater than both of the conventional methods and the RCS. For 1,4 dioxane, the HydraSleeve® was most comparable to both conventional methods, and was greater than both the PsMS and the RPPS. The conclusions involving hexavalent chromium and 1,4 dioxane are tentative due to the limited number of comparisons and resulting low statistical power of the tests performed. The HydraSleeve® and Snap Sampler™ were not tested in the same wells; therefore, analytical results for these two samplers were not compared with each other.

The HydraSleeve® was the least expensive method demonstrated according to the cost analysis (Section 5).

6.1.4 SNAP SAMPLER™

For the majority of comparisons, the concentrations in the Snap Sampler™ samples were higher than corresponding concentrations in samples from all other sampling methods. This was true for all comparisons involving VOCs, and for all comparisons of anions and 1,4 dioxane except for the three-volume purge samples, which were roughly comparable to the Snap Sampler™ concentrations for those constituents. It should be noted that the 1,4 dioxane comparisons included few data points. The Snap Sampler™ was not used to sample for metals or hexavalent chromium. The observed 'high bias' in the Snap Sampler™ concentrations suggests that they may be more representative of the actual concentrations in the well at the time of sample collection, particularly for VOCs as described below.

The fact that water for VOC analysis does not have to be transferred from the Snap Sampler™ into separate sample containers appears to be the most reasonable explanation for the relatively higher VOC concentrations obtained using this method. The lack of sample transfer eliminates the potential for VOC loss as a result of sample transfer. The developer of this sampler reports that results of other tests also exhibit the same higher-concentration trends for VOCs as seen in this study (Britt *et al*., 2005). For anions and 1,4 dioxane, it is not clear why the Snap Sampler™ concentrations were typically higher than those in samples collected using other methods.

It should be noted that the relatively high VOC concentrations in the Snap Sampler™ may also be due, at least in part, to differences in how these samples were treated at the laboratory. As stated in Section 3.3, most of the VOC samples submitted to the analytical laboratory in 20-ml vials (i.e., samples collected using the PDBS, RPPS, RCS, PsMS, and HydraSleeve®) were composited at the laboratory into one 40-ml vial for analysis. Therefore, most of the VOC samples collected using no-purge techniques, except for the Snap™ samples, underwent two episodes of sample transfer (one in the field and one at the laboratory). These transfers may have resulted in some VOC loss and increased the "noise" or variability in these no-purge VOC data sets. The VOC data indicate that minimizing VOC sample transfer can result in more accurate detection of VOC concentrations present in the well water. The data also indicate that caution is advised when scoping the use of 20-ml VOA vials for VOC sample collection. The ability of the laboratory to analyze VOC samples contained in 20-ml vials without sample transfer should be confirmed, and use of 40-ml vials wherever possible is recommended.

The Snap Sampler™ was more expensive than the other no-purge sampling methods based on the cost analysis described in Section 5, but as described above, it produced the most conservative sample results from a protectiveness standpoint. The cost per sample could be reduced by approximately $16 if two sample vials per sample are used instead of three, as was used at McClellan AFB and assumed in the cost analysis. It should be noted that the volume of water that can be collected using this device is relatively small compared to most of the other methods (Table 3.5). The vendor has developed a 125-ml sample bottle to accommodate somewhat larger sample volume needs.

6.1.5 PDBS

The PDBS was only used to monitor VOCs. This diffusion sampler tended to return higher concentrations of VOCs than the low-flow method, the RCS, and the RPPS. It was most comparable to the three-volume purge, PsMS, and HydraSleeve® methods, and typically returned lower VOC concentrations than the Snap Sampler™.

The PDBS was the second least expensive of the non-conventional samplers and was the least expensive diffusion sampler evaluated, according to the cost analysis described in Section 5. It has been shown in several other studies (e.g., Parsons, 2003b and 2004b) to be a reliable and inexpensive method of monitoring for most commonly-occurring VOCs in groundwater.

6.1.6 RPPS

For VOCs and 1,4 dioxane, the results obtained using the RPPS were generally comparable (i.e., similar concentrations) to those obtained using the low-flow purge, PsMS, and the RCS methods. Conversely, the RPPS results for these analytes were usually less than (i.e., lower concentrations) obtained with the three-volume purge, HydraSleeve®, PDBS, and Snap Sampler™ methods. For anions, the RPPS was generally comparable with all other methods except the Snap Sampler™, which typically yielded higher concentrations. The RPPS results for hexavalent chromium tended to be higher than the low-flow purge, three-volume purge, and RCS results, but were similar to the HydraSleeve® and PsMS results for that analyte. For metals, the RPPS results were most comparable to the three-volume purge, HydraSleeve®, and PsMS; usually less than results obtained with the low-flow purge; and greater than results obtained with the RCS.

In summary, the RPPS seems to have performed well at monitoring for anions, metals, and hexavalent chromium, but not as well at monitoring for VOCs and 1,4 dioxane. It is perhaps noteworthy that the RPPS appears to have performed best for inorganic, non-volatile parameters, and less well for organic parameters (i.e., VOCs and 1,4 dioxane). Considering the relatively large pore size of the membrane used for this sampler relative to some of the other devices (Section 2.1.2), there may be a higher potential for volatilization when using this sampling device.

The RPPS was the most expensive diffusion-based sampler according to the cost analysis (Section 5).

6.1.7 RCS

Based on the statistical analysis results presented in Section 4, the RCS had lower concentrations of metals (not including hexavalent chromium) than all other methods. In contrast, this sampler returned hexavalent chromium concentrations that were similar to or higher than obtained using conventional methods. With the exception of the Snap Sampler™, it was generally comparable to all other methods for anions. The RCS also usually had lower concentrations of VOCs than the other methods except for the RPPS and low-flow purge methods, which produced results that were more similar to the RCS results. Based on limited data, the RCS performed acceptably for 1,4 dioxane. In general, the demonstration results indicate that this sampling device was in a lower bracket in terms of its performance at McClellan AFB. It usually produced concentrations that are comparable to or lower than the other devices. It was relatively inexpensive according to the cost analysis, being the third least expensive device evaluated (Section 5). In addition, the cellulose membrane of the RCS was occasionally observed to become brittle or was more easily torn upon retrieval of the sampler (see also Section 2.1.4).

6.1.8 PsMS

The PsMS results for anions are comparable to anions results obtained using all other methods. Although the data set for 1,4 dioxane is small, the comparative analyses performed indicated that the PsMS is generally comparable to both the conventional methods and the RPPS, and usually produced lower concentrations than the HydraSleeve® and the Snap Sampler™. For hexavalent chromium and metals, the PsMS was comparable to all methods except low-flow purge, which generally returned lower-magnitude concentrations than the PsMS. For VOCs, the PsMS was comparable to the other diffusion samplers against which it was compared (PDBS and RPPS) and the low-flow purge, but returned lower-magnitude concentrations than the HydraSleeve® and the three-volume purge. The PsMS was not installed in the same wells as the RCS and Snap Sampler™ except for well MW-453, which was sampled using both the PsMS and Snap Sampler™. Therefore, the PsMS was not compared to these other devices.

This method was relatively expensive compared to the most of the other diffusion-based devices, but it still was significantly less expensive than the conventional methods.

6.2 SUMMARY OF RESULTS BY ANALYTE

6.2.1 1,4-DIOXANE

As indicated in Table 4.2, a low degree of confidence is assigned to the statistical results for this analyte due to the relatively small number of comparisons that could be made (ranging from 3 to 9). Therefore, the following conclusions and observations regarding 1,4 dioxane are tentative.

- In the limited number of cases where two diffusion samplers were compared against each other (i.e., RCS vs.RPPS, PsMS vs. RPPS), the results were found to be generally equivalent.
- 1,4 dioxane concentrations obtained using discrete-interval grab samplers (i.e., Snap Sampler™ and HydraSleeve®) were typically equivalent to or higher than other methods tested for this analyte. The Snap Sampler™ in particular tended to yield concentrations that were relatively high.
- Conventional sampling results were mixed, with low-flow purge results typically equivalent to or lower than other sampling methods and three-volume purge results equivalent to or higher than other sampling methods.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then the HydraSleeve®, Snap Sampler™, PsMS, and RCS appear to produce results that are similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Although similar to low-flow results, the RPPS results tended to be biased low relative to three-volume results; therefore, this sampler can not be wholeheartedly endorsed for use with 1,4 dioxane on the basis of the McClellan results.

