Ground Water Sampling Technologies Verification Test Plan

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Version 2

Environmental Technology Verification Program

Sponsored by

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Abbreviations and Acronyms

ANOVA	Analysis of variance
BFB	Bromofluorobenzene
BNZ	Benzene
BTEX	Benzene, toluene, ethylbenzene and xylenes
CFR	Code of Federal Regulations
CPR	Cardio-pulmonary resuscitation
1,2-DCA	1,2-Dichloroethane
1,1-DCE	1,1-Dichloroethene
DMLS `	Diffusional multi-level sampler
DNAPL	Dense non-aqueous phase layer
DOT	Department of Transportation
EPA	Environmental Protection Agency
ES&H	Environmental Safety and Health
ETV	Environmental Technology Verification Program
FPA	Field Portable Analytical Inc.
FY	Fiscal year
GC/MS	Gas chromograph/mass spectrometer
GW	Ground water
HASP	Health and safety plan
HIF	Hydrological Instrumentation Facility
LNAPL	Light non-aqueous phase layer
LRL	Lower recovery limit
MS	Mass spectrometry
NASA	National Aeronautics and Space Administration
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAH	Polycyclic aromatic hydrocarbons
PCE	Tetrachloroethene
PE	Performance evaluation
PPE	Personal protective equipment
QA	Quality assurance
QAPP	Quality assurance program plan
QC	Quality control
%REC	Percent recovery
RSD	Relative standard deviation
SAB	Science Advisory Board
SAP	Sampling and analysis plan
SCMT	Site Characterization and Monitoring Technologies Pilot
SD	Standard deviation
SNL	Sandia National Laboratories
SOP	Standard operating procedures
SP	Standpipe
SSC	Stennis Space Center

1,1,2-TCA	1,1,2-Trichloroethane
TCE	Trichloroethene
USGS	United States Geological Survey
VO	Verification organization
VOA	Volatile organics analysis
VOC	Volatile organic compound

Section 1 Introduction

This section summarizes the objectives of the ground water (GW) sampling technologies demonstration that is being conducted under the US EPA Environmental Technology Verification program. The plan also provides an overview of the Environmental Technology Verification Program Site Characterization and Monitoring Technologies Pilot Project under whose direction this demonstration is being conducted.

Demonstration Objectives

The overall purpose of this demonstration of GW sampling technologies is to produce a set of field data which can be used to systematically document the performance characteristics of the participating technologies. This particular demonstration is targeted at demonstrating groundwater sampling technologies for the collection of water samples containing volatile organic compounds (VOC). The technologies chosen for this demonstration are all suited for the collection of VOC-contaminated water from monitoring wells and offer a range of capabilities applicable to GW sampling. The technologies have been designed with cost-efficiencies in mind, thereby reducing the overall costs associated with routine groundwater monitoring programs at contaminated sites. The primary objectives of this demonstration are:

1) Produce a verified data set suitable for evaluating important sampler operating parameters such as accuracy and precision.
2) Compare sampler performance to a reference sampling method.
3) Demonstrate sampler attributes that may be of particular interest in the technologies intended scope of application.
4) Record and evaluate the logistical and financial resources needed to operate each sampler.

Secondary objectives of this demonstration are to evaluate the sampling technologies for their reliability, durability, useful range, and ease of operation. The demonstration is not intended to compare the various technologies with each other and the evaluation of each technology will be published in a separate technical report.

ETV Program - Site Characterization and Monitoring Pilot Background

Throughout its history, the US Environmental Protection Agency (EPA) has evaluated technologies to determine their effectiveness in monitoring, preventing, controlling, and cleaning up pollution. Since the early 1990s, however, numerous government and private groups have identified the lack of an organized and ongoing program to produce independent, credible performance data as a major impediment to the development and use of innovative environmental technology. Such data are needed by technology buyers and permitters both at home and abroad to make informed technology decisions. Because of this broad input, the President's environmental technology strategy, Bridge to a Sustainable Future, and the Vice President's National Performance Review, contain initiatives for an EPA program to accelerate the development of environmental technology through objective verification and reporting of technology performance. In 1994, EPA's Office of Research and Development formed a work group to plan the implementation of the Environmental Technology Verification Program (ETV). The work group produced a Verification White Paper that guided the initial stages of the program. Following the efforts of this work group, a Verification Strategy was developed that updates the earlier paper based upon the evolution of the program over recent years. The Verification Strategy outlines the operating principles and implementation activities that are shaping the program, as well as the challenges that are emerging and the decisions that must be addressed in the future. The program will continue to be modified through input from all parties having a stake in environmental technology, through further operational experience, and through formal evaluation of the program. The Site Characterization and Monitoring Technologies Pilot is one of 12 pilots operating under the ETV umbrella. The other eleven pilots are listed below:

1) Drinking Water Systems
2) Pollution Prevention/Waste Treatment
3) Pollution Prevention/Metal Finishing
4) Pollution Prevention/Innovative Coatings
5) Indoor Air Products
6) Advanced Monitoring Systems
7) Air Pollution Prevention and Control
8) EvTEC (an independent private-sector approach)
9) Wet Weather Flows Technologies
10) Source Water Pollution Technologies
11) Climate Change Technologies

The goal of the overall ETV program, which remains unchanged, is to verify the environmental performance characteristics of commercial-ready technology through the evaluation of objective and quality assured data, so that potential purchasers and permitters are provided with an independent and credible assessment of what they are buying or approving for use in environmental characterization or monitoring activities requiring regulatory agency oversight.

Several important operating principles have defined the basic ETV program structure and remain fundamental to its operation. These are briefly outlined below.

Performance Evaluation Goal

Under ETV, environmental technologies are evaluated to ascertain and report their performance characteristics. EPA and its partners will not seek to determine regulatory compliance; will not rank technologies or compare their performance; will not label or list technologies as acceptable or unacceptable; and will not seek to determine "best available technology" in any form. In general, the Agency will avoid all potential pathways to picking "winners and losers". The goal of the program is to make objective performance information available to all of the actors in the environmental marketplace for their consideration and decision making.

Commercial-Ready Technologies

The ETV program is a service of EPA to the domestic and international marketplace in order to encourage rapid acceptance and implementation of improved environmental technology. ETV, therefore, focuses its resources on technologies that are either in, or ready for, full-scale commercialization. The program does not evaluate technologies at the pilot or bench scale and does not conduct or support research. Participation in ETV is completely voluntary.

Third-Party Verification Organizations

ETV leverages the capacity, expertise, and existing facilities of others through third-party partnerships in order to achieve universal coverage for all technology types as rapidly as possible. Third-party verification organizations are chosen from the both the public and private sector, including states, universities, associations, business consortia, private testing firms, and federal laboratories. EPA designs and conducts auditing and oversight procedures of these organizations, as appropriate, to assure the credibility of the process and data. In order to determine if EPA participation is important to the commercialization process, ETV is testing the option of one totally unstructured and independent, private sector pilot in which EPA's role will be solely fiduciary. In addition, the Agency will continue to publish the results of commercial-ready technology evaluations that it conducts in the normal course of its business.

Pilot Phase

The program is currently in the middle of a five-year pilot phase to test a wide range of partner and procedural alternatives, as well as the true market demand for and response to such a program. Throughout the pilot period, EPA and its partners operate in a flexible and creative manner in order to identify new and efficient methods to verify environmental technologies, while maintaining the highest credibility standards. The operational objective is to actively look for ways to optimize procedures without compromising quality. The ultimate objective of the pilot phase is to design and implement a permanent verification capacity and program within EPA by 2000, should the evaluation of the effectiveness of the program warrant it.

Pilot Technology Areas

ETV has begun with pilots in narrow technology areas in each of the major environmental media and will expand as appropriate, based on market forces, availability of resources, and the willingness of the marketplace to pay for third-party verification. For example, the drinking water technology pilot has started with a focus on microbial and particulate contaminants, and disinfection byproducts in small systems (less than 3300 users), an obvious and very large domestic and international market with pressing environmental problems. In fiscal year 1997 (FY97), the program will be expanded to the wider area of nitrates and synthetic organic chemicals and pesticides in all drinking water systems. Success in particular technology areas will allow the program to have a “pump-priming” effect to bring new technologies to the marketplace. Selection criteria for ETV pilot programs and other verification focus areas are discussed in a subsequent section of this paper.

Stakeholder Groups

The ETV program is guided and shaped by the expertise of appropriate stakeholder groups in all aspects of the program. These groups consist of representatives of all customer groups: buyers and users of technology, developers and vendors, and, most importantly, technology “enablers”, i.e., the consulting engineering community that recommends technology alternatives to purchasers, and the state permitters and regulators who allow it to be used. Stakeholder groups must be unique to each technology area in order to capture the important individual aspects of the different environmental media and to get buy-in from affected groups. For example, state drinking water permitters are necessary to participate in development of testing protocols for cryptosporidium; air pollution regulators are needed to evaluate innovative compliance monitoring devices; metal production parts manufacturers need to help design testing procedures for new coating compounds. In general, the role of stakeholders will be to assist in the development of procedures and protocols, prioritize types of technologies to be verified, review all important documents emerging from the pilot, assist in defining and conducting outreach activities appropriate to the particular area, and, finally, to serve as information conduits to the particular constituencies that they represent. As of June 1996, over 80 individuals are serving in the three stakeholder groups formed to date.

Private Sector Funding

Over the pilot phase of the program, the costs of verifying technologies in many pilots will move from a primarily government-funded effort to a primarily private-sector funded effort. At least two pilots will be vendor supported from the beginning. The original goal, as articulated in the 1994 strategy, called for complete private sector sponsorship within three years. A recent review of the program by a panel of outside experts convened by the EPA Science Advisory Board (SAB) concluded that such a goal was probably not achievable in so short a time-frame (they suggested five to eight years) and that some level of government support (10 to 20% of ongoing costs) would remain necessary to keep the activity viable. Conclusions on this issue will have to be reached as data emerge on the economic value-added of the program and the cost that the private sector is willing to bear in the various technology sectors.

Pilot Evaluation and Program Decisions

The Agency will collect data on operational parameters, e.g., number of participants; cost and time required to perform tests and report results, and on outcomes, e.g., use of data by the states and public; sales reported by vendors, in order to evaluate all aspects of the program. EPA will use this information to make long-term recommendations to the Congress on the future and shape of the program in December 1998. Among the choices at that time will be the formulation of a permanent, broad scale program; the narrowing of efforts to certain areas in which ETV appears to be effective; or the discontinuance of verification efforts. The latter conclusion could be reached either because state regulators/permit writers and the technology innovation industry are not assisted by ETV or because the cost of verification proves to be prohibitive.

Outreach and Information Diffusion

As was pointed out by the SAB in its 1995 review of ETV, verification alone will not move better, cheaper, faster technologies to success in the marketplace. Substantive and substantial interface with the permitters of environmental technology (primarily at the state level) will be necessary to have any chance of rapidly implementing innovative approaches. To date, the outreach activities of the program have been limited to assuring substantial state representation on the Stakeholder Groups that are designing the protocols and procedures for each pilot; developing informational fact sheets about the program; and placing a Web page on the Internet. In 1997, the Agency intends to develop an overarching outreach strategy with the help of a “corporate board” of major organizations in the technology area, e.g., National Governors Association, Western Governors Association, Environmental Council of the States, National Pollution Prevention Roundtable, appropriate corporations, and others. State permitter training, a national conference and other efforts will be included.

Market Gap Definition

Lastly, EPA will track applications and expressions of interest on the part of technology developers who come to all parts of the Agency that do not fit into the present suite of verification activities. This universe will be characterized during the initial stages of the pilot period and a strategy to address gaps will be developed.

The Technology Verification Process

The SCMT Pilot provides developers with a clearly defined technology verification pathway to follow, from demonstration planning to data evaluation and verification, as shown in Figure 1. The demonstration process is a cooperative effort of EPA, the Verification Organization (VO), in this case Sandia National Laboratories (SNL), and the participating vendors.

Environmental Technology Demonstration and Verification Process

Site Characterization and Monitoring Technologies Pilot

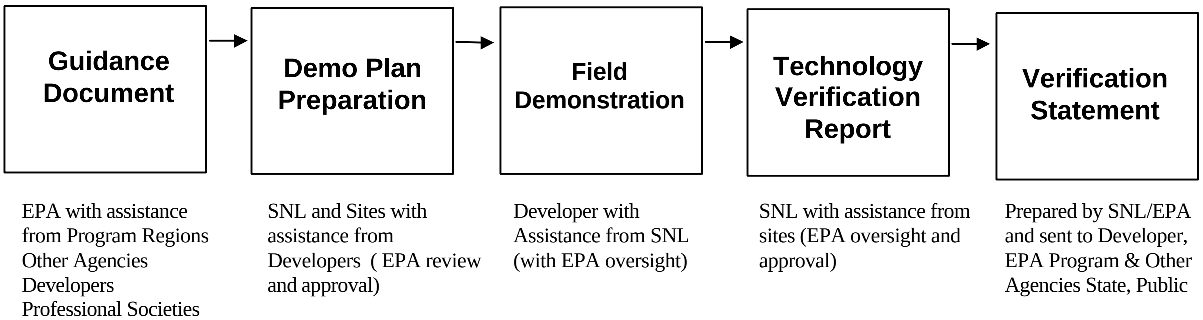


Figure 1 The Environmental Technology Demonstration Verification Process

The technology verification process established by the Pilot is intended to serve as a template for conducting technology demonstrations that will generate high quality data that can be used to verify technology performance. This process will be applied to demonstrations conducted by both private and public (e.g., DoD and DOE) entities. The pilot's verification process can help in moving innovative site characterization and monitoring technologies into routine use more quickly.

The verification of a technology's performance involves six sequential steps :

1) Identification of technology needs
2) Solicitation and selection of vendors
3) Development of demonstration/test plan
4) Field demonstration
5) Data analysis and reporting
6) Information transfer

Although the Agency is interested in any and all innovative site characterization and monitoring technologies, resources for verification testing are limited. Consequently, an important Pilot activity is the identification of technology and data gaps that impede cost-effective and efficient environmental problem-solving. This assessment, done through stakeholder interactions, enables the prioritization of technology demonstrations to best meet user community needs.

The Pilot also provides technology cost and performance data to the intended technology user groups. An important product of the Pilot is the preparation of reports that contain the data generated for each technology demonstration along with a summary of technology performance. The distribution of this performance information to the user community facilitates user community acceptance of innovative technologies. Following a field demonstration, the data are evaluated by the verification organization and a report that systematically evaluates technology performance characteristics is distributed. A verification statement[1] will be issued summarizing the technology's performance and ability to meet the user communities' site characterization and monitoring needs.

[1] The verification statement is prepared by the verification organization, is signed by the EPA, and is provided to the developer. It is a three-page summary of the performance results for each participating technology.

Identification of Technology Needs

Technology categories are reviewed and selected based stakeholder group feedback and the perception of pilot personnel with regard to user-community needs. Technology categories are considered in light of their ability to meet one or more of the following criteria:

capable of being used in the field or in a mobile laboratory
applicable to a variety sites (hazardous waste, contaminated, brownfields)
acceptable performance in comparison to conventional analytical methods
acceptable logistical and economic resources to operate
adequate maturity
meets a recognized environmental characterization or monitoring need
represents a special request priority
addresses a unique problem

Solicitation and Selection of Vendors

Technology solicitation and selection are carried out through the use of a Developers' Conference at which Developers, Verification Organization, and EPA personnel come together to discuss and review the applicability of various candidate technologies to an identified need in the environmental characterization and monitoring community. Following the conference, the Verification and EPA personnel review the candidate technologies and select those that best fit the anticipated demonstration area. In some cases, additional technology solicitation may be carried out following the conference in order to populate the demonstration with the most applicable technologies.

Demonstration/Test Plan Development

After a technology has been judged appropriate for an ETV Demonstration, the developers are asked to submit a letter of intent to participate in the demonstration. This letter provides a description of the technology along with technology performance characteristics such as instrument detection levels, accuracy, precision, linear range and others. These vendor-supplied instrument performance characteristics are particularly useful in the development of a comprehensive demonstration design by the verification organization. The activities listed below are carried out in the process of demonstration design

- Identifying demonstration sites that will provide the appropriate analytes in the desired environmental sample media or media (contaminants must be present in concentrations amenable to the technology being evaluated)
- Defining the roles of appropriate demonstration participants, observers, and reviewers
- Arranging analytical support for comparative testing (for example, reference analysis)
- Supplying standard operating procedures (SOPs), analysis methodologies, and other relevant protocols
- Addressing the experimental design, sampling design, QA/QC, health and safety considerations
- Scheduling field and laboratory operations, data analysis procedures, and data output format
- Determining logistical requirements and support (for example, field equipment, power and water sources, mobile laboratory, communications network)
- Anticipating possible corrective actions that may be required during the actual demonstration and providing this information to the demonstration participants
- Assuring the overall demonstration design will provide a data set adequate for the determination of instrument performance characteristics.

Field Demonstration

The technologies are evaluated under field test conditions at real environmental sites. The evaluations of each technology is conducted independently from other participating technologies and each evaluation includes a comparison with reference technologies where applicable. Testing is generally conducted at two sites in at attempt to broaden the range of conditions under which the evaluation is conducted. An audit of each technology is also conducted in the field to thoroughly document performance conditions and method of use.

Data Analysis and Reporting

Data from the field demonstration are analyzed and a summary of sampler performance is prepared by the verification organization. The data are organized into a indexed data volume, with accompanying analytical procedures and analytical results. The data and accompanying analyses are subjected to peer review to insure data quality and integrity. A summary report, called an Environmental Technology Verification Report, that outlines technology performance along with a summary of the sites used for the demonstration and the demonstration design is prepared and published as an official EPA document.. A three-page verification statement will accompany this report and serve as an executive summary of the demonstration and the technology performance. In this demonstration, the data analysis and reporting will be conducted by Sandia National Laboratories (SNL), one of the SCMT Pilot's verification organizations.

Information Outreach

The ETV program has an aggressive and varied program of information outreach. The program has an extensive web site that includes all lists of all stakeholder groups, testing schedules, test plans, verification reports and statements as well as other supporting information. Although limited paper copies of verification reports and statements are prepared, the web site is viewed as the primary tool for information outreach. The program also participates in a wide variety of conferences and professional society meetings with exhibit booths and organized panel discussions. The Site Characterization and Monitoring Pilot also, through the coordination of EPA's Technology Integration Office, hosts periodic electronic brown-bag seminars featuring discussion of verification testing results. These seminars utilize a conference call mechanism combined with visual aids that are available via the Web to those participating in the call.

Section 2 Roles and Responsibilities

This section identifies the organizations involved in this technology demonstration and describes the responsibilities of each organization throughout the demonstration process.

Demonstration Participant Roles

The primary demonstration participants and roles are shown in Table 1. Roles for each participant are briefly discussed in the following paragraphs.

Table 1 Demonstration Participants and Roles

Agency/Company	Point of Contact	Role
US EPA -NERL (Las Vegas)	Eric Koglin	EPA Project Officer
	Steve Gardner	Technical Review
Sandia National Laboratories	Wayne Einfeld	Verification Org. Project Manager
	Tom Burford	QA/QC Officer
	Gary Bailey Robert Lynch	Reference Sampling Team Members
US Geological Survey	Ed Ford Bill Davies	NASA SSC Interface Standpipe Facility Support USGS ES&H Officers
NASA	Janette Gordon	GW Monitoring Admin Oversight
Foster Wheeler	Greg New	GW Well Selection Consultant
Johnson Controls	Paul Byrd	ES&H Officer
	Wendy Robinson	Onsite GW Monitoring and Waste Management Coordinator
Field Portable Analytical	Craig Crume Dave Curtis	Onsite Sample Analysis
Burge Environmental	Scott Burge	Technology Vendor
Clean Environment Engineering	Michael Breslin	Technology Vendor
GeoLog	Jim Mirand	Technology Vendor
QED	David Kaminski	Technology Vendor
Margan	Dan Ezra	Technology Vendor
Sibak Industries	Tom Kabis	Technology Vendor
W. L. Gore	Andre' Brown	Technology Vendor

A description of the roles of the various participants in the demonstration is given below: This demonstration is being conducted by SNL under the guidance of the U.S. EPA National Exposure Research Laboratory/Environmental Sciences Division/Characterization Research Branch, located in Las Vegas. The EPA's role is to administer the overall Site Characterization and Monitoring Technologies Pilot. The EPA Project Officer is Eric Koglin. The EPA personnel will also serve in a technical review and QA audit capacity during the demonstration.

Sandia National Laboratories' role as the Verification Organization (VO) is to provide technical and administrative leadership and support in demonstration planning, demonstration conduct, data analysis, and documentation. Sandia will take the lead in the process of technology solicitation and selection and demonstration planning. Prior to and during the field demonstration, Sandia will work closely with site personnel and technology developers to efficiently plan and carry out the demonstration. Sandia will provide technology auditors to oversee sample management and review the technologies used during the field demonstration. Sandia have the lead role in analysis of the data following the field demonstration and will summarize its findings in a Technology Verification Report for each participating technology.

The technology developers are required to submit written technology descriptions for inclusion in the demonstration plan. They will also be required to review and comment on the draft demonstration plan. At the demonstration, the developers will operate the technology and be responsible for submitting their analytical data to the verification organization at the conclusion of the demonstration. The developers will also be required to review their respective Technology Verification reports prior to final publication.

Responsibilities

Specific responsibilities for each of the demonstration participants are outlined in detail below.

Project Sponsor: EPA National Exposure Research Laboratory-Environmental Sciences Division (Las Vegas)

- Overall project management responsibilities
- Technical review of demonstration plan and verification reports
- Final approval on vendor selection and demonstration plan
- Program management oversight during field demonstration
- Quality assurance project plan audits
- Coordination of EPA peer-review of demonstration documents
- Final approval of Technology Verification Reports and Verification Statements

Verification Organization: Sandia National Laboratories

- Design and prepare all elements of the demonstration plan with developer input.
- Develop a quality assurance project plan (QAPP) and a health and safety plan (HASP) for the demonstration activities in consultation with the site representatives.
- Coordination of all interagency and vendor communications both prior to, during, and following the field demonstration.
- Field demonstration site selection
- Review and selection of reference laboratory support
- Providing detailed procedures for technology field use with developer input.
- Oversight of Performance Evaluation sample preparation and distribution
- Oversight of field sample collection, management and transport
- Coordinate site logistical and other support, as required
- Coordinate pre-demonstration and field demonstration activities
- Providing documentation of the experimental methodology and operation of the technology with developer input.
- Data reduction and technical reporting

Demonstration Site: NASA, USGS and associated contractors

- Grant access to the site and help coordinate standpipe facility and monitoring well access
- Review of demonstration plan
- Supporting role in field sample collection, management and transport
- Waste management responsibilities
- Visitor's Day Coordination

Technology Vendors

Pay a non-negotiable $5,000 verification testing fee to Sandia National Laboratories

Provide input (technology description and performance specifications) for the demonstration plan
Review and comment on the proposed demonstration plan
Provide formal written procedures for technology field use
Operate the technology during the demonstration
Participate in the demonstration in accordance with the procedures outlined in the demonstration plan.
Review and comment on draft Technology Verification Report

The Verification Organization, prior to the onset of the field demonstration, will provide a complete hazard communication briefing in collaboration with the site owner or its contractor. The briefing will include a description of environmental safety and health hazards likely to be encountered during the field demonstration along with safe work practices to be followed by all demonstration participants. The Verification Organization will take appropriate steps to provide a safe working environment during the demonstration, however the ultimate responsibility for vendor participant safety rests with each vendor organization for its representatives at the field demonstration.

Communications, Documentation, Logistics, and Equipment
SNL will communicate regularly with the demonstration participants to coordinate all field activities associated with the demonstration and to resolve any logistical, technical, or QA issues that may arise as the each demonstration progresses. A short briefing and time for resolution of issues will be held at the start of each day during the demonstration. The successful implementation of the demonstration will require detailed coordination and constant communication between all demonstration participants.

All critical vendor field activities will be documented both by the vendor and verification organization. Means of field documentation will include field logbooks, photographs, field data sheets, and chain-of-custody forms. The SNL field team leader will be responsible for maintaining all field documentation. Field notes will be kept in a bound logbook. Each page will be sequentially numbered and labeled with the project name and number. Completed pages will be signed and dated by the individual responsible for the entries. Errors will have one line drawn through them and this line will be initialed and dated. Specific notes about each sample collected, as required, will be written on sample field sheets, and in the field logbook. Any deviations from the approved final demonstration plan will be thoroughly documented in the field logbook and communicated to the SNL technical lead and other parties that may be affected by the change.

Original field sheets and chain-of-custody forms will accompany all samples shipped to the reference laboratory. Copies of field sheets and chain-of-custody forms for all samples will be maintained in the project file, maintained by Sandia, the Verification Organization.

Logistical Responsibilities

The responsibility for providing the necessary equipment to conduct this demonstration is shared between the verification organization and the vendors. The following two tables (Table 2 and 3) list the support equipment and services to be provided by the VO and vendors, respectively.

Table 2 VO/Site-Supplied Field Equipment

Chemicals and mixed solutions for standpipe
Equipment for preparation of standpipe mixtures
Deionized water for sampler decon (for both VO and vendors)
Receptacle for decon wastewater (for both VO and vendors)
Pre-cleaned 40 mL VOA vials (for both VO and vendors)
Sample labeling materials and Chain of Custody forms
Purge water quality monitoring instrumentation (for VO use only, not for vendor use)
Data reporting forms (sreadsheet templates, forms, etc.)
Coolers and Blue Ice for sample storage

Vendor Equipment Shipments to SSC

Vendors must accept all responsibility for the timely shipment of their equipment to SSC in preparation for the demonstration. Vendors should assume that they should provide all equipment not included in the above list unless other arrangements have been made.