6.2.2 ANIONS

The holistic conclusions for anions summarized in Table 4.3 indicate a relatively high degree of parity among the samplers in terms of anion results. Fourteen of the 17 sampler-pair comparisons performed for anions (82 percent) generally yielded comparable results (indicated by an ‘equal’ sign in the ‘Holistic Conclusion’ column). In contrast, only 56 percent of 1,4 dioxane sampler-pair comparisons (Table 4.2), 36 percent of hexavalent chromium comparisons (Table 4.4), 43 percent of metals comparisons (Table 4.5), and 38 percent of VOC comparisons (Table 4.6) yielded equivalent results. The three sampler-pair comparisons for anions that did not yield equivalent results involved the Snap Sampler™, which tended to yield anion concentrations that were relatively elevated.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then all of the diffusion and grab samplers tested for anions (i.e., HydraSleeve®, Snap Sampler™, PsMS, RCS, and RPPS) appear to produce results that are either similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations.

6.2.3 HEXAVALENT CHROMIUM

Similar to 1,4 dioxane, many of the holistic conclusions for hexavalent chromium listed in Table 4.4 are assigned a relatively low degree of confidence because they are based on a small number of comparisons. Therefore, the following conclusions and observations regarding hexavalent chromium are tentative.

- The two conventional methods did not produce equivalent results; concentrations obtained using the three-volume purge method tended to be higher than concentrations obtained using the low-flow purge method.
- The only grab sampler tested for hexavalent chromium (HydraSleeve®) tended to yield concentrations that were higher than those obtained using conventional methods and equivalent to or higher than those obtained using diffusion samplers.
- Diffusion samplers tended to yield concentrations that were higher than those obtained using the low-flow method and equivalent to or higher than those obtained using the three-volume purge method.
- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for hexavalent chromium. While PsMS and RPPS results were generally equivalent, the RCS results tended to be lower than RPPS results.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then all of the tested grab and diffusion samplers (i.e., the HydraSleeve®, PsMS, RPPS, and RCS) appear to produce results that are similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Of the three diffusion samplers tested, the RCS would rank the lowest in terms of monitoring for hexavalent chromium based on the McClellan data.

6.2.4 METALS

The holistic conclusions for TAL metals summarized in Table 4.5 indicate the following general conclusions and observations:

- Despite being field-filtered, metals concentrations in low-flow samples were generally higher than concentrations obtained using other conventional, diffusion, and grab samplers tested for this analyte group. A potential reason for this trend is discussed in Section 6.1.1.
- Metals concentrations obtained using the only discrete-interval grab sampler tested for this analyte group (the HydraSleeve®) tended to be equivalent to or higher than other sampling methods except for low-flow purge.
- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for TAL metals. While PsMS and RPPS results were generally equivalent to each other, the RCS results tended to be lower than RPPS results. The PsMS and RPPS results were also generally equivalent to both the three-volume purge and HydraSleeve® results, while the RCS results tended to be lower than the results obtained from these conventional and grab sampling methods.

In summary, the McClellan data suggest that the low-flow results for TAL metals are anonymously high relative to results obtained using all of the other tested methods, and therefore they may not be a good indicator of ‘baseline’ results for comparison purposes. If the three-volume purge results are used as a baseline for comparison purposes, then the HydraSleeve®, PsMS, and RPPS appear to produce results that are similar to or higher than the baseline conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Of the three diffusion samplers tested, the RCS would rank the lowest in terms of monitoring for TAL metals based on the McClellan data. Comparison of metals results for filtered vs. unfiltered samples does not indicate a trend of low bias in the filtered samples relative to the unfiltered samples.

6.2.5 VOCs

The holistic conclusions for VOCs summarized in Table 4.6 indicate the following general conclusions and observations:

- VOC concentrations in the low-flow purge samples were typically lower than the concentrations of the same analytes derived using the three-volume purge method, HydraSleeve®, Snap Sampler™ and PDBS. As discussed in Section 6.1.1, this may be due at least in part to heat generated by the pump motor and impeller.
- VOC concentrations obtained using discrete-interval grab samplers (i.e., HydraSleeve® and Snap Sampler™) were generally similar to or higher than concentrations obtained using other methods. In particular, the concentrations in the Snap Sampler™ samples were higher than corresponding concentrations in samples from all other sampling methods. Likely reasons for this occurrence are discussed in Section 6.1.4.
- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for VOCs. PDBS concentrations were generally similar to or higher than concentrations obtained from other diffusion samplers, the three-volume and low-flow purge methods, and the HydraSleeve®. In contrast, the PsMS and RPPS produced concentrations that tended to be lower than the three-volume and HydraSleeve® methods, and the RCS produced concentrations that tended to be lower than the three-volume purge method but was not compared to the HydraSleeve®.

In summary, if the conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then the Snap Sampler™, HydraSleeve®, and PDBS appear to produce results that are similar to or higher than the baseline conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Although similar to low-flow results, the RPPS results tended to be biased low relative to three-volume, HydraSleeve®, Snap Sampler™, and PDBS results. Similarly, the PsMS results tended to be biased low relative to the 3-volume and HydraSleeve® results, and the RCS tended to be biased low relative to the 3-volume, PDBS, and Snap Sampler™ results; therefore, these three diffusion samplers can not be confidently endorsed for use with VOCs on the basis of the McClellan results.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

The overall objective of this demonstration was to evaluate and demonstrate the use of selected diffusion and grab sampling devices that potentially represent useful and cost-effective alternatives to conventional groundwater sampling approaches (e.g., 3-volume purge/sample and low-flow purge/sample) for analytes other than VOCs. Specifically, devices that potentially can be used to sample for metals, anions, and 1,4 dioxane were evaluated. Expansion of the suite of accepted no-purge sampling methods could be useful in augmenting or possibly substituting for the PDBS method in certain applications.

From a performance perspective, the HydraSleeve® and Snap Sampler™ methods typically produced results that are most similar to the more conservative (i.e., higher-concentration) results obtained from the two conventional sampling methods. Both of these methods are characterized as grab-type samplers, and although they do allow for well equilibration, they do not use diffusion as the operative mechanism, therefore the results obtained are more of a "snapshot" in time. It should be noted that all of the diffusion and grab samplers collect samples over a 'short' time frame with respect to the groundwater velocity at many sites. Of these two sampling methods, the HydraSleeve® was substantially less expensive based on the assumptions used in the cost analysis, although both methods were less expensive than the conventional approaches. The HydraSleeve® was simpler to deploy and retrieve, and permits a larger volume of water to be collected. Comparisons involving the Snap Sampler™ on the other hand indicate that the VOC data set for this sampler may be more consistently representative of the actual VOC concentrations in the well at the time of sample collection. A fully non-metallic version of the Snap Sampler™ is available in the event that the metal construction of the Snap Sampler™ tested in this study is of concern.

For the diffusion-based methods, the PDBS provided the most conservative results (i.e., highest concentrations) for VOCs, but this device is only appropriate for monitoring most VOCs. The other diffusion-based devices evaluated occasionally produced results that were, on average, lower in concentration than the conventional and/or grab sampler results. Although much less expensive than the conventional sampling methods, these devices were generally more expensive to use than the HydraSleeve® based on the assumptions used in the cost analysis (the PDBS and HydraSleeve® costs were very similar, see Table 5.2).

Finally, although the conventional methods evaluated are well accepted throughout the industry (Newell *et al.*, 2000), they did not always provide the most conservative (i.e., highest-magnitude) results. These methods also were more expensive than the diffusion and grab samplers used in the demonstration.

The American Petroleum Institute (Newell *et al.*, 2000) concluded that three-volume purge/sample data are broadly accepted by regulatory agencies, suggesting a consensus that these data are *adequately representative* of formation conditions to ensure protection of human health and the environment. One of the primary objectives of this demonstration is to identify cost-effective alternatives to conventional groundwater sampling approaches for analytes other than VOCs. Accordingly, one critical question is whether the diffusion and grab devices are also *adequately representative* and therefore protective (or more conservative), but not systematically biased low relative to conventional methods. A particular grab or diffusion sampling device was considered to be viable when the analyte concentrations obtained using that device were similar to or higher than those obtained using conventional sampling methods. Conversely, if the results obtained using the grab or diffusion device exhibited low bias relative to the conventional results, then the ability of that device to accurately detect concentrations of that particular analyte group was considered to be suspect. In summary, high bias was considered to be acceptable, but low bias was not. Of the four diffusion and two grab sampling devices evaluated, the following conclusions were derived based on the results of this demonstration. In addition, Table 7.1 contains a summary of key conclusions and observations derived from this technology demonstration.

- The HydraSleeve® appears to be a technically viable method for monitoring all of the compounds included in this demonstration. Concentrations of metals obtained using this device tended to be lower than low-flow-purge concentrations, but the low-flow concentrations appear to be anomalously high.