The mailing address for vendors to send equipment to is.

U.S. Geological Survey
Building 2101
Stennis Space Center, MS 39529-6000
ATTENTION: Ed Ford - ETV

Any packages sent to the above address will not be opened but will be held until the vendors arrive to claim them. Vendors should make sure that any equipment mailed to us is well packaged to prevent damage by the carrier and that they are insured.

Table 3 Vendor-Supplied Field Equipment (as required by each technology)

Vehicle for transportation to the demonstration sites.
Complete sampling apparatus.
Sampler decon equipment (or use onsite equipment after coordination with VO)
Purge water quality monitoring instruments (if required)
Purge water monitoring data forms
Calibration solutions for water quality monitoring instruments (if required)
General field supplies (solvents, tissues, etc.) as needed.
Appropriate clothing and equipment for field sampling activities
Appropriate protective gear (gloves, safety glasses etc.) for GW well sampling
OSHA 40-hr HAZWOPER Training for GW sampling crews

Section 3 Technology Descriptions

This section includes a description of each of the technologies who will be participating in this demonstration. At the present time, seven technologies have expressed an interest in participating in this demonstration. The technologies range from simple to complex and address a broad spectrum of characterization and monitoring needs encountered in regional or local groundwater monitoring programs. Each fulfills a specific characterization or monitoring role; and, in some cases, the technologies may be viewed as complementary to each other. The various technologies are presented in alphabetical order in the following sections.

Discrete-Level Pump/grab Samplers

The participating technologies have been categorized into two general categories, namely, discrete level pump/grab samplers and multi-level samplers. The discrete level samplers are briefly outlined below

Clean Environment Equipment - SamplEase/SampleMan

BACKGROUND

Since 1982 Clean Environment Equipment (CEE) has a manufacturer of pneumatic pumps and controls which are used in the sampling and remediation of ground water. The SamplEase™ sampling system designed by CEE has a number of unique products consisting of a several models of Teflon-bladder pumps, pneumatic controllers, well caps, fittings, tubing and accessories.

EQUIPMENT DESIGN

The SamplEase™ pump is typically installed in a well and submerged in the ground water. It is filled via hydrostatic pressure through its lower check valve. When the annulus between the stainless outer tube and the Teflon bladder is pressurized with compressed gas, the bladder is squeezed and the collected ground water is forced upwards through the pump's upper check valve and is thus expelled from the well. When the compressed gas is released from the annular space outside the bladder, the pump can fill again.

The SamplEase™ pumps are designed to disassemble easier than prior art. They are available in two lengths with PVC or Teflon heads. CEE has a wider range of tubing fittings for sampling pumps than what is normally available. These options give the user the ability to better use the pump in a portable or dedicated mode.

The SampleMan™ Controllers are designed to be the smallest, lightest, most durable and reliable controllers on the market. They were designed for ease of understanding, use and handling. The circuit design has been used for many years in remediation systems created by CEE. The bright yellow color was selected to show up easily so it is easy to find in storage bags, the back of pickup trucks, in darkened vans and on the site at dusk.

The controls are designed to be user friendly, operate with wet compressed air, to operate in rain storms, and to survive submersion in water and be ready to be used within minutes afterwards.

The SamplEase™ System can be used in either portable or dedicated mode and can perform in either the high-purge or low-flow sample collection mode of operation.

NEW SAMPLING PROCEDURE

CEE has also developed what is believed to be a new sampling method to be used with bladder pumps and the low-flow sampling method. The **CEEP**™ method overcomes some of the arguments against the typical use of bladder pumps for sampling. It has not been mentioned in any of the literature on bladder pumps or the low-flow sampling method read by CEE employees. When introduced to people in the sampling industry, the universal response is one of interest and a statement that they have not heard of it previously. It is hoped the method would be tested by this EPA evaluation test program.

UNIQUE ADVANTAGES OF THE CEEP™ SAMPLING METHOD -

Low-flow CEEP sampling is from within the well screen can greatly reduce the volume of water purged from a well before samples are collected. The typical advantages include:

- Reduced Purge volume of up to 95%.
- Quality and accuracy is improved
- Consistency is improved

In addition, the method not only discharges the contents of the pump at the low-flow rate (100 to 500 ml/min.), but it also intakes the fluid at the about the same rate. This is unlike other methods which discharge slowly, but then intake rapidly. Such an operation can defeat the purpose of the low-flow sampling technique.

QED Environmental Systems – MicroPurge/Well Wizard

BACKGROUND

Sampling ground water has traditionally involved purging a monitoring well to remove stagnant water in the well casing prior to sampling. The approach of removing 3-5 volumes of the well often results in the removal of large volumes of water. Users resort to high pumping rates to purge efficiently; where wells are hand bailed, large purge volumes make bailing a tedious and time-consuming task. If purge water must be collected or treated, large purge volumes create handling problems, and treatment costs can add greatly to sampling budgets.

These traditional purging methods can affect sample quality and greatly increase sample turbidity, causing false-positive analytical results that can trigger re-sampling or assessment. Sample filtration simply adds to the time and cost of sampling and analysis, and can cause bias or error in results.

MICROPURGE SAMPLING

The MicroPurge sampling method is based on the "low-flow/minimal drawdown" sampling procedure described by Puls and Barcelona in their 1996 EPA Ground Water Issue paper (EPA/540/S-95/504). The three main elements of their approach are:

1. Place a variable-flow sampling pump within the well intake zone
2. Operate the pump at a low flow rate while continuously monitoring the water level in the well
3. Monitor water chemistry indicator parameters to determine when purging is completed.

The well must be pumped at flow rates low enough to avoid turbulent flow through the well screen that could mobilize fine particles from the sand pack and surrounding formation and increase sample turbidity. To prevent movement of overlying stagnant water into the sampling device and over-stressing the surrounding formation, the water level in the well must be monitored during pumping and the flow rate adjusted to prevent continuous drawdown of the water level. Indicator parameter monitoring is achieved through use of an in-line flow cell chamber with associated sensors and instrument.

ADVANTAGES OF MICROPUURGE SAMPLING

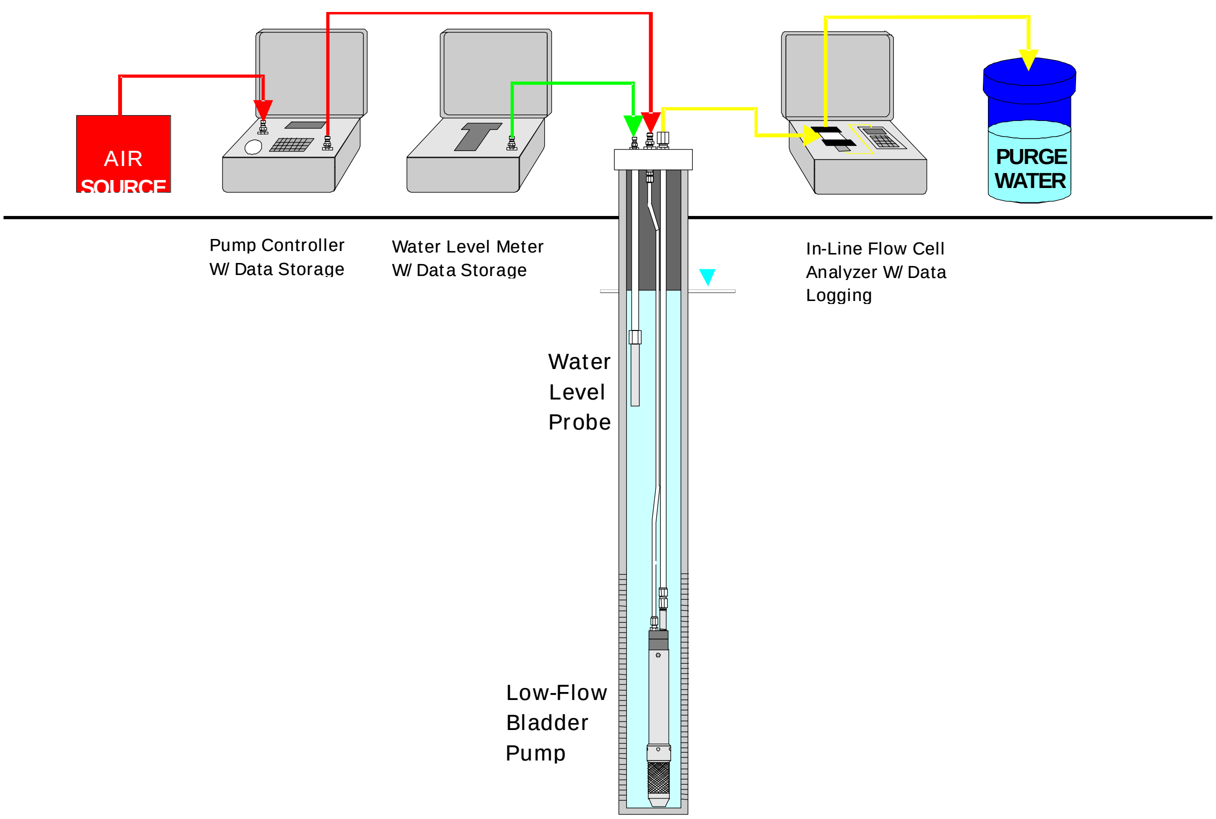
Low-flow MicroPurge sampling from within the well screen can greatly reduce the volume of water purged from a well before samples are collected. The advantages include:

- Purge volume is typically reduced 90-95%, with resultant purge time reduction for most wells.
- Sample quality and accuracy are improved through reduced turbidity and minimized alteration. False-positive results for turbidity-affected analytes can be eliminated.
- Sample precision can also improve, making it easier to "pass" statistical data evaluation.

MICROPURGE SAMPLING SYSTEM COMPONENTS

QED's MicroPurge sampling system is made up of the following components (as shown in the figure below):

- A dedicated Well Wizard® bladder pump system (pump, inlet screen, tubing and well cap assembly)
- Model 400 Digital Controller for controlling pump flow rate
- Model 6400 Digital Water Level Measurement system (down-well probe and instrument)
- Model FC4000 Flow Cell Water Analyzer
- System driver (portable electric or gasoline-powered compressor, or compressed gas cylinder)



APPICATIONS AND LIMITATIONS

MicroPurge sampling systems can be used in a wide variety of hydrogeologic setting and monitoring programs. MicroPurge sampling is appropriate for collection of ground-water samples for all ground-water contaminants and any naturally occurring analytes, including metals and other inorganics, pesticides, PCBs, volatile and semi-volatile organic compounds (VOCs and SVOCs), other organic compounds, radiochemical and microbiological constituents. This method is not applicable to the collection of light or dense non-aqueous phase liquids (LNAPLs or DNAPLs). Nearly any type of well configuration can be accommodated, though long-screened wells may require equipment modifications. Systems have been installed to depths of 1,100 feet (335 meters). Well diameters of 1.5 inches (38 mm) and larger can be equipped with MicroPurge systems.

MicroPurge® and Well Wizard® are registered trademarks of QED Environmental Systems, Inc.

Geolog – Geoguard

A bladder pump is submersible, air-operated pump that was developed on or about 1980, the cooperative efforts of an independent manufacturer and a USGS scientist. The device was developed as a better way to acquire samples from ground water monitoring wells. Simple in design, a bladder pump has inlet and outlet check valves, and an internal membrane (bladder) that separates the drive air from the sample.

Since 1980 as many as nine different companies have manufactured bladder pumps. During this time numerous studies and technical papers have been published that have promoted the benefits of using bladder pumps over other lift devices such as bailers, electric submersible pumps and peristaltic pumps. The U.S. EPA has stated that “bladder pumps are generally recognized as the best overall sampling device for both organic and inorganic constituents…” (ref. U.S. EPA Solid Waste Disposal Facility Criteria, Nov. 1993 Technical Manual). The U.S. Army Corp of Engineers has approved and recommended this technology for use on numerous DOE and DOD facilities. Conservative estimates indicate that over 60,000 of these devices have been commercially produced and installed since the technology was first conceived.

The use of a dedicated bladder pump is critical to the success of the low-flow method. By having the pump permanently in place, turbidity is significantly eliminated, and there is no potential of agitating the water column, as is common when portable pumps or hand bailers are used. Also, the manner in which a bladder pump is actuated allows the sample to be obtained without agitation, which is critical to the preservation of volatile organic compounds. Finally, since the internal membrane separates the drive air from the sample, there is no mixing or potential for aeration.

The low-flow method relies on purging at a rate not to exceed 500 ml per minute, also while monitoring specific water quality parameters such as pH, temperature, conductivity, and dissolved oxygen. When specific parameters stabilize, the sample can be obtained at a rate of 100 ml per minute or less. Studies have indicated that purge water volumes are greatly reduced when using this method, as compared to a volumetric purging protocol, which often required 3 to 5 well volumes. When considering the disposal costs associated with purge water, facilities with large numbers of monitoring wells can significantly reduce the operating costs associated with their sampling programs.