- The Snap Sampler™ appears to be a technically viable method for monitoring all of the compounds it was tested for in this demonstration (i.e., anions, 1,4 dioxane, and VOCs). This method was not tested for metals and hexavalent chromium.

- The PDBS is a technically viable method for monitoring VOCs only. PDB samples may be advantageous when sampling for VOCs in waters where matrix interferences, such as highly turbid or alkaline conditions, may compromise results.

- The RPPS appears to be a technically viable method for monitoring hexavalent chromium, metals, and anions. Although concentrations of VOCs and 1,4 dioxane obtained using this method are statistically similar to low-flow concentrations of these analytes, they tended to be biased low relative to concentrations obtained using the three-volume-purge method. Further development of this technology may be warranted.

- The RCS appears to be a technically viable method for monitoring anions and possibly 1,4 dioxane and hexavalent chromium. Although other studies have shown that the RCS is appropriate for monitoring VOCs (Ehlke *et al.*, 2004; Imbrigiotta *et al.*, 2002; Vroblesky *et al.*, 2002), that observation was not validated during this demonstration.

- The PsMS appears to be a technically viable method for monitoring hexavalent chromium, metals, and anions, and may be technically viable for monitoring VOCs (although VOC results using this method were typically less than those obtained using the three-volume purge and HydraSleeve® methods and were not compared with the Snap Sampler™ or RCS results because, with one exception, they were not installed in the same wells). Although all comparative tests indicate that 1,4 dioxane concentrations in the PsMS are similar to concentrations of this analyte obtained using conventional sampling methods, a more definitive endorsement regarding the use of the PsMS method for dioxane sampling was not reached due to the relatively low number of comparisons. Metal concentrations obtained using the PsMS method tended to be lower than low-flow concentrations, but the low-flow concentrations tended to be anomalously high. Further development of this technology may be warranted.

TABLE 7.1
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler	**1,4 Dioxane**[a/]	**Anions**	**Hexavalent Chromium**[b/]	**Metals**	**VOCs**	**Advantages**	**Disadvantages**	**Remarks**
PDBS	N[c/]	N	N	N	Y[d/]	--Widely tested for VOCs --Relatively inexpensive --Commercially available --Technical Guidance available --Alkalinity is excluded --No well diameter limitation	--Suitable for VOCs only --Potential for VOC loss during sample transfer --Not suitable for all VOCs	Abundant information available on ITRC website (www.itrc-web.org)
RPPS	?[e/]	Y	Y	Y	?	Good results for inorganics	--Most expensive diffusion sampler --May need to de-gas pores prior to use --Size and volume limited by large pore size --Not commercially available --Mixed results for organic compounds at McClellan --Potential for VOC loss during sample transfer	Large pore size may increase potential for VOC loss via volatilization
PsMS	Y	Y	Y	Y	?	Good results for inorganics	--Small volume for some applications --Not commercially available --Mixed results for VOCs at McClellan --Potential for VOC loss during sample transfer	
RCS	Y	Y	Y	N	?	--Relatively inexpensive --Commercially available --Inorganic and organic analytes	--Cellulose membrane may be easily damaged --Relatively poor performance overall at McClellan --Potential for VOC loss during sample transfer	Other studies have had better results for VOCs (e.g., Ehlke *et al.*, 2004; Imbrigiotta *et al.*, 2002; Vroblesky *et al.*, 2002)
Hydra-Sleeve®	Y	Y	Y	Y	Y	--Relatively large sample volumes possible --Works for wide variety of analytes --Relatively inexpensive --Commercially available in multiple sizes	Potential for VOC loss during sample transfer	Detailed information available on Vendor's website (www.hydrasleeve.com)
Snap Sampler™	Y	Y	NT[f/]	NT	Y	--No sample transfer required, potentially reducing data 'noise' and VOC loss --Commercially available, including variety of sizes and materials	--Most expensive no-purge sampler tested --More involved field procedure --Small volume for some applications	Detailed information available on vendor's website (www.snapsampler.com)

a/ Comparisons involving 1,4 dioxane are based on a relatively small data set and therefore there is a lower confidence in the associated conclusions.

b/ Some of the comparisons involving hexavalent chromium are based on a relatively small data set and therefore there is a lower confidence in the associated conclusions.

c/ N = Sampler does not appear to be a technically viable method for monitoring that particular analyte or analyte group based on McClellan results.

d/ Y = Sampler appears to be a technically viable method for monitoring that particular analyte or analyte group based on McClellan results.

e/ ? = Mixed results were obtained, and further evaluation is required to reach a more definitive conclusion. See text in Sections 6 and 7 for more details.

f/ NT = Sampler not tested for that analyte or analyte group.

SECTION 8

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APPENDIX A

DATA QUALITY ASSESSMENT REPORT

Electronic file provided separately

APPENDIX B

WELL-SPECIFIC PLOTS DEPICTING VERTICAL STRATIFICATION OF VARIOUS TARGET COMPOUNDS

Electronic file provided separately

APPENDIX C

NORMALITY TESTING RESULTS

Electronic file provided separately

APPENDIX D

X-Y SCATTER PLOTS

Electronic file provided separately

APPENDIX E

ELECTRONIC DATA DELIVERABLE
AND
ELECTRONIC VERSION OF THE WORK PLAN
(PARSONS, 2004A)

Electronic file provided separately

APPENDIX F

FIELD NOTES

Electronic file provided separately

APPENDIX G

REVIEW COMMENTS AND RESPONSES

Electronic file provided separately

APPENDIX C

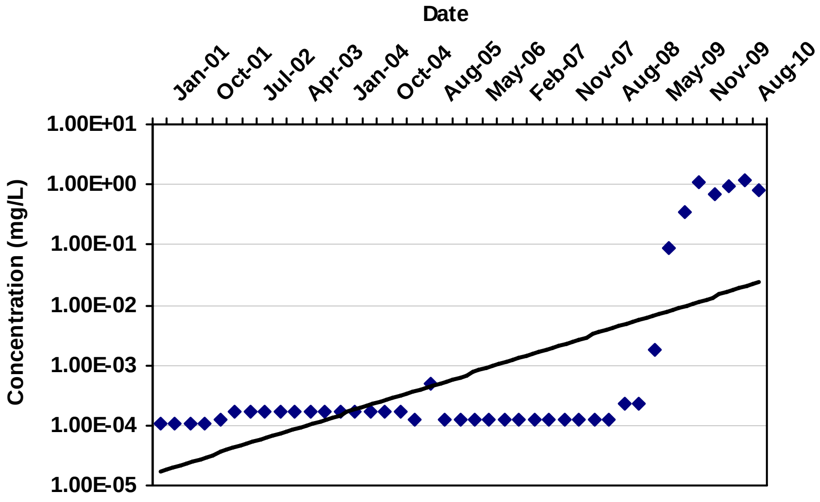
MAROS RESULTS

Linear Regression Trend Analysis

MAROS Linear Regression Statistics

Well: WT008
Well Type: S
COC: TETRACHLOROETHYLENE(PCE)

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



COV:

2.55

Confidence in Trend:

100.0%

Ln Slope:

2.0E-03

LR Concentration Trend:

I

Consolidation Data Table:

Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	4/26/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	7/24/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	10/24/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	1/21/2002	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	4/24/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	7/22/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	11/14/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/29/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	4/22/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	8/19/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	11/3/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	4/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	7/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	10/18/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/28/2005	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	5/2/2005	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/1/2005	TETRACHLOROETHYLENE(PCE	4.9E-04		1	1
WT008	S	10/28/2005	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	1/12/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0

MAROS Linear Regression Statistics

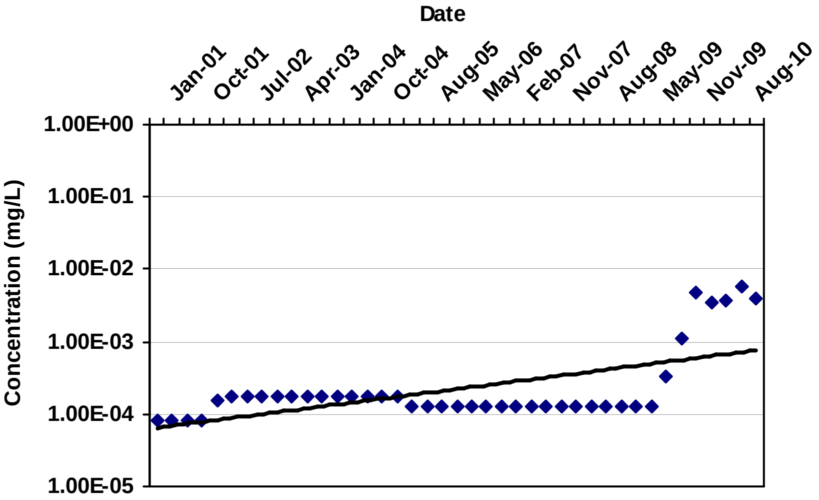
Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	5/12/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/10/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/16/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	2/9/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	5/3/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/15/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/28/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	2/27/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	5/2/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/8/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/11/2008	TETRACHLOROETHYLENE(PCE	2.3E-04	ND	1	0
WT008	S	2/10/2009	TETRACHLOROETHYLENE(PCE	2.3E-04	ND	1	0
WT008	S	5/8/2009	TETRACHLOROETHYLENE(PCE	1.8E-03		1	1
WT008	S	8/3/2009	TETRACHLOROETHYLENE(PCE	8.6E-02		1	1
WT008	S	9/22/2009	TETRACHLOROETHYLENE(PCE	3.4E-01		1	1
WT008	S	11/5/2009	TETRACHLOROETHYLENE(PCE	1.1E+00		1	1
WT008	S	2/12/2010	TETRACHLOROETHYLENE(PCE	6.9E-01		1	1
WT008	S	5/24/2010	TETRACHLOROETHYLENE(PCE	9.2E-01		1	1
WT008	S	8/9/2010	TETRACHLOROETHYLENE(PCE	1.2E+00		1	1
WT008	S	11/12/2010	TETRACHLOROETHYLENE(PCE	8.2E-01		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = All Samples are Non-detect

MAROS Linear Regression Statistics

Well: WT008
Well Type: S
COC: TRICHLOROETHYLENE (TCE)

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



COV:

2.08

Confidence in Trend:

100.0%

Ln Slope:

6.6E-04

LR Concentration Trend:

I

Consolidation Data Table:

Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	4/26/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	7/24/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	10/24/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	1/21/2002	TRICHLOROETHYLENE (TCE)	1.6E-04	ND	1	0
WT008	S	4/24/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	7/22/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	11/14/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/29/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	4/22/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	8/19/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	11/3/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	4/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	7/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	10/18/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/28/2005	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	5/2/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/1/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	10/28/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	1/12/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0

MAROS Linear Regression Statistics

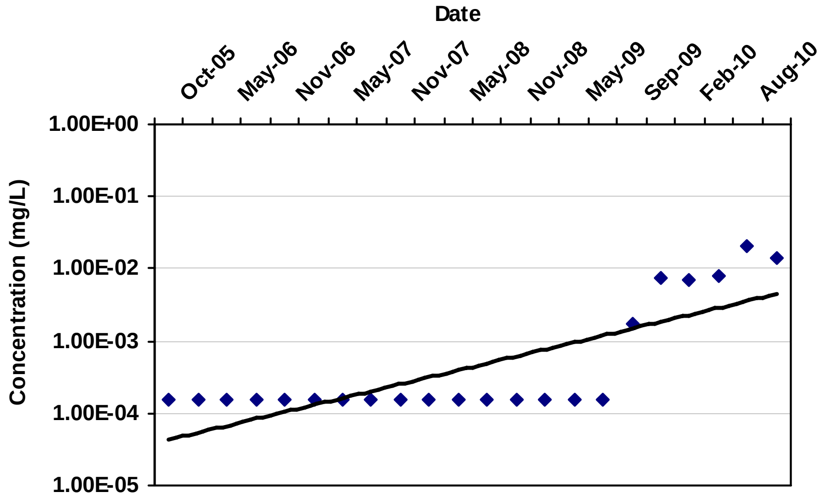
Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	5/12/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/10/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/16/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/9/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/3/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/15/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/28/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/27/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/2/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/8/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/11/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/10/2009	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/8/2009	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/3/2009	TRICHLOROETHYLENE (TCE)	3.3E-04		1	1
WT008	S	9/22/2009	TRICHLOROETHYLENE (TCE)	1.1E-03		1	1
WT008	S	11/5/2009	TRICHLOROETHYLENE (TCE)	4.9E-03		1	1
WT008	S	2/12/2010	TRICHLOROETHYLENE (TCE)	3.6E-03		1	1
WT008	S	5/24/2010	TRICHLOROETHYLENE (TCE)	3.7E-03		1	1
WT008	S	8/9/2010	TRICHLOROETHYLENE (TCE)	5.7E-03		1	1
WT008	S	11/12/2010	TRICHLOROETHYLENE (TCE)	3.9E-03		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = All Samples are Non-detect

MAROS Linear Regression Statistics

Well: WT008
Well Type: S
COC: cis-1,2-DICHLOROETHYLENE

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



COV:

1.96

Confidence in Trend:

100.0%

Ln Slope:

2.4E-03

LR Concentration Trend:

I

Consolidation Data Table:

Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	10/28/2005	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	1/12/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/12/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/10/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/16/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/9/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/3/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/15/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/28/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/27/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/2/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/8/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/11/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/10/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/8/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/3/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	9/22/2009	cis-1,2-DICHLOROETHYLENE	1.8E-03		1	1
WT008	S	11/5/2009	cis-1,2-DICHLOROETHYLENE	7.6E-03		1	1
WT008	S	2/12/2010	cis-1,2-DICHLOROETHYLENE	6.8E-03		1	1
WT008	S	5/24/2010	cis-1,2-DICHLOROETHYLENE	7.9E-03		1	1
WT008	S	8/9/2010	cis-1,2-DICHLOROETHYLENE	2.1E-02		1	1

MAROS Linear Regression Statistics

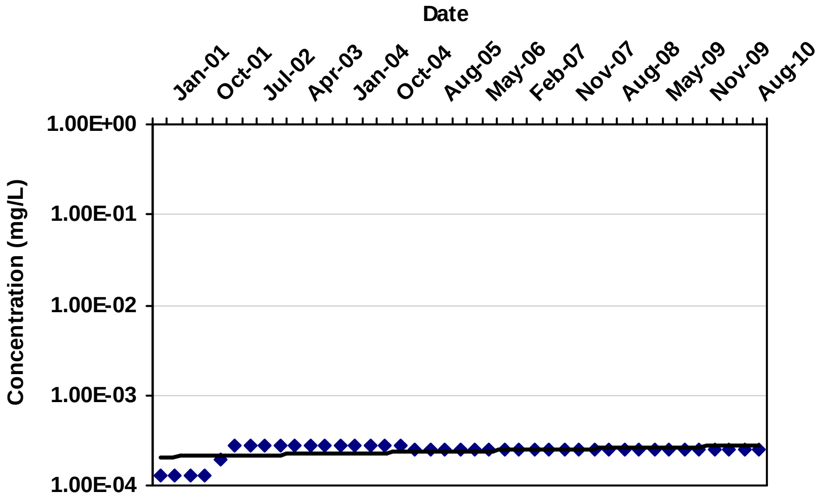
Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	11/12/2010	cis-1,2-DICHLOROETHYLENE	1.4E-02		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = All Samples are Non-detect

MAROS Linear Regression Statistics

Well: WT008
Well Type: S
COC: VINYL CHLORIDE

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



COV: 0.17

Confidence in Trend: 99.6%

Ln Slope: 8.1E-05

LR Concentration Trend: ND

Consolidation Data Table:

Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	4/26/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	7/24/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	10/24/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	1/21/2002	VINYL CHLORIDE	2.0E-04	ND	1	0
WT008	S	4/24/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	7/22/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	11/14/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/29/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	4/22/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	8/19/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	11/3/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	4/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	7/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	10/18/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/28/2005	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	5/2/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/1/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	10/28/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	1/12/2006	VINYL CHLORIDE	2.5E-04	ND	1	0

MAROS Linear Regression Statistics

Well	Well Type	Consolidation Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	5/12/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/10/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/16/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/9/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/3/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/15/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/28/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/27/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/2/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/8/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/11/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/10/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/8/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/3/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	9/22/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/5/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/12/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/24/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/9/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/12/2010	VINYL CHLORIDE	2.5E-04	ND	1	0

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = All Samples are Non-detect

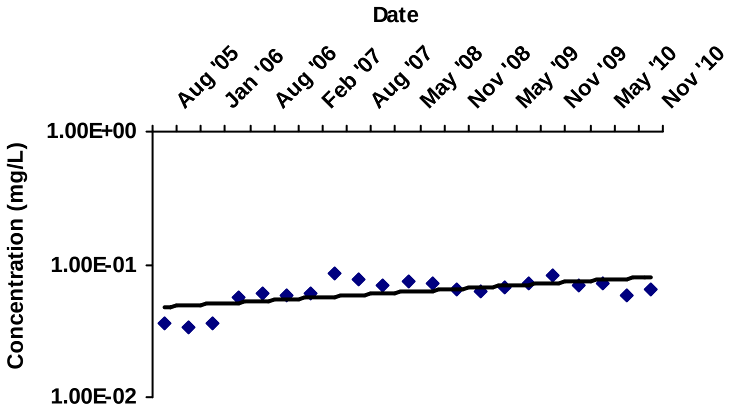
Linear Regression Plot

Well	OCS002	**Chemical**	TETRACHLOROETHYLENE(PCE)

Graph Type

● **Log**

○ **Linear**



Ln Slope:

2.65E-04

Confidence in Trend:

99.9%

COV:

0.22

Linear Regression Trend: I

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - due to insufficient data.