In summary, the low-flow sampling method utilizing dedicated bladder pumps is a cost effective way to acquire ground water samples. Solid waste disposal facilities (landfills) represent the largest potential end user of this technology, specifically if the international market begins to adopt U.S. EPA standards.

Sibak Industries – Kabis Sampler

Introduction

The KABIS Sampler is a revolutionary new groundwater sampling device designed to eliminate sample turbidity, eliminate organic constituent volatilization, and eliminate costly well purging. There are three versions, one of which easily fits any 2" well. The other two versions may be used in wells 4" diameter or larger, and will take either 1 liter bottle sample or three simultaneous 40 ml vial samples.

Sampler Operation

General - KABIS Sampler cap is loaded with any standard VOA vial and the cap is screwed to the weighted body. The sampler is then lowered down the well to the predetermined sampling depth at which point the sampler automatically begins filling (sampling) by means of differential head pressure. Sampling is facilitated via laminar flow directly into the sample container. Low turbidity is achieved through the minimal disturbance caused by the hydrodynamic shape of the sampler. The minor field modification, the KABIS Sampler can sample through free-floating product, or scavenge from the bottom of the well.

Well Purging - The KABIS Sampler is engineered to obtain a sample from any depth desired. This means that the sampler can be lowered down the well to a depth substantially below the top of the screened interval, where the well is free to communicate with formational ground-water. The result is a representative sample of the formational groundwater without the generation of hazardous purge-water waste and associated disposal costs.

Turbidity - Turbidity is kept low due to the hydrodynamic shape of the sampler. The "bullet" shape of the sampler weight, attached to the sampler body, gently and almost imperceptibly pierces the water column creating laminar flow across the smooth outer sampler body surface. The result is minimal disturbance to the settled flocculants and clay/silt particles in the well and therefore, less turbid sample collection.

Low VOC Loss - The sample collection tube is positioned so that it rests approximately ¼ inch above the bottom of the sample container. The container is slowly filled from the bottom up. Using the best laboratory procedures, the receiving container is repeatedly rinsed with the receiving sample, assuring purity through repeated flushing (a procedure recommended in "Standard Methods"). In fact, the KABIS Sampler flushes the sample container a minimum of six times (3 times for the liter sampler) before actually taking the sample for laboratory analysis.

Because the sample is collected directly into the sampling container, VOC loss through sampler transfer is eliminated. Because there is little disturbance to the water column during sampler penetration, VOC loss is eliminated. Finally, because the sample container is filled from the bottom-up via laminar flow and in the absence of air (at the point of filling), effervescence, splashing, and bubbling (sources for volatilization) are eliminated. The sample container is removed from the sampler, preserved if necessary, and immediately capped.

Sample Preservation

The sample may be preserved using sodium thiosulfate directly through the fill tube, or by acidifying after removing the sample container (VOA vial or other container) from the sampler.

Construction

The KABIS Sampler is precision machined from solid stainless steel. All crevices and corners have been radiused or hollow-ground to leave no “square” edges. The sampler is sturdy and field-ready. The sampler is stored and carried in a sturdy carrying case which is fitted with holders for sample containers, cleaning solutions, preservation solutions and an upright can postioner for the sampler when it is being downloaded.

There are no moving parts, so there is nothing to break down. If the sampler is accidentally run over by a vehicle or damaged in any way, components are easily removed and replaced (there are only two; the cap and the body). Even dented (in the middle), the sampler will still operate and be capable of obtaining a viable sample.

Decontamination

The KABIS Sampler is designed for ease of operation and decontamination. In order to decontaminate the sampler after use, simple immerse the sampler alternately in ALCONOX ™ (or equivalent) and deionized water. Let the sampler air dry after use (in the field) or immediately load another sample container and proceed to the next well. The all-stainless steel construction also allows the sampler to be periodically cleaned in an autoclave.

Multi-Level Samplers

This technology category includes those samplers that have the capability of sampling at multiple levels within a monitoring well. The category includes both pump/grab samplers, diffusional samplers, and integrating samplers.

Burge Environmental -- Multiprobe 100

Product Name: Multiprobe 100

Physical Characteristics

Size: Lower Unit: 12 inches long for 4-inch diameter wells
Upper Unit: 18 inches long and 4 inches in diameter
Available Diameters: 2- and 4-inch
Weight: Approximately 3 pounds for 4-inch diameter unit

Method of Operation

To be provided…

Range of Applications

Ground Water Sampling-The system may be placed into a monitoring well to collect discrete samples from any interval within the well. The sampling system uses a micro-purging technology to reduce the amount of water brought to the surface.
Sensor Platforms-The system was designed to locate sensors inside or outside of a monitoring well. The sampling system is capable of creating a headspace over a volume of water while under the static water level of the well. This design allows various sensors to be placed within a monitoring well

without becoming wet. Alternatively, the sensors can be placed at the top of the well casing or in specially designed, environmentally controlled boxes adjacent to the monitoring wells. A calibration module is available which allows the sensors to be calibrated while residing inside the monitoring well.

Multi-Level Sampling-The standard system is capable of sampling up to 4 separate levels within existing monitoring wells without any major modifications of the sampling modules. Stacking two modules allows for multi-level sampling of up to 8 separate levels.

Required Support Equipment

The system requires a cylinder of compressed gas (nitrogen). The operation pressure is usually less than 30 psi, which allows a cylinder of nitrogen to collect hundreds of samples before recharging the cylinder.

Cost

The cost of the basic 4-inch diameter ground water sampling system capable of collection samples from four levels within a monitoring well is $3,000.00.

Maintenance Requirements

Periodic replacement of the nitrogen cylinder is required. Because the only moving parts of the ground-water sampling system are electrically controlled valves, the system is capable of years of operation without replacement of electrical components.

Materials of Construction

The system is constructed of Teflon™, Pyrex™ glass, stainless steel and Delrin™.

Flow Rate versus Depth

The flow rate is independent of depth, because the system moves approximately 200 mL of water per sample through the Teflon™ tubing.

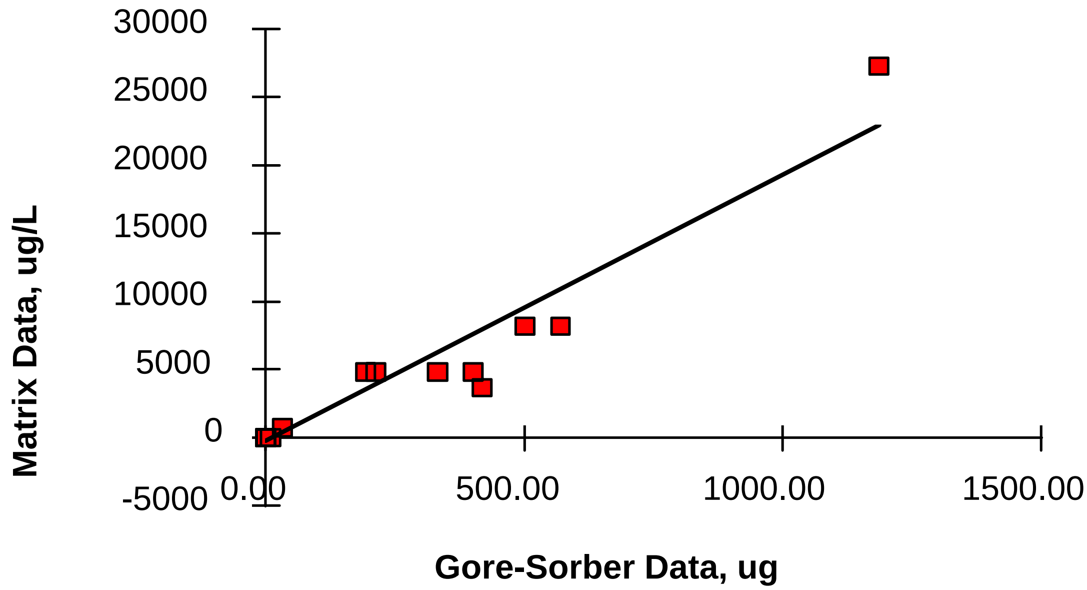
W. L. Gore – Gore Sorber

The GORE-SORBER® Screening Survey has been validated and applied on over 1,000 projects since 1992. When placed in the screened, saturated interval of a monitoring well or piezometer, the waterproof, vapor-permeable GORE-TEX® (ePTFE) membrane collector housing allows for water/air partitioning (in accordance with Henry's Law) of dissolved-phase organic compounds while preventing transfer of liquid water and eliminating impact from suspended solids on the adsorbent. Outlined below are some general guidelines for the use and installation of passive, adsorbent-based GORE-SORBER collectors in monitoring wells as a means of qualitatively screening water quality as part of a ground water monitoring program.

- GORE-SORBER collectors can be used to reduce the frequency of ground water purging and sampling for petroleum and chlorinated organic chemicals, including PAHs.
- We recommend an initial round of testing consisting of matrix (water) sampling and testing by conventional means and testing using GORE-SORBER modules. The deployment and retrieval of the GORE-SORBER modules should occur prior to any purging/sampling of the well for matrix testing purposes. This is done in order to establish a baseline relationship at this site between the matrix concentration data and the sorber mass data. The results will then be plotted on a scatter diagram to show the site-specific relationship between ground water concentration and mass on the GORE-SORBER module (see an example scatter plot below).
- Subsequent testing is performed only using GORE-SORBER modules to monitor trends in water quality over time on an individual well basis.

- Periodic purging and sampling with concurrent GORE-SORBER collector monitoring is recommended every four to six sampling events. To ensure comparability of the data, the periodic matrix samples must be collected and analyzed in a consistent manner.
- GORE-SORBER modules should be placed adjacent to the screened interval in the monitoring well, not in the headspace of the well or outside the screened interval. This is done to avoid any stagnation effects. The modules should not be installed to a depth greater than 25 feet below the water surface.
- Modules should not be placed in direct contact with free product (that is, liquid hydrocarbons or solvents).
- Only a two-day exposure period is required for modules deployed directly in the groundwater. This exposure period has been derived experimentally as part of our validation.
- GORE-SORBER® Screening Modules can be used to test for BTEX, Petroleum Hydrocarbons, chlorinated solvents and many semi-volatile organic compounds, such as PAHs. Application for ethers, alcohols, ketones or most other highly water-soluble compounds has not been validated at this time.
- Information relative to the site, the well construction, and matrix sampling and testing procedures being used, will be useful for data interpretation purposes.
- Monitoring wells being used as soil vapor extraction points are NOT suitable to this application.

TCE COMPARISON



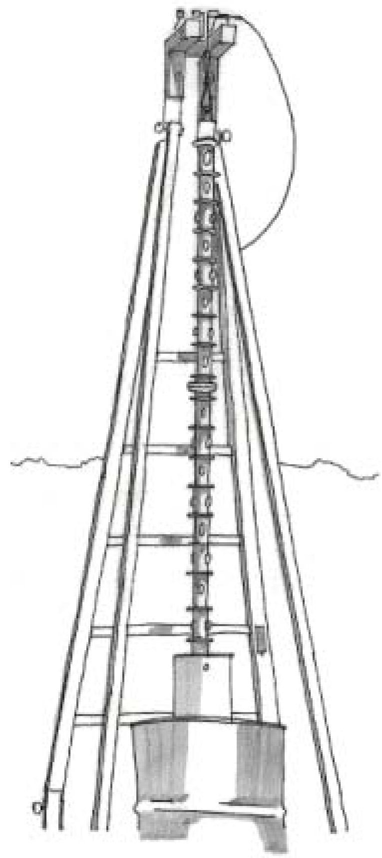
Margan – Diffusional Multi-Level Sampler

1. Background

DMLS is a passive multi-layer sampler for groundwater that is based on dialysis cell technology. It was developed as a research tool by a group of scientists at the Weizmann institute who studied processes in the water table zone. Since its introduction in 1985, the DMLS has been incorporated into many studies throughout the world, providing information never available before. Margan has a world wide exclusive license to commercialize the DMLS.

2. The DMLS principle

A dialysis cell is a vial that is filled with distilled and covered by permeable membranes at both ends. When a dialysis cell is exposed to an external water having concentration of solutes different from the that inside the cell, a natural process of diffusion of solutes from the high concentration to the low one occurs across the membrane, until a dynamic equilibrium is reached. At this stage the contents of the cell will be representative of the water surrounding the cell. The process is dynamic and concentration of solutes inside the cell will change as the concentration outside the cell changes with a lag period (the equilibration period) which varies from one solute another.



The DMLS comprises a rod on which dialysis cells are placed. The cells are separated by seals which fit the inner diameter of the well. When lowered into the well, the seals form layers corresponding the layers of the aquifer. Therefore, each cell accommodated between two seals, samples the layer formed.

While being lowered into the well, the DMLS (as any other externally introduced device) mixes the water column inside the well. Therefore it must be left in the well for the minimum period of time required for the natural flow of the aquifer to exchange at least one volume of water and to reestablish the natural stratification of the solutes of the aquifer. This minimum period of time depends on the nature of the aquifer and the diameter of the borehole. No active purging is required when using the DMLS.