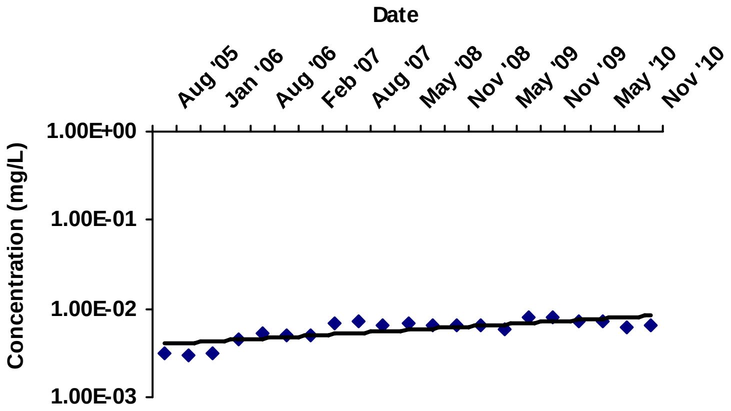
Linear Regression Plot

Well OCS002 **Chemical** TRICHLOROETHYLENE (TCE)

Graph Type

● **Log**

○ **Linear**



Ln Slope: 3.77E-04

Confidence in Trend: 100.0%

COV: 0.25

Linear Regression Trend: I

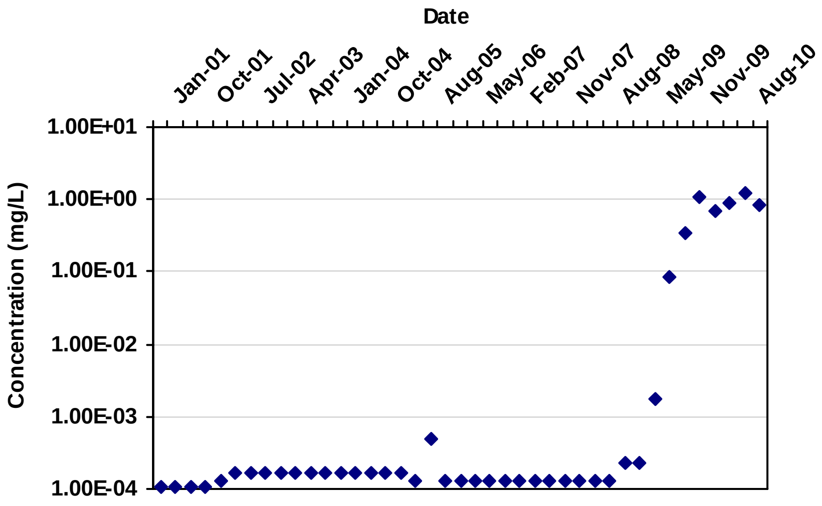
Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - due to insufficient data.

Mann-Kendall Trend Analysis

MAROS Mann-Kendall Statistics Summary

Well: WT008
Well Type: S
COC: TETRACHLOROETHYLENE(PCE)

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



Mann Kendall S Statistic:
306

Confidence in Trend:
100.0%

Coefficient of Variation:
2.55

Mann Kendall Concentration Trend: (See Note)
I

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	4/26/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	7/24/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	10/24/2001	TETRACHLOROETHYLENE(PCE	1.1E-04	ND	1	0
WT008	S	1/21/2002	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	4/24/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	7/22/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	11/14/2002	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/29/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	4/22/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	8/19/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	11/3/2003	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	4/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	7/21/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	10/18/2004	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	1/28/2005	TETRACHLOROETHYLENE(PCE	1.7E-04	ND	1	0
WT008	S	5/2/2005	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/1/2005	TETRACHLOROETHYLENE(PCE	4.9E-04		1	1
WT008	S	10/28/2005	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	1/12/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	5/12/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0

MAROS Mann-Kendall Statistics Summary

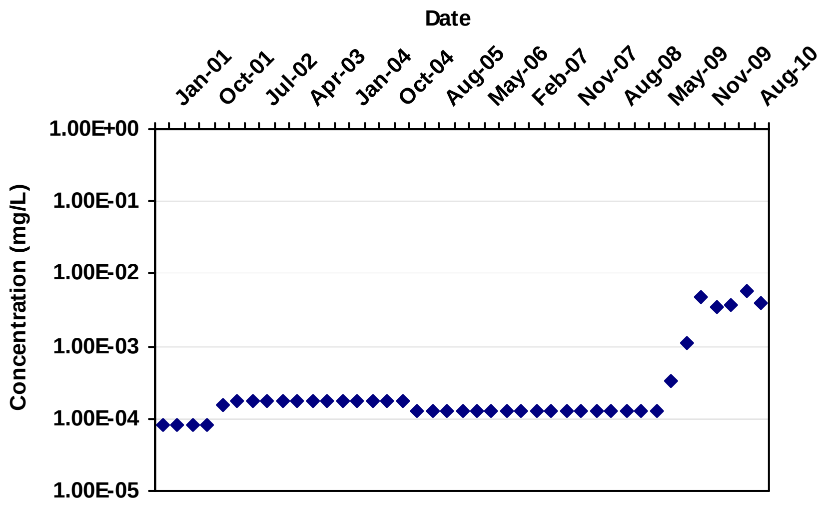
Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	8/10/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/16/2006	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	2/9/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	5/3/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/15/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/28/2007	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	2/27/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	5/2/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	8/8/2008	TETRACHLOROETHYLENE(PCE	1.3E-04	ND	1	0
WT008	S	11/11/2008	TETRACHLOROETHYLENE(PCE	2.3E-04	ND	1	0
WT008	S	2/10/2009	TETRACHLOROETHYLENE(PCE	2.3E-04	ND	1	0
WT008	S	5/8/2009	TETRACHLOROETHYLENE(PCE	1.8E-03		1	1
WT008	S	8/3/2009	TETRACHLOROETHYLENE(PCE	8.6E-02		1	1
WT008	S	9/22/2009	TETRACHLOROETHYLENE(PCE	3.4E-01		1	1
WT008	S	11/5/2009	TETRACHLOROETHYLENE(PCE	1.1E+00		1	1
WT008	S	2/12/2010	TETRACHLOROETHYLENE(PCE	6.9E-01		1	1
WT008	S	5/24/2010	TETRACHLOROETHYLENE(PCE	9.2E-01		1	1
WT008	S	8/9/2010	TETRACHLOROETHYLENE(PCE	1.2E+00		1	1
WT008	S	11/12/2010	TETRACHLOROETHYLENE(PCE	8.2E-01		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect

MAROS Mann-Kendall Statistics Summary

Well: WT008
Well Type: S
COC: TRICHLOROETHYLENE (TCE)

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



Mann Kendall S Statistic:

162

Confidence in Trend:

100.0%

Coefficient of Variation:

2.08

Mann Kendall Concentration Trend: (See Note)

I

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	4/26/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	7/24/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	10/24/2001	TRICHLOROETHYLENE (TCE)	8.0E-05	ND	1	0
WT008	S	1/21/2002	TRICHLOROETHYLENE (TCE)	1.6E-04	ND	1	0
WT008	S	4/24/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	7/22/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	11/14/2002	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/29/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	4/22/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	8/19/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	11/3/2003	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	4/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	7/21/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	10/18/2004	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	1/28/2005	TRICHLOROETHYLENE (TCE)	1.8E-04	ND	1	0
WT008	S	5/2/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/1/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	10/28/2005	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	1/12/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/12/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0

MAROS Mann-Kendall Statistics Summary

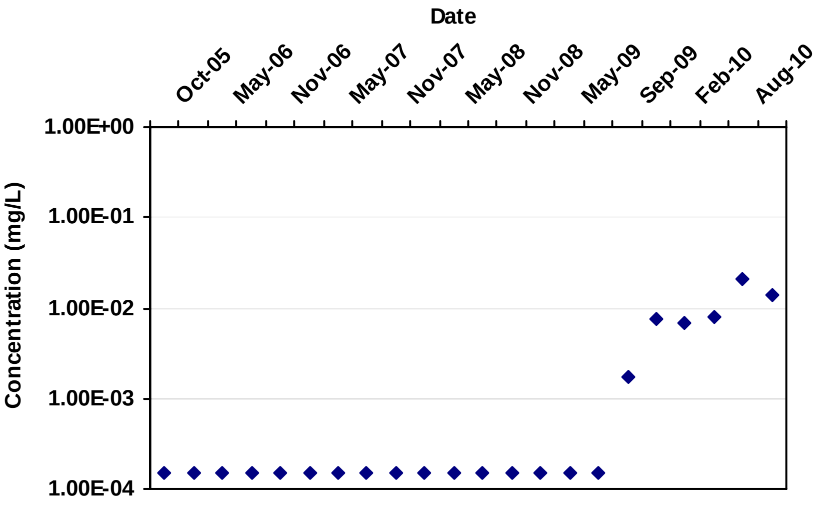
Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	8/10/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/16/2006	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/9/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/3/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/15/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/28/2007	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/27/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/2/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/8/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	11/11/2008	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	2/10/2009	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	5/8/2009	TRICHLOROETHYLENE (TCE)	1.3E-04	ND	1	0
WT008	S	8/3/2009	TRICHLOROETHYLENE (TCE)	3.3E-04		1	1
WT008	S	9/22/2009	TRICHLOROETHYLENE (TCE)	1.1E-03		1	1
WT008	S	11/5/2009	TRICHLOROETHYLENE (TCE)	4.9E-03		1	1
WT008	S	2/12/2010	TRICHLOROETHYLENE (TCE)	3.6E-03		1	1
WT008	S	5/24/2010	TRICHLOROETHYLENE (TCE)	3.7E-03		1	1
WT008	S	8/9/2010	TRICHLOROETHYLENE (TCE)	5.7E-03		1	1
WT008	S	11/12/2010	TRICHLOROETHYLENE (TCE)	3.9E-03		1	1

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect

MAROS Mann-Kendall Statistics Summary

Well: WT008
Well Type: S
COC: cis-1,2-DICHLOROETHYLENE

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



Mann Kendall S Statistic:
107

Confidence in Trend:
99.9%

Coefficient of Variation:
1.96

Mann Kendall Concentration Trend: (See Note)
I

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	10/28/2005	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	1/12/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/12/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/10/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/16/2006	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/9/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/3/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/15/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/28/2007	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/27/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/2/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/8/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	11/11/2008	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	2/10/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	5/8/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	8/3/2009	cis-1,2-DICHLOROETHYLENE	1.5E-04	ND	1	0
WT008	S	9/22/2009	cis-1,2-DICHLOROETHYLENE	1.8E-03		1	1
WT008	S	11/5/2009	cis-1,2-DICHLOROETHYLENE	7.6E-03		1	1
WT008	S	2/12/2010	cis-1,2-DICHLOROETHYLENE	6.8E-03		1	1
WT008	S	5/24/2010	cis-1,2-DICHLOROETHYLENE	7.9E-03		1	1
WT008	S	8/9/2010	cis-1,2-DICHLOROETHYLENE	2.1E-02		1	1
WT008	S	11/12/2010	cis-1,2-DICHLOROETHYLENE	1.4E-02		1	1

MAROS Mann-Kendall Statistics Summary

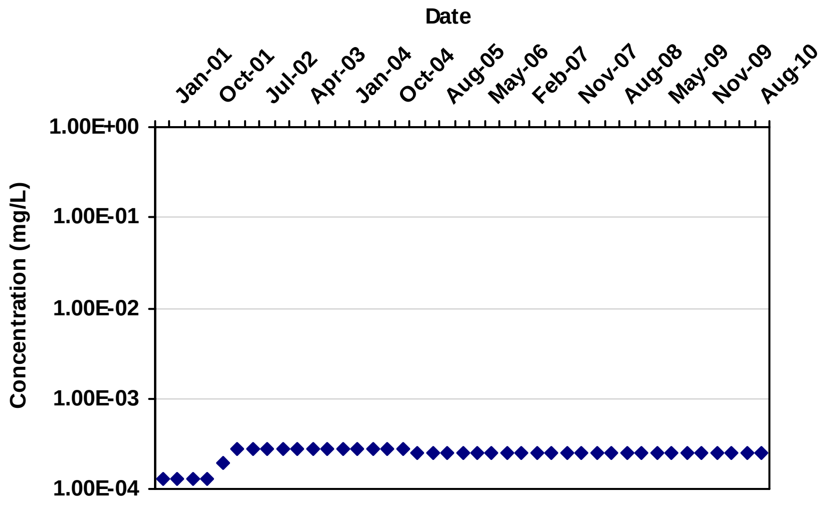
Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect

MAROS Mann-Kendall Statistics Summary

Well: WT008
Well Type: S
COC: VINYL CHLORIDE

Time Period: 1/22/2001 **to** 11/12/2010
Consolidation Period: No Time Consolidation
Consolidation Type: Median
Duplicate Consolidation: Average
ND Values: 1/2 Detection Limit
J Flag Values : Actual Value



Mann Kendall S Statistic:

-104

Confidence in Trend:

100.0%

Coefficient of Variation:

0.17

Mann Kendall Concentration Trend: (See Note)

ND

Data Table:

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	1/22/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	4/26/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	7/24/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	10/24/2001	VINYL CHLORIDE	1.3E-04	ND	1	0
WT008	S	1/21/2002	VINYL CHLORIDE	2.0E-04	ND	1	0
WT008	S	4/24/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	7/22/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	11/14/2002	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/29/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	4/22/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	8/19/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	11/3/2003	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	4/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	7/21/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	10/18/2004	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	1/28/2005	VINYL CHLORIDE	2.8E-04	ND	1	0
WT008	S	5/2/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/1/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	10/28/2005	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	1/12/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/12/2006	VINYL CHLORIDE	2.5E-04	ND	1	0

MAROS Mann-Kendall Statistics Summary

Well	Well Type	Effective Date	Constituent	Result (mg/L)	Flag	Number of Samples	Number of Detects
WT008	S	8/10/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/16/2006	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/9/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/3/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/15/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/28/2007	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/27/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/2/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/8/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/11/2008	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/10/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/8/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/3/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	9/22/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/5/2009	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	2/12/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	5/24/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	8/9/2010	VINYL CHLORIDE	2.5E-04	ND	1	0
WT008	S	11/12/2010	VINYL CHLORIDE	2.5E-04	ND	1	0

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); ND = Non-detect

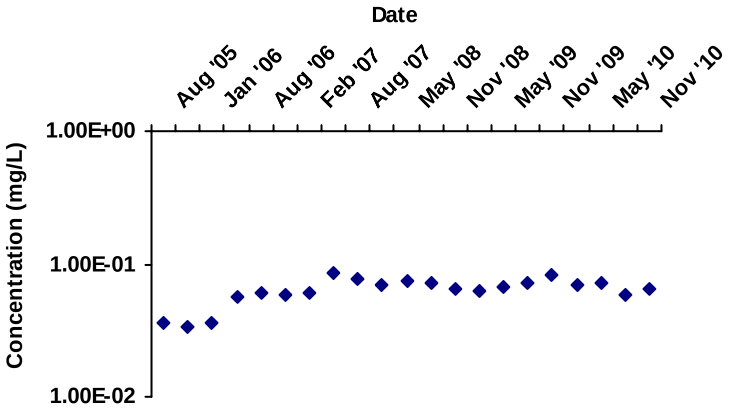
Mann Kendall Plot

Well OCS002 **Chemical** TETRACHLOROETHYLENE(PCE)

Graph Type

● **Log**

○ **Linear**



MK (S): 74

Confidence in Trend: 98.7%

COV: 0.22

MK Concentration Trend: I

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - due to insufficient data.