After the DMLS is retrieved from the well, the cells are capped and sent to the lab, or analyzed in the field. When plotted, the results show a vertical profile of the chemical composition of the groundwater at a resolution of 1 ft or higher. It is also possible to obtain a vertical profile of horizontal component of specific discharge, by a reverse diffusion of a tracer which is loaded in the cell and by applying the modified point dilution technique.

The DMLS is modular and flexible in use. Its units can be connected one to the other to fit existing wells and any sampling program.

Section 4 Site Description

A single site, the NASA John C. Stennis Space Center (SSC) in southwestern Mississippi has been selected for use in this demonstration. The demonstration will incorporate three testing phases at this site. The first testing phase will involve preliminary testing at a 100-ft standpipe, operated by the US Geological Survey (USGS) and selected GW monitoring wells at Stennis prior to the vendors being onsite. This pre-demonstation effort will help to define sampling procedures used in the following demonstration activities. The second phase will involve all vendors and will incorporate the use of the standpipe as an above-ground well that can be accessed by external sampling ports. The third phase will involve the use of onsite GW monitoring wells known to be contaminated with a chlorinated VOC. This section provides a brief description of the facilities to be used in these two demonstration phases.

The NASA-Stennis Space Center

The John C. Stennis Space Center in South Mississippi is one of ten NASA field centers in the United States. It is NASA's lead center for testing and flight certifying rocket propulsion systems for the Space Shuttle and future generations of space vehicles. Because of its important role in engine testing for more than three decades, SSC has been designated NASA's Center of Excellence for rocket propulsion testing. Stennis is also NASA's lead center for rocket propulsion testing and has the responsibility for conducting and/or managing all NASA propulsion test programs.

Over the years, SSC has evolved into a multiagency, multidisciplinary facility for federal, state, academic and private organizations engaged in space, oceans, environmental programs and the national defense. In addition to NASA, there are 30 other agencies located at Stennis. Of approximately 4,100 employees, about l,500 work in the fields of science and engineering. These agencies work side by side and share common costs related to infrastructure, facility and technical services, thus making it economical for each tenant to accomplish its independent mission at SSC.

US Geological Survey Standpipe

The USGS is a resident agency at SSC and operates a number of testing facilities, as a part of the Hydrologic Instrumentation Facility (HIF). This facility supports USGS agency-wide hydrologic data-collection activities through the identification of needs, development of technical specifications, design or development of specialized interfaces, contracts and procurements, testing and evaluation, specialized field applications, repair and calibration, quality control and assurance, and storage and distribution of hydrologic instrumentation.

The HIF Standpipe Facility was designed by Doreen Tai, an HIF chemical engineer, and is housed in a Saturn V rocket storage building at SSC. A schematic diagram of the standpipe and accessories is shown in Figure 2. The standpipe is an above-ground, 100-foot long, 5-inch diameter, stainless steel pipe with numerous external sampling ports along its length. Two large tanks at the top of the standpipe are used to prepare solutions prior to filling the standpipe. The tanks are equipped with floating lids to minimize loss of volatile compounds during solution preparation and transfer. An external fill/drain line enables the pipe to be filled from the bottom up, thereby minimizing flow turbulence in the prepared solutions. The external access ports allow control samples to be taken simultaneously with the collection of samples inside the pipe. As shown in Figure 2, the indoor facility has six levels of access, including the ground floor, and all levels are serviced by a freight elevator. In this demonstration, the standpipe will be used in a series of controlled water sampling experiments. VOC-contaminated water solutions will be prepared in the standpipe. Technology vendors will sample from the pipe while reference samples are simultaneously taken from the external ports.

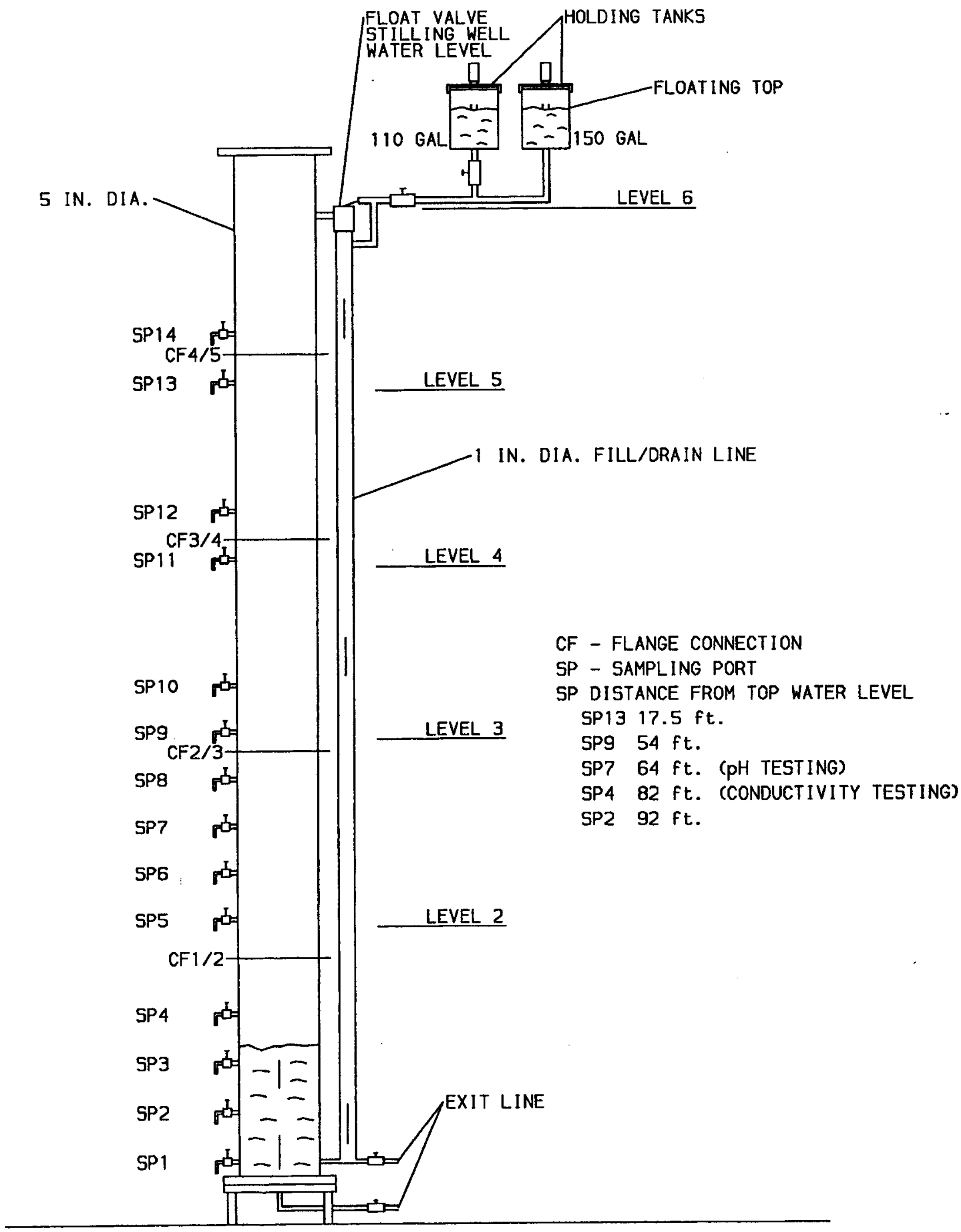


Figure 2 A schematic diagram of the USGS Standpipe (Drawing courtesy of USGS-HIF). Note that two new sampling ports, not shown in the figure, have been added midway between SP 10 and 11 and SP 12 and 13.

Site Geology

In 1998, Foster Wheeler Environmental Corporation published an investigation report on the hydrogeologic characteristics of the Stennis Space Center [Foster Wheeler, 1998]. The following text is adapted from this report.

Literature on the regional and local geology and hydrology were surveyed to determine the stratigraphic relationships as defined by published works for southern and coastal Mississippi. Using field data recorded on lithologic boring logs from over 190 borings, a database of hydrogeologic data was constructed for SSC with a commercial software package. This database was then utilized to construct site-specific cross-sections for each of the 16 investigation sites within the SSC. The shallow near surface geology of can be summarized as follows: This geology generally consists of a thin veneer of clayey sediments (Upper Clay) overlying a sandy unit named the Upper Sand. The Upper Sand is underlain by a second clayey unit named the Lower Clay and a second sandy unit called the Lower Sand. Below the Lower Sand another clayey unit is present which represents an unnamed or undifferentiated Pleistocene deposit. This deposit is underlain by a thick zone of interbedded sand and clay deposits which form the Citronelle Formation. Table 4 includes summary of the relationship between stratigraphic and hydrogeologic units at SSC.

Table 4 Hydrogeologic Units as SSC

Epoch	Lithologic Units	Regional Hydro-geologic Unit	SSC Hydrogeologic Unit	Approximate Elevation Range (relative to MSL, feet)
Holocene	Recent	Surficial Aquifer	Surface Soil	+10 to +30
Pleistocene	Upper Clay	Surficial Aquifer	Semi-Confining Upper Clay Unit	+10 to +30
Pleistocene	Upper Sand	Surficial Aquifer	1st Water-Bearing Zone (watertable)	+5 to +15
Pleistocene	Lower Clay	Surficial Aquifer	Semi-Confining Unit	-15 to +10
Pleistocene	Lower Sand	Surficial Aquifer	2nd Water-Bearing Zone	-35 to +5
Pleistocene	Undifferentiated Pleistocene/Possible Bioloxi Formation	Surficial Aquifer	Semi-Confing Unit	-20 to –40
Pliocene	Citronelle	Surficial Aquifer	3rd Water-Bearing Zone	-40 to –100
Pliocene	Citronelle	Surficial Aquifer	Semi-Confining Unit	-75 to –130
Pliocene	Citronelle	Surficial Aquifer	4th Water-Bearing Zone	Below –120
Miocene	Pacagoula Clay or Hattiesburg Clay	Chickasawhay River Upper Confining Unit	Semi-Confining Unit	-140 to –300
Miocene/Oligocene	Catahoula Sandstone, Glendon, Marianna, Mint Springs or Forest Hills Formations	Chickasawhay River Aquifer	Chichasawhay River Aquifer	Unknown, below –300 feet

Table adapted from SSC Hydrogeologic Investigation Report [Foster Wheeler, 1998]

Site Hydrology

As a part of the hydrogeologic investigation, data from a series of single well slug tests were evaluated and used with hydraulic gradient determinations, made from the potentiometric surface maps and estimates of the aquifer's porosity, to estimate the minimum and maximum rate of groundwater flow in each of the first three water-bearing zones. *In-situ* hydraulic conductivity or slug tests were conducted on over 80 of the existing monitoring wells at SSC. Of the 80 wells which were tested, more than 70 percent of the wells were screened in Water-Bearing Zone 1, about 20 percent were screened in Water-Bearing Zone 2 , and 10 percent were screened in Water-Bearing Zone 3. Specific details on the methodology used to estimate hydraulic conductivity are included in the previously referenced Foster Wheeler report. Table 5 summarizes the hydraulic conductivity values for each water-bearing zone. Using groundwater gradients from the potentiometric surface maps prepared for each water-bearing zone and estimates of the porosity for each zone, the average groundwater flow was estimated for each water-bearing zone using Darcy's Law.

Table 5 Hydrologic Conductivity Parameters for SSC

Parameter	Water-Bearing Zone 1	Water-Bearing Zone 2	Water-Bearing Zone 3
Number of wells evaluated	59	16	5
Range of hydraulic conductivity (ft/day)	1 – 67	1—49	1—30
Average hydraulic conductivity (ft/day)	11.0	10.9	13.1
Standard deviation of hydraulic conductivity (ft/day	12.9	14.7	13.9
Hydraulic gradient	$2x10^{-3}$—$4x10^{-3}$	$6.2x10^{-3}$	$1.9x10^{-3}$
Estimated range of aquifer porosity	25—35%	25—35%	25—35%
Range of groundwater flow rates (ft/day)	0.006—1.18	0.012—1.22	0.005—0.023
"Best guess" groundwater flow rate (feet/day)	0.18	0.22	0.08

NASA-Stennis GW Monitoring Wells

The third phase of this technology demonstration involves the collection of ground water samples from onsite wells at SSC. The site has about 200 wells that have been used for characterization and ground water monitoring. A list of candidate wells for use in this demonstration is given in Table 6. The wells shown offer a range of sampling depths and penetrate the three top water bearing zones at SSC. The water from these wells is contaminated with TCE to varying degrees. The TCE concentrations given for each of the wells is only an approximation since many of these wells have only been sampled once or twice in the last several years.