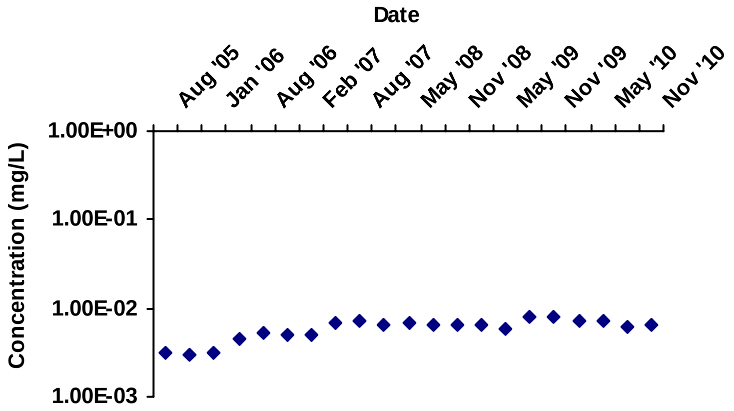
Mann Kendall Plot

Well OCS002 **Chemical** TRICHLOROETHYLENE (TCE)

Graph Type

● **Log**

○ **Linear**



MK (S): 113

Confidence in Trend: 100.0%

COV: 0.25

MK Concentration Trend: I

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A) - due to insufficient data.

MAROS Statistical Trend Analysis Summary

MAROS Statistical Trend Analysis Summary

Project: Pinewood - WT008 and OCS002

Location: Pinewood

User Name: Kourlas

State: South Carolina

Time Period: 1/22/2001 **to** 11/12/2010

Consolidation Period: No Time Consolidation

Consolidation Type: Median

Duplicate Consolidation: Maximum

ND Values: 1/2 Detection Limit

J Flag Values : Actual Value

Well	Source/ Tail	Number of Samples	Number of Detects	Average Conc. (mg/L)	Median Conc. (mg/L)	All Samples "ND" ?	Mann-Kendall Trend	Linear Regression Trend
cis-1,2-DICHLOROETHYLENE								
WT008	S	22	6	2.8E-03	1.5E-04	No	I	I
TETRACHLOROETHYLENE(PCE)								
OCS002	T	21	21	6.4E-02	6.6E-02	No	I	I
WT008	S	41	9	1.3E-01	1.7E-04	No	I	I
TRICHLOROETHYLENE (TCE)								
OCS002	T	21	21	6.0E-03	6.4E-03	No	I	I
WT008	S	41	7	6.8E-04	1.3E-04	No	I	I

Note: Increasing (I); Probably Increasing (PI); Stable (S); Probably Decreasing (PD); Decreasing (D); No Trend (NT); Not Applicable (N/A); Not Applicable (N/A) - Due to insufficient Data (< 4 sampling events); No Detectable Concentration (NDC)

The Number of Samples and Number of Detects shown above are post-consolidation values.

APPENDIX D

GROUNDWATER SAMPLING OPTIMIZATION

APPENDIX D
Groundwater Sampling Optimization
Pinewood Landfill
Pinewood, South Carolina

Identification	Water Bearing Zone	Quarterly							Annual							Baseline		
		Water Level	pH, Conductivity, Temperature and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metal COCs	Water Level	pH, Conductivity, and Turbidity	ORP and DO	Chloride	1,4-dioxane	VOC COCs	Metal COCs	Metals$^{(1)}$	Anions$^{(2)}$	Cations$^{(3)}$
WATER TABLE MONITORING PROGRAM																		
WT008	WT	x	x	x			x	x	x							x	x	x
WT010	WT	x	x	x					x							x	x	x
WT011	WT	x	x	x					x							x	x	x
WT012	WT	x	x	x					x							x	x	x
WT015	WT	x	x	x					x							x	x	x
WT016	WT	x	x	x					x							x	x	x
WT020	WT	x	x	x					x							x	x	x
WT022	WT	x	x	x					x							x	x	x
WT023	WT	x	x	x					x							x	x	x
WT024	WT	x	x	x					x							x	x	x
WT025	WT	x	x	x					x							x	x	x
WT026	WT	x	x	x					x					x		x	x	x
WT027	WT	x	x	x					x							x	x	x
WT030	WT	x	x	x					x					x		x	x	x
WT032	WT	x	x	x					x					x		x	x	x
MW-33	WT	x	x	x					x							x	x	x
MW-34	WT	x	x	x					x							x	x	x
MW-35	WT	x	x	x					x							x	x	x
MW-36	WT	x	x	x					x							x	x	x
MW-37	WT	x	x	x					x							x	x	x
MW-38	WT	x	x	x					x							x	x	x
MW-39	WT	x	x	x					x							x	x	x
MW-40	WT	x	x	x					x							x	x	x
New MW	WT	x	x	x	x	x	x	x	x							x	x	x
New MW	WT	x	x	x	x	x	x	x	x							x	x	x
New MW	WT	x	x	x	x	x	x	x	x							x	x	x
New MW	WT	x	x	x	x	x	x	x	x							x	x	x
OC002	OC	x	x	x					x							x	x	x
OC003	OC	x	x	x					x							x	x	x
OC004	OC	x	x	x					x							x	x	x
OC005	OC	x	x	x					x							x	x	x
OC006	OC	x	x	x					x							x	x	x
OC007	OC	x	x	x					x							x	x	x
OC008	OC	x	x	x					x							x	x	x
OC009	OC	x	x	x					x							x	x	x
OC010	OC	x	x	x					x							x	x	x
OC011	OC	x	x	x					x							x	x	x
OC012	OC	x	x	x					x							x	x	x
OC013	OC	x	x	x					x							x	x	x
OC014	OC	x	x	x					x							x	x	x
OC015	OC	x	x	x					x							x	x	x
OC016	OC	x	x	x					x							x	x	x
OCS001	OC	x	x	x					x							x	x	x
OCS002	OC	x	x	x			x	x	x							x	x	x
OCS003A	OC	x	x	x					x							x	x	x
OCS003B	OC	x	x	x					x							x	x	x
OCS004	OC	x	x	x					x							x	x	x
OCS006A	OC	x	x	x					x					x		x	x	x
OCS006B	OC	x	x	x					x					x		x	x	x
OCS008	OC	x	x	x					x							x	x	x
OCS005	OC	x	x	x					x							x	x	x
OCS011	OC	x	x	x					x							x	x	x
DETECTION MONITORING PROGRAM																		
MW005A	TLS	x			x	x			x	x	x	x	x			x	x	x
MW006TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW008TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW009A	TLS	x			x	x			x	x	x	x	x			x	x	x
MW016TR	TLS	x							x	x	x	x	x			x	x	x
MW019A	TLS	x			x	x			x	x	x	x	x			x	x	x
MW020A	TLS	x			x	x			x	x	x	x	x			x	x	x
MW022TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW023ATR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW024TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW026ATR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW027BTR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW028A	TLS	x			x	x			x	x	x	x	x			x	x	x
MW029	TLS	x			x	x			x	x	x	x	x			x	x	x
MW030	TLS	x			x	x			x	x	x	x	x			x	x	x
MW031TR	TLS	x							x	x	x	x	x			x	x	x
MW033	TLS	x			x	x			x	x	x	x	x			x	x	x
MW034	TLS	x							x									
MW041T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW042TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW043T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW045T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW048TR	TLS	x							x	x	x	x	x			x	x	x
MW049T	TLS	x							x	x	x	x	x			x	x	x
MW050T	TLS	x							x	x	x	x	x			x	x	x
MW051T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW052T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW054T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW061T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW071T	TLS	x							x	x	x	x	x			x	x	x
MW073T	TLS	x							x	x	x	x	x			x	x	x
MW078T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW080TR	TLS	x			x	x			x	x	x	x	x			x	x	x
MW081T	TLS	x							x	x	x	x	x			x	x	x
MW089T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW096T	TLS	x							x									
MW097T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW098TR	TLS	x							x									
MW101T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW114T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW115T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW116T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW117T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW126T	TLS	x							x	x	x	x	x			x	x	x
MW127T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW131T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW132T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW133T	TLS	x			x	x			x	x	x	x	x			x	x	x
MW136T	TLS	x			x	x			x	x	x	x	x			x	x	x
PSDL009TR	TLS	x							x									
PSDL021	TLS	x			x	x			x	x	x	x	x			x	x	x
SL001	TLS	x							x									
SL002	TLS	x							x									
SL003	TLS	x							x									
SL004	TLS	x							x									
SL006	TLS	x							x	x	x	x	x			x	x	x
SL008	TLS	x							x									
MW134T	TLS	x			x	x			x	x	x	x	x			x	x	x
P042T	TLS	x							x	x	x	x	x			x	x	x
P112A	TLS/Paleo-channel	x							x									
P112B	TLS/Paleo-channel	x							x									
P112C	TLS/Paleo-channel	x							x									
P112D	TLS/Paleo-channel	x							x									
P114A	TLS/Paleo-channel	x			x	x			x	x	x	x	x			x	x	x
P114B	TLS/Paleo-channel	x			x	x			x	x	x	x	x			x	x	x
P114C	TLS/Paleo-channel	x			x	x			x	x	x	x	x			x	x	x
P114D	TLS/Paleo-channel	x			x	x			x	x	x	x	x			x	x	x
PSDL001	TLS	x			x	x			x									
PSDL005	TLS	x							x	x	x	x	x			x	x	x
PSDL012	TLS	x							x									
PSDL014	TLS	x							x									
PSDL017	TLS	x							x	x	x	x	x			x	x	x
New MW	TLS	x							x	x	x	x	x			x	x	x
New MW	TLS	x							x	x	x	x	x			x	x	x
New MW	TLS	x							x							x	x	x
New MW	TLS	x							x							x	x	x
New MW	TLS	x							x							x	x	x
MW001	SSDL	x							x									
MW005BSR	SSDL	x							x									
MW007SR	SSDL	x							x									
MW009	SSDL	x							x									
MW010	SSDL	x							x									
MW011	SSDL	x							x									
MW012	SSDL	x							x									
MW013	SSDL	x							x									
MW014	SSDL	x							x									
MW015	SSDL	x							x	x	x	x	x			x	x	x
MW017	SSDL	x							x									
MW018B	SSDL	x							x	x	x	x	x			x	x	x
MW020B	SSDL	x							x									
MW021	SSDL	x							x									
MW023SR	SSDL	x							x	x	x	x	x			x	x	x
MW025SR	SSDL	x							x	x	x	x	x			x	x	x
MW026B	SSDL	x							x									
MW027A	SSDL								x									
MW027AR	SSDL	x							x									
MW028B	SSDL	x							x									
MW032	SSDL	x							x									
MW035S	SSDL	x							x	x	x	x	x			x	x	x
MW036SR	SSDL	x							x	x	x	x	x			x	x	x
MW037SR	SSDL	x							x	x	x	x	x			x	x	x
MW038SR	SSDL	x							x	x	x	x	x			x	x	x
MW057S	SSDL	x							x									
MW059S	SSDL	x							x									
MW060SR	SSDL	x							x									
MW062S	SSDL	x							x	x	x	x	x			x	x	x
MW063SR	SSDL	x							x	x	x	x	x			x	x	x
MW082S	SSDL	x							x	x	x	x	x			x	x	x
MW086SR	SSDL	x							x	x	x	x	x			x	x	x
MW090SR	SSDL	x							x	x	x	x	x			x	x	x
MW092SR	SSDL	x							x	x	x	x	x			x	x	x
MW102S	SSDL	x							x	x	x	x	x			x	x	x
MW128S	SSDL	x							x	x	x	x	x			x	x	x
MW129S	SSDL	x							x	x	x	x	x			x	x	x
MW135S	SSDL	x							x									
PSDL004	SSDL	x							x									
PSDL007	SSDL	x							x									
PSDL009ASR	SSDL	x							x	x	x	x	x			x	x	x
PSDL014A	SSDL	x							x									
PSDL017A	SSDL	x							x	x	x	x	x			x	x	x
PSDL021A	SSDL	x							x	x	x	x	x			x	x	x
SL007	SSDL	x							x									
SL009	SSDL	x							x									
SL019SR	SSDL	x							x	x	x	x	x			x	x	x
SL020SR	SSDL	x							x	x	x	x	x			x	x	x
New MW	SSDL	x							x	x	x	x	x			x	x	x
New MW	SSDL	x							x	x	x	x	x			x	x	x
New MW	SSDL	x							x	x	x	x	x			x	x	x
New MW	SSDL	x							x							x	x	x
New MW	SSDL	x							x							x	x	x
New MW	SSDL	x							x							x	x	x
MW018APR	PSDL	x							x	x	x	x	x			x	x	x
MW039P	PSDL	x							x									
MW040P	PSDL	x							x									
MW044P	PSDL	x							x									
MW046P	PSDL	x							x									
MW047P	PSDL	x							x	x	x	x	x			x	x	x
MW053P	PSDL	x							x									
MW055P	PSDL	x							x									
MW056P	PSDL	x							x									
MW058P	PSDL	x							x									
MW064P	PSDL	x							x	x	x	x	x			x	x	x
MW072P	PSDL	x							x	x	x	x	x			x	x	x
MW077P	PSDL	x							x	x	x	x	x			x	x	x
MW087P	PSDL	x							x	x	x	x	x			x	x	x
MW091PR	PSDL	x							x	x	x	x	x			x	x	x
MW093PR	PSDL	x							x									
MW094PR	PSDL	x							x	x	x	x	x			x	x	x
MW095P	PSDL	x							x									
MW099P	PSDL	x							x	x	x	x	x			x	x	x
MW100P	PSDL	x							x									
MW103P	PSDL	x							x	x	x	x	x			x	x	x
MW123P	PSDL	x							x									
MW124P	PSDL	x							x									
MW125P	PSDL	x							x									
MW130P	PSDL	x							x	x	x	x	x			x	x	x
PSDL013	PSDL	x							x									
PBC004	UBC-A	x							x									
SL005	PSDL	x							x									
SL013	PSDL	x							x									
SL014PR	PSDL	x							x									
SL015	PSDL	x							x	x	x	x	x			x	x	x
SL016	PSDL	x							x	x	x	x	x			x	x	x
SL021PR	PSDL	x							x	x	x	x	x			x	x	x
SL022	PSDL	x							x									
SL023	PSDL	x							x									
SL024	PSDL	x							x									
UBC003	PSDL	x							x									
New MW	PSDL	x							x	x	x	x	x			x	x	x
New MW	PSDL	x							x	x	x	x	x			x	x	x
New MW	PSDL	x							x	x	x	x	x			x	x	x
New MW	PSDL	x							x	x	x	x	x			x	x	x
New MW	PSDL	x							x	x	x	x	x			x	x	x
New MW	PSDL	x							x							x	x	x
New MW	PSDL	x							x							x	x	x
CBC004	UBC-A	x							x									
PBC002	UBC-A	x							x									
PBC006	UBC-A	x							x									
P042B	UBC-A	x							x									
UBC002AIR	UBC-A	x							x									
UBC004	UBC-A	x							x									
UBC010	UBC-A	x							x									
UBC011	UBC-A	x							x									
UBC012	UBC-A	x							x									
UBC013	UBC-A	x							x									
UBC014	UBC-A	x							x									
UBC015AR	UBC-A	x							x									
UBC016	UBC-A	x							x									
UBC017	UBC-A	x							x									
UBC018	UBC-A	x							x									
UBC019	UBC-A								x									
UBC021	UBC-A								x	x	x	x	x			x	x	x
UBC022AR	UBC-A	x							x									
UBC023	UBC-A	x							x									
UBC024	UBC-A	x							x	x	x	x	x			x	x	x
UBC025	UBC-A	x							x	x	x	x	x			x	x	x
UBC026	UBC-A	x							x	x	x	x	x			x	x	x
UBC027	UBC-A	x							x	x	x	x	x			x	x	x
UBC028AR	UBC-A	x							x	x	x	x	x			x	x	x
UBC029AR	UBC-A	x							x									
UBC030	UBC-A	x							x									
UBC031	UBC-A	x							x									
UBC034	UBC-A	x							x									
UBC035	UBC-A	x							x									
UBC036	UBC-A	x							x									
UBC048	UBC-A	x							x									
UBC049	UBC-A	x							x									
UBC051	UBC-A	x							x									
UBC052	UBC-A	x							x	x	x	x	x			x	x	x
UBC053	UBC-A	x							x									
New MW	UBC-A	x							x							x	x	x
New MW	UBC-A	x							x							x	x	x
CBC008	UBC-B	x							x									
PW004	UBC-B	x							x									
UBC001	UBC-B	x							x									
UBC005	UBC-B	x							x									
UBC006	UBC-B	x							x									
UBC008	UBC-B	x							x									
UBC009	UBC-B	x							x									
UBC017B	UBC-B	x							x									
UBC018B	UBC-B	x							x									
FDSecl															x				
SBD#1								x										
SBD#2								x										

Notes:

Baseline Metals^{1} **-** Geochemical Water Analysis ICP-ES/ICP-MS (FullSuite of 70 elements)

Anions^{2} - One time analysis of major anions (alkalinity, chloride, and sulfate) for water fingerprinting

Cations^{3} - One time analysis of major cations (calcium, magnesium, potassium, and sodium) for water fingerprinting

ORP - Oxygen Reduction Potential

DO - Dissolved Oxygen

VOC COCs - PCE, TCE, cis-1,2-DCE, VC

Metals COCs - Cadmium, Chromium, Lead, Arsenic