Table 6 Candidate GW Monitoring Wells at SSC

Well No.	Relative Sampling Depth	Total Well Depth (feet)	Well Dia. (inches)	Top of Casing (ref. MSL feet)	Approx. Depth to Water (feet)	Screened interval (ref. MSL feet)	Approx. TCE Concentration (µg/L)
12-09MW	Shallow	18	2	28.0	9.8	18.0 to 8.0	10
12-06MW	Shallow	17	2	28.11	9.7	21.0 to 11.0	110
18-08MW	Shallow	19	2	28.75	7.6	18.7 to 8.7	200
06-09MW	Intermediate	18	2	13.0	8.6	4.0 to –6.0	110
06-08MW	Intermediate	17	2	10.5	6.5	1.7 to –8.4	580
06-04MW	Intermediate	39	2	28.8	24.6	-1.3 to –11.3	450
06-16MW	Deep	45	2	242	20.3	-3.3 to –13.3	22
06-12MW	Deep	100	4	28.8	28.0	-57.9 to –67.9	4
06-11MW	Deep	150	4	15.3	14.1	-62.8 to –72.8	36

Section 5 Sampling Plan

Summary Objectives

The objectives of this verification effort are to evaluate key performance parameters of the participating GW sampling technologies. The specific application being evaluated is the sampling of volatile organic compounds from ground water. Important sampler performance parameters include: accuracy, precision, and comparability to reference sampling methods. Other important attributes include: ease of use, personnel and equipment support requirements, and sampler throughput. The verification experiments will be conducted under two testing scenarios: 1) samples collected from an above-ground well, referred to as a standpipe, with known sample constituents and concentrations; and, 2) samples collected from onsite GW monitoring wells.

Experimental Design Summary

The study will be conducted in three phases. The first phase will be a preliminary assessment of the standpipe and selected onsite GW monitoring wells. This phase will be conducted without vendor involvement and will be for the benefit of study designers and field support personnel in order to gain familiarity with the site, understand the characteristics of the standpipe, and identify and characterize candidate onsite GW monitoring wells for use in the later phases of the verification. The second phase will involve collection of water samples from the standpipe by the technology vendors and the third phase will involve vendor sample collection at onsite GW monitoring wells. Further descriptions of the three study phases as given in following paragraphs.

General descriptions of key elements in the demonstration design are introduced and discussed below. A more detailed description of the sampling scheme for the various experimental trials in included elsewhere in this section.

Technology categories

Those vendors participating in the demonstration have been grouped into two categories: Pump/grab samplers and multi-level samplers. The pump/grab samplers include the bladder pumps, a discrete-level bailer and a multi-level sampling pump. The multi-level category includes a diffusional system and integrating system. Table 7 shows the grouping of the participating vendors into the two categories.

Table 7 Sampling Technology Categories

Pump/grab Sampling Technologies	Multi-Level Sampling Technologies
CEE – Bladder pump	W. L. Gore – Sorbent sampler
QED – Bladder pump	Margan – Diffusional sampler
Geolog – Bladder pump	
Sibak – Grab sampler	
Burge – Multi-level sampler	

Experimental factors – pump/grab samplers

The study design includes an evaluation of a number of potentially influential factors on sampler performance. A summary of these are listed in the Table 8. A further breakdown of assigned levels for the various factors is also included in the table.

Table 8 Experimental Factors for Pump/grab and Multi-Level Samplers

Factor	Pump/Grab Samplers	Multi-Level Samplers
Depth	Two Levels	Five Levels
Concentration	Two Conc. Levels Low – 10 ppb High – 200 ppb	
Compound Volatility	Three Volatility Levels Low – 12DCA/112TCA Mid – TCE/Benzene High – PCE/ 11DCE	

This GW well sampling phase of the study will have fewer experimental factors than the standpipe testing phase. Two factors, namely sampling depth and contaminant concentration will be used to select four wells for use in the study. TCE is the only major contaminant at the site, and thus compound volatility will not be a factor in this phase of the study.

Target VOC compounds

The target compounds to be used in the investigation are listed in Table 9. The compounds are all regulated contaminants under the EPA Safe Drinking Water Act and have MCLs of 5 ug/L. The compounds possess a range of volatilities, as delineated by the Henry's Law Constant, also shown in the table.

Table 9 Target VOC compounds

Compound	Volatility (Henry's Constant, atm/ mole frac.)	Boiling Pt. °C
Tetrachloroethene (PCE)	High (1492)	121
1,1-Dichloroethene (11DCE)	High (1270)	32
Trichloroethene (TCE)	Mid (648)	87
Benzene (BNZ)	Mid (309)	80
1,2-Dichloroethane (12DCA)	Low (65)	84
1,1,2-Trichloroethane (112TCA)	Low (54)	114

Standpipe standard mixture preparation

A number of standard mixtures of VOCs in water will be prepared in large mixing tanks located at the top of the standpipe. These mixtures will then be loaded into the standpipe for subsequent sampling by the participating technologies as well as by reference sampling methods. Stock solutions of chlorinated VOCs will be prepared from pure compounds. Known volumes of these stock solutions will be added to the mixing tanks. The total water volume in the mixing tanks will be metered using an in-line flow meter positioned at the tank inlet. Using this technique, the final concentration of VOCs in the SP will be known to an accuracy of about ±5%.

Standpipe reference samples

The use of the standpipe enables the collection of reference samples from sampling ports on the exterior of the pipe while vendor sampling is being conducted inside the pipe. The reference samples will be processed through the same analytical sequence as the vendor samples. Two types of reference samples will be collected. For those technologies classified as pump/grab samplers, the reference sample will also be a pumped sample, collected from the external port adjacent to the point where the vendor sample is taken. A second category of samplers being evaluated is multi-level samplers and at least one of the technologies in this category is an integrating sampler. In this case the reference sample will be a time-integrated sample, collected over the duration which the samplers are in the well. The means of collecting the reference sample has not been determined at this time and is dependant upon the stability of the mixtures in the standpipe. Collection of this time-integrated sample may be by periodic collection of pumped samples with subsequent compositing into a single sample, or by continuous withdrawal of a sample with a syringe pump or similar device. Results from the pre-demonstration test will be used to help in the selection of a reference method for this integrating multi-level sampler type.

GW well reference samples

The selection of a GW well reference sampler is more difficult. Choices include the collection of a syringe sample at the same time and point of sample collection by the technology sample. A syringe sampler is desirable from the point of view that no chemical losses can occur in tubing lines extending from the down-well collection point to the point of sample collection at the well head. The use of syringe samplers is complicated by the requirement for replicate samplers however and for this reason they are unsuitable for use in this experiment. As an alternative, we have chosen a low-flow submersible electric gear pump as a reference sampler. The pump has only stainless steel and inert polymer parts and is very small and compact. The tubing lines from point of sample collection to the surface will be constructed of inert fluorocarbon polymer material. Most importantly, the performance characteristics of the reference pump will be verified during the pre-demonstration phase of the experiment at the standpipe. The pump will be used to sample known mixtures of VOCs with varying volatilities at several sampling depths to assess its accuracy and precision in sample collection at the range of depths used in the GW sampling portion of the study.

GW well reference samples will be collected simultaneously with vendor sample collection. This scheme will require that two samplers (the vendor and reference) will be co-located in the well during the sample collection period.

Sampling procedures

Two types of reference sampling activities will be conducted during this demonstration. The first involves the collection of reference samples from the external ports of the standpipe. These samples will be collected directly into 40-ml VOA vials using the written method included in the appendix. Sampling will also be conducted by the VO using the submersible electric gear pump sampling method described previously.

During the pre-demonstration sampling of GW wells with the submersible electric gear pump, a low-flow purge will be used to insure that formation water is being sampled from each of the wells. In these situations, ground water quality parameters such as temperature, pH, redox potential, and turbidity will be monitored using procedures that are also included in the appendix.

Finally, each vendor organization will also operate their own technology and collect a variety of samples from both the standpipe and GW wells as specified in this demo plan. Each of vendors will follow their own written sampling procedures that are normally used in the operation of their sampling technology. [An exception to this requirement may be made for the multi-level sampler category. To lessen vendor time on site, vendors may request that multi-level samplers be either deployed or retrieved by the verification organization.]

Sample analysis

With one exception, all samples will be analyzed using the same analytical methodology. A field-portable GC/MS and a temperature-controlled headspace sampling accessory will be used in this demonstration. The analytical method used will be a variation of SW846 Method 8260A. Reasons for selection of the field-portable method include the following: 1) The performance of the method, is as good as or better than conventional laboratory purge-and-trap GC/MS methods. This was established in an earlier ETV Program verification study [EPA, 1998c] 2) The costs are equivalent to conventional lab analysis costs. 3) Analytical data will be available in near real time, allowing prompt feedback to experiment planners. 4) All sample analysis will be complete within several days of the end of the field sample collection period, thus allowing results to be processed more quickly. A more complete description of the analytical procedures is given in Section 6. The one exception to this analysis plan is that the Gore Sorber samples will be analyzed by Gore's own laboratory using their proprietary method. The Gore laboratory will report the total loading of the various contaminants on the sorber units and the VO will conduct all further analysis of the data.

Sample Management

Formal chain of custody protocol will be maintained for all samples collected and distributed during the demonstration. A sample chain of custody form is included in Appendix B. Each participant is also required to keep a written logbook during the demonstration in which sample receipt is documented. All samples will be maintained by the sampling team in coolers or insulated shipping containers until delivery to participants. It is the responsibility of each participant to maintain samples at appropriate temperature and storage conditions following release of samples to their custody.

Deviations from the Sampling Plan

Deviations from the sampling plan outlined in this document may occur for a variety of reasons. Deviations will be noted by the field sampling team or the assigned sample management auditor and brought to the attention of the test director such that corrective actions, if warranted, may be taken.

Data analysis

Test data analysis will concentrate on determination of sampler accuracy (or recovery), sampler precision (both with and without analytical method contributions) and comparability of sampler results to a reference method. The sampling plan incorporates the collection of a number of replicate samples by both vendor and reference sampling technique at each level of the standpipe and at each GW monitoring well. The replicates will allow precision parameters to be computed for each of the technologies. Analytical method variability is a complicating factor and its contribution to the overall variability of a particular method must be assessed using statistical techniques. The study design incorporates a suitable number of replicate samples to do this. Analysis of variance methods (ANOVA) will be used to make quantify sources of imprecision in the overall sampling and analysis process.

Phase 1 Pre-Demonstration

A preliminary evaluation of the standpipe will be conducted by SNL in cooperation with the USGS prior to the actual demonstration. The objectives of this investigation for both the standpipe and the onsite GW monitoring wells are listed below:

Pre-demonstration standpipe sampling objectives

- Develop and test operational procedures to be used in the full demonstration.
- Determine the degree of stability of a homogeneous mixture of VOCs in water at fixed sampling points over time.
- Determine the degree of vertical stability of a homogeneous mixture of VOCs in the standpipe over time.

* Determine the rate and extent of intermixing between clean and dirty layers within the standpipe.
* Determine the amount of clean water flushing required to bring the standpipe to background levels of VOCs.
* Assess the accuracy and precision of the reference sampling method to be used in the GW sampling portion of the test.
* Assess the accuracy and precision of the chemical analytical method to be used during the demonstration

Pre-demonstration GW well sampling objectives

* Develop and test sampling procedures to be used in the full demonstration.
* Characterize ground water quality parameters in the candidate wells.
* Characterize TCE concentration levels in the candidate wells.
* Assess the degree of comparability between two identical reference samplers that sample simultaneously from the same wells.

Pre-demonstration test schedule and task list

A detailed task list for the pre-demonstration study is given in the following paragraphs. The procedures to be used during these various tasks are included in the appendix. A diagram showing the standpipe and associated sampling port depths from the top of the pipe is given in Figure 3.

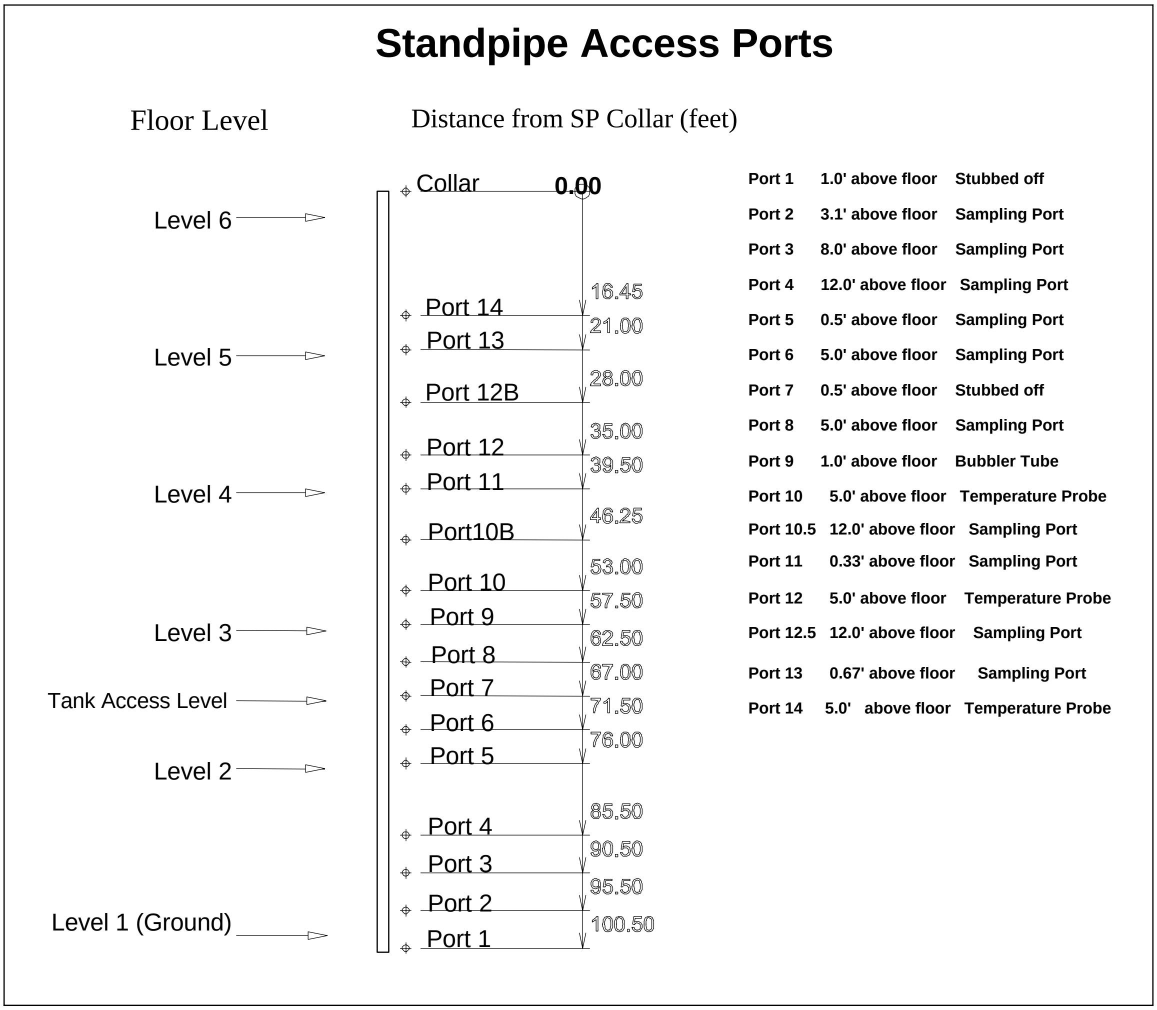


Figure 3 The USGS standpipe showing the depth of sampling ports from the top of the pipe.

Day 1 Tasks

- SP Facility Orientation—Setup working space; verify engineering modifications to SP; write SP mix, fill, drain, and flush procedures.
- GC-MS/Headspace system setup and calibration—To be done by FPA personnel according to written procedures.
- SP clean and flush—Clean and flush the mixing tanks and SP as required for the first test mixture.
- Sampler checkout—Check out reference samplers in preparation for SP and GW well sampling.
- GW well orientation—Determine well locations and best grouping for the following two days of well sampling.

Day 2 Tasks

- Prepare Mix 1 (10 ppb concentration level), sample the mixing tank (3 replicates) and then fill SP. SP sampling to follow the matrix given in Table 10.

Table 10 Pre-demo Standpipe Sampling Matrix – Trial P1

SP Level	T_o	T + 1hr	T+ 2hr	T + 4hr	T + 24hr
Mixing Tank	3				
SP13	3 external 3 reference	3 external 3 reference	3 external 3 reference	3 external 3 reference	3 external 3 reference
SP11	2	3	2	3	2
SP9	2	2	2	2	2
SP5	3 external 3 reference	3 external 3 reference	3 external 3 reference	3 external 3 reference	3 external 3 reference
SP2	2	2	2	2	2

Note: Three replicate external samples and three reference (pump) samples will be collected at the SP13 and SP5 levels. All other replicate samples will be collected from the SP external sampling ports.

- Analyze water samples via onsite GC/MS—Headspace and evaluate data.
- Collect samples from candidate GW monitoring wells using an electric submersible gear pump and a low-flow purge and sampling protocol. Collect replicate sample when turbidity or dissolved oxygen parameter stabilizes to ± 10%, using the sampling matrix given in Table 11.

Table 11 Pre-demo GW Well Sampling Matrix – Trial P4

GW Monitoring Well No.	Well Dia. (inches)	Depth from top of well casing to middle of screen	Approx. TCE Conc. (ppb)	Number of Replicate Samples
12-06MW	2	12.1	110	4
06-16MW	2	35.5	22	4
06-11MW	4	83.1	36	4
06-04MW	2	35.1	450	4

- Analyze GW samples using Headspace—GC/MS and evaluate data.

Day 3 Tasks

- Additional multi-level sample collections from Mix 1 after setting overnight (last column of Table 1).
- Drain Mix 1and flush SP.
- Analyze SP samples for residuals at three levels following each flush using the sampling matrix given in Table 12.

Table 12 Pre-demo Standpipe Flush Sampling Matrix – Trial P2

SP Level	Flush 1	Flush 2	Flush 3 (if necess.)
SP13	2 (replicates)	2	2
SP9	2	2	2
SP2	2	2	2

- Prepare Mix 2 (200 ppb) and Mix 3 (10 ppb) in the two mixing tanks, sample both mixing tanks (3 replicates)
- Fill SP to 50% level with Mix 2, then add Mix3 from the bottom fill port until standpipe is full.
- Collect periodic replicate reference samples (submersible pump and external sampling port) from several sampling levels as specified in the sampling matrix shown in Table 13.

Table 13 Pre-demo Standpipe Dirty/Clean Sampling Matrix – Trial P3

SP Level	T_0		T + 1 hr		T + 2 hr		T + 3 hr	
	Pump	Port	Pump	Port	Pump	Port	Pump	Port
Mixing Tank 1		3						
Mixing Tank 2		3						
SP12	3	3		2	3	3		2
SP9		2		2		2		2
SP5	3	3	3	3	3	3	3	3

- Analyze samples using GC/MS—Headspace and evaluate data.
- Collect samples from candidate GW monitoring wells using an electric submersible gear pump and a low flow sampling protocol. Collect replicate sample when turbidity or dissolved oxygen parameter stabilizes to ± 10%, using the sampling matrix given in Table 14.

Table 14 Pre-demo GW Well Sampling Matrix – Trial P5

GW Monitoring Well No.	Well Dia. (inches)	Depth from top of well casing to middle of screen	Approx. TCE Conc. (ppb)	Number of Replicate Samples
18-08MW	2	15.1	200	4
06-08MW	2	13.8	580	4
06-12MW	4	91.7	4	4
12-09MW	2	15.0	4	10

Day 4 Tasks

- Collect simultaneous replicate samples using two submersible electric gear pumps and a low-flow purge protocol, using the sample matrix given in Table 15. The two pumps will be positioned in the well above and below the desired sampling point.

Table 15 Pre-demo GW Well Sampling Matrix – Trial P6

GW Monitoring Well	Well Dia. (inches)	Depth from top of well casing to middle of screen	Approx. TCE Conc. (ppb)	Number of Replicate Samples	
				Reference 1	Reference 2
18-08MW	2	15.1	200	5	5
06-11MW	4	83.1	36	5	5
06-16MW	2	35.5	22	5	5

- Analyze GW samples using Headspace—GC/MS and evaluate data.

Day 5 Tasks

- Complete sample analysis; complete preliminary data evaluation.
- Secure SP and GW sites.
- Pack up and depart the site.

Post-demo Tasks

- Complete data evaluation.
- Revise and update the demo plan as necessary to accommodate that learned in the pre-demo experiments.

Phase 2 Full Demonstration Standpipe Sampling

In this phase of the study, vendors will be included and samples will be collected from prepared mixtures in the standpipe. Reference samples will be collected at designated sample ports on the exterior of the standpipe simultaneously with the collection of water samples with the technologies under evaluation. Two sets of experiments will be conducted on two different weeks; one week for the pump/grab samplers and a second week for the multilevel samplers.

Standpipe test objectives

The following objectives have been identified for the standpipe testing activities:

- Assess accuracy of each sampling technology for the 6 target compounds by comparison with the true concentration levels in the standpipe.
- Assess precision of each sampling technology through the collection of replicate samples.
- Assess the effects of compound volatility, compound concentration, and sample depth on sampler precision and accuracy.
- Assess comparability of each sampling technology with the reference sample collection method through the collection of co-located samples.

Standpipe sampling matrix – Pump/grab samplers

The sampling design will involve the collection of samples from six different standpipe mixtures and sampling depths by all participating technologies. Each sampling system will be required to collect five replicate samples from the standpipe at the designated collection depths. Replicate reference samples will be collected from the adjacent standpipe external sampling port simultaneously with each technology sample collection. The sampling matrix for pump/grab samplers is given in Table 16. During the experiment, the trials will be conducted blind. Thus, for a given trial the technology vendors will be directed to sample at a designated level but they will not know the concentration level of the VOCs in the standpipe. One of the trials listed in Table 16 is labeled “clean-through-dirty.”

This trial will involve a clean layer of water in the standpipe that is overlaid with a contaminated layer. The vendors will be asked to sample from the clean layer. The results from this trial will be used to assess the extent of sample contamination that results from lowering the sampling unit through the contaminated layer into the clean layer.

Table 16 Pump/grab Sampler Matrix for Standpipe Experiment

Trial No.	Standpipe Port	Sampler Depth	VOC Concentration Level	Number Replicates/ Technology
1	SP14	Low (17 ft)	Low (10 ppb)	5
2	SP3	High (92 ft)	Low (10 ppb)	5
3	SP14	Low (17 ft)	High (200 ppb)	5
4	SP3	High (92 ft)	High (200 ppb)	5
5	SP3	High (92 ft)	Blank	3
6	SP3	High (92 ft)	Blank/Low (Clean through dirty)	3

Note: Burge Environmental will collect samples from multiple levels (SP14, SP12, SP10, and SP3) for each of the six trials shown in Table 16.

Standpipe sampling matrix – Multi-level samplers

The multi-level samplers will be evaluated separately from the pump/grab samplers since their mode of operation differs. In these tests the DMLS and Gore samplers will be positioned in the SP simultaneously. Three different test mixtures will be evaluated at multiple levels, as outlined in Table 17.

Table 17 Multi-Level Sampler Matrix for Standpipe Experiment

Trial	Sampler Ports (Depth-ft)		Concentration Level	Replicates
	DMLS	GORE		
7	SP14 (16.5) SP 12 (35) SP 10 (53) SP 6 (71.5) SP 2 (95.5)	SP 14 (16.5) SP 12B (28) SP 12 (35) SP 10B (46.3) SP 10 (53)	Low	4 (for each technology at each level)
8	SP14 (16.5) SP 12 (35) SP 10 (53) SP 6 (71.5) SP 2 (95.5)	SP 14 (16.5) SP 12B (28) SP 12 (35) SP 10B (46.3) SP 10 (53)	High	4 (for each technology at each level)
9	SP 13 (21) SP 9 (57.5)	SP 13 (21) SP 9 (57.5)	Blank/Low (Clean through dirty)	4 (for each technology at each level)

Note: Control for the DMLS will be 4 replicates collected with the reference sampler following DMLS equilibration. Control for Gore will be 2 replicates taken with reference sampler every 12 hours (6 sets of samples per trial) from which a time-averaged well concentration will be computed.

Phase 3 Full Demonstration—GW Well Sampling

In this third phase of the demonstration, samples will be collected from a number of monitoring wells at the NASA-Stennis site. Trichloroethene is the primary contaminant at this site. Wells for use in the verification test have been selected to cover a range of TCE concentrations and sampling depths. The historical data from previous well characterization studies has been used to aid in well selection.

GW well sampling test objectives

The following objectives have been identified for the GW well sampling test activities:

- Assess the performance of each sampling technology in terms of ease of use, logistical requirements, sample throughput, etc.
- Assess the comparability GW well sample results for each sampling technology with the results obtained with a co-located reference sampler.

GW sampling matrix – Pump/grab samplers

This phase of the demonstration incorporates the collection of contaminated water samples by both vendor and reference method from onsite GW wells. The two samplers (vendor and reference) will be co-located in the well, with the reference sampler positioned below the vendor's sampler. The vendor technologies will be sequenced through the well and the reference sampler will remain in place in the well throughout the sampling sequence. Replicate samples will be simultaneously be collected by the vendor and reference. The vendor has the discretion to choose his own purging protocol in preparation for sampling. The reference sampler will not purge the well, except to purge the sampling lines between the down-well pump and the sample collection vessel prior to collection of each set of replicate reference samples. Each vendor will be cycled through the well with the reference sampler left in the well throughout the collection of all vendor samples. The sampling matrix for the GW well sampling is given in Table 18.

Table 18 Full Demonstration Pump/grab Samples from GW Wells

Trial	Well	Distance from top of well to screen mid point (feet)	Distance from top of well to water (feet)	Approximate TCE Conc. (ppb)	No. of Replicates per technology
10	18-08MW	15.1	8.2	200	4
11	06-11MW	83.1	15.2	36	4
12	06-04MW	35.1	24.6	450	4
13	12-06MW	12.1	10.0	110	4

GW sampling matrix – Multi-level samplers

The GW well sampling phase for the multi-level samplers will be carried out much like that prescribed for the standpipe sampling effort with all three systems deployed simultaneously. Two of the multi-level samplers (Margan and Gore) have a requirement to be in the well at the sampling location for at least 72 hours so in the interest of time savings, a number of samplers will be deployed over the same time interval in separate wells. A reference sampler will also be positioned in the wells to collect periodic reference samples over the duration that the samplers are in the well. The sampling matrix for this phase of the experiment is included in Table 19.

Table 19 Full Demonstration Multi-level Samples from GW Wells

Trial	Well	Distance from top of well to screen mid point (feet)	Distance from top of well to water (feet)	Approximate TCE Conc. (ppb)	No. of Replicates per technology
14	18-08MW	15.1	8.2	200	4
15	06-11MW	83.1	15.2	36	4
16	06-04MW	35.1	24.6	450	4
17	12-06MW	12.1	10.0	110	4

Note: The Burge sampler will collect four replicates sequentially. The Gore and Margan samplers will position four separate units simultaneously in the well.

Schedule

The anticipated schedule for the pre-demo and full demonstration testing is given in the following Tables 20 and 21. The tables are laid out as follows: The first column gives the date of testing, the second gives the trial numbers scheduled for that date (as outlined in the foregoing material), the third gives another table reference which outlines the specific sampling matrix for the trial. The fourth column gives the sample count, the fifth gives an estimate of the amount of waste water to be generated, and last gives the groups participating in the test. The test is expected to take place over a total period of three weeks with the first week allocated to the pre-demonstration tests, a second week allocated for the pump/grab samplers to collect samples from both the standpipe and GW wells, and a third week allocated for the multi-level sampling technologies to collect samples from both the standpipe and GW wells.

Table 20 Pre-demo Schedule

Date	Trial Numbers	Table Reference	Sample Count	Approx. Waste Volume (gal)	Participants
July 12, Mon			0	0	VO only
July 13, Tue	P1 P4	Table 10 Table 11	77 16	0 10 (MW)	VO only
July 14, Wed	P2 P3 P5	Table 12 Table 13 Table 14	18 54 22	120 (SP) 120 (SP) 10 (MW)	VO only
July 15, Thu	P6	Table 15	30	10 (MW)	VO only
July 16, Fri			0	0	VO only
Total Number of Samples (Pre-demo)			217		

Table 21 Full Demo Schedule

Date	Trial Numbers	Table Reference	Sample Count	Approx. Waste Volume (gal)	Participants
August 9, Mon	1 2	Table 16 Table 16	60 60	120 (SP) 120 (SP)	VO + Pump/grab
August 10, Tue	3 4	Table 16 Table 16	60 60	120 (SP) 120 (SP)	VO + Pump/grab
August 11, Wed	5 6 10 11	Table 16 Table 16 Table 18 Table 18	36 36 48 48	120 (SP) 120 (SP 10 (MW) 10 (MW)	VO + Pump/grab
August 12, Thu	12 13	Table 18 Table 18	48 48	10 (MW) 10 (MW)	VO + Pump/grab
August 13, Fri			0	0	VO + Pump/grab
Total Number of Samples (Pump/grab)			504		
August 14, Sat			0	0	VO + ML
August 15, Sun			0	0	VO + ML
August 16, Mon	7 14	Table 17 Table 19	64 16	0	VO + ML
August 17, Tue			0	0	VO + ML
August 18, Wed			0	0	VO + ML
August 19, Thu	8 15 16	Table 17 Table 19 Table 19	64 16 16	120 (SP) 10 (MW) 10 (MW)	VO + ML
August 20, Fri			0	0	VO + ML
August 21, Sat			0	0	VO + ML
August 22 Sun	9 17	Table 18 Table 19	24 16	120 (SP) 10 (MW)	VO + ML
August 23, Mon			0	0	VO
Total Number of Samples (ML)			216		

Note: A more detailed schedule for GW well sampling will be developed after the pre-demo and prior to the full demo.

Field Observations

The field verification test will also incorporate field observation of technology performance in addition to the sampling activities outlined above. Personnel from SNL and the EPA will observe each technology in operation both at the standpipe and at the onsite monitoring wells to assess its performance in a number of qualitative categories including: ease of use, support equipment requirements, field personnel support requirements, and decontamination methods. Two separate field auditors will spend at least 4 hours observing the operation of each technology throughout the course of the verification test. A suggested list of items to be covered in the technology audit is included below.   Auditor observations will be summarized in the verification report.

Audit Checklist (all may not apply to this technology category)

- Description of equipment used (weight, size, number of pieces)
- Logistical considerations including setup time, power requirements, and other accessories needed, but not provided by the developer
- Historical uses and applications of the technology
- Maintenance activities associated with the equipment
- Estimated acquisition, deployment and maintenance costs associated with the equipment
- Number of people required to operate the equipment
- Qualifications and training of technology operators
- Description of data each technology can produce and a description of the operational mode required for producing this data
- Analytes which the technology can detect
- Approximate detection levels of each analyte
- Initial calibration criteria
- Calibration check criteria
- Corrective action used for unacceptable calibrations
- Other QC measures employed
- Corrective action for QC data failure
- Description of the number of samples that can be collected in a work day
- Description of the amount of time required for data interpretation
- Description of the reports and graphics that each technology will produce
- Specific problems or breakdowns occurring during the demonstration
- Matrix interferences found during the demonstration

Section 6 Sample Analysis

Introduction

Approximately 700 water samples will be collected by a variety of sampling technologies over a ten-day demonstration period. Each sample will require analyses for a specific short list of Volatile Organic Compounds (VOC's) by field-portable gas chromatography/mass spectrometry (GC/MS) using an equilibrium headspace interface. The use of two field-portable GC/MS systems will provide rapid, definitive data for the compounds of interest for approximately 60 to 70 samples per day.

Analytical Qualifications

Field-Portable Analytical, Inc. (*FPA*) is uniquely qualified for this project. As the name states, *FPA* is dedicated to the analysis of samples at the site of investigation utilizing the latest field-portable instrumentation. The principals of *FPA* have significant experience using both fixed laboratory and field-portable equipment. They understand all aspects of high quality, rapid analysis at the site of investigation. Their experience positions them to be able to understand the abilities and limitations and take full advantage of this technology.

Analytical Procedures

Water samples will be collected in 40 milliliter VOA bottles and delivered to *FPA* personnel at a predetermined location on-site. Samples will be analyzed for a specific short list of VOC's by field-portable GC/MS utilizing an equilibrium headspace interface. Rapid, on-site analysis will provide 'over the shoulder' information to the project team. Two field-portable GC/MS's will easily keep up with the heavy sample volume produced during this demonstration and will provide real time feedback to the project team. A complete written method, adapted from SW846 Method 8260 is included in Appendix D.

All phases of this project will be overseen by Mr. David Curtis or Mr. Craig Crume of Field-Portable Analytical, Inc. Both individuals have extensive experience in performing testing and analysis at the site of investigation.

Analytical System

FPA utilizes an Inficon Hapsite GC/MS. This is a truly portable GC/MS designed specifically for the analysis of volatile compounds. The Hapsite is a full featured quadrupole GC/MS capable of meeting all of the EPA's stringent SW-846 QC criteria even though it weighs only 37 pounds and can be carried over the shoulder.

The Hapsite GC/MS uses a sampling wand with an internal pump to collect the sample. The sample is pulled into a sample loop with variable injection capabilities. The column is a 30 meter OV-1 with a 3 meter backflush column. The backflush column allows the volatile organic target compounds to get onto the column, then backflushes off the non-target semivolatile compounds. This keeps the instrument free of contamination and eliminates the need to 'bake out' the contamination between analyses. The interface between the GC and MS is a methyl silicone membrane. This membrane allows organics to migrate through to the MS while sweeping most non-organics out through the vent.

By minimizing what gets into the MS, this instrument is able to utilize a chemical 'getter' pump rather than a mechanical pump. The getter pump maintains adequate vacuum for weeks at a time. It is very compact and allows the GC/MS to be used in a portable mode without the need to drag heavy mechanical pumps around.

The run time on the Hapsite GC/MS is typically about 10 minutes even for a very aggressive list of compounds. Since the column is isothermal and the heavier compounds never reach the analytical column, there is no cool down time and the next analysis can be started immediately after the last for maximum throughput.

In addition to target compounds, the Hapsite GC/MS produces standard NIST searchable spectra to identify and semi-quantitate unknown compounds. The Hapsite GC/MS co-injects 2 compounds as internal standards with every analysis. These compounds are used for semi-quantitation of any unknowns and as additional QA/QC for each analysis.

In addition to full scan mode, the Hapsite can be operated in Selected Ion Mode (SIM). In this mode, a few selective compounds can be monitored at lower concentrations. It is common to obtain an order of magnitude more sensitivity in this mode.

The Hapsite GC/MS can also be operated in MS only mode. This mode is well suited towards compound specific real time 'sniffing'. The instrument can be carried over the shoulder and operated in continuous mode directly at the site of concern. This allows for a real time, target specific screening for contamination in the ppbv range.

The Hapsite GC/MS will be connected to a heated, equilibrium headspace sampler. The sampler allows analytes of interest to migrate from the water sample into equilibrium with the headspace above the water. The samples are allowed to equilibrate at 60°C for at least 20 minutes before analysis. All standards, blanks, and samples are treated identically.

Quality Assurance/Quality Control

The GC/MS will be calibrated for the specific short list of VOC's. A five point calibration will be performed. The five concentration levels will span the linear range of the instrument. The linear range of the instrument is from 5 to 10 ug/L (dependant on the compound) to 1000 ug/L. The calibration will have a relative standard deviation (RSD) of less than or equal to 30%.

There will be a mid-level calibration check standard analyzed on the GC/MS at the beginning and end of each day of analyses. The acceptance criteria for the calibration check standards will be ± 30% of the expected concentration for the specific compounds of concern.

The instrument tune will be verified using to Bromofluorobenzene (BFB) at the beginning of each day of analyses. Standard SW-846 acceptance criteria will be used.

In addition, internal standards and surrogates will be added to every sample analyzed on the GC/MS. These internal standards and surrogates will be used to monitor and adjust for any drift within the mass spectrometer. Acceptance criteria for the internal standard recovery will follow the criteria set forth in Method 8260A.

A blank sample will be analyzed daily prior to analysis of any samples. A blank sample will also be analyzed after any high level samples. The acceptance criteria for the blank samples will be that there are no compounds above the detection limits.

Reporting

Preliminary data will be provided as it is available. Preliminary data will also be provided in spreadsheet form upon completion of each day of analyses. A complete report, describing the procedures and methods used, the data collected, and the analytical results will be prepared within ten working days of completion of the project.

Facility Support Requirements
Field-Portable Analytical, Inc. will require the following at the USGS the facility in Mississipi:

1) At least eight feet of bench inside a building on-site for equipment set-up and operation
2) Four 115 volt power outlets
3) 24-hour access to the analysis area during entire sampling event

Waste Handling and Management
A minimal amount of waste will be generated in the preparation and analysis of the water samples. These wastes will be collected in suitable containers that will be obtained and set up by the USGS. USGS will label the drums in the field to indicate waste description (i.e decontamination water), well number, and date. USGS will obtain Waste Disposal Forms from Johnson Controls, and submit completed forms to Johnson Controls for all wastes generated during sampling activities. USGS will provide to Johnson Controls a 'drum log' of all waste drums generated, and for each drum include drum contents, drum location, and the analytical results of the water sampled at the station where the waste was generated.

A hazardous waste determination will be made by Johnson Controls, Inc. based on the characteristic of toxicity. Wastes produced during the sampling of each well/stand pipe will be considered a hazardous waste if the sample obtained from the well/stand pipe contains any contaminant listed in 40CFR 261.24, shown in Table 22 in a concentration that exceeds its respective regulatory level. The analysis of the water samples from the testing activities will be sufficient to make this determination (a TCLP analysis of wastewater will not be required).

Waste Disposal
Based on the hazardous waste determination previously mentioned, Johnson Controls Inc. will appropriately dispose of the wastes. All Johnson Controls, Inc. support associated with waste disposal will be funded by USGS. Non-hazardous wastes will be treated in SSC's on site waste water treatment system or pre-treatment system. Hazardous waste will be disposed off site at a permitted facility. The cost of the disposal of hazardous waste will be funded by USGS.

Table 22 Hazardous Waste Action Levels from 40CFR261.24

EPA HW No.	Contaminant	CAS No.	Level (mg/L)
D004	Arsenic	7440-38-2	5.0
D005	Barium	7440-39-3	100.0
D018	Benzene	71-43-2	0.5
D006	Cadmium	7440-43-9	1.0
D019	Carbon tetrachloride	56-23-5	0.5
D020	Chlordane	57-74-9	0.03
D021	Chlorobenzene	108-90-7	100.0
D022	Chloroform	67-66-3	6.0
D007	Chromium	7440-47-3	5.0
D023	o-Cresol	95-48-7	200.0
D024	m-Cresol	108-39-4	200.0
D025	p-Cresol	106-44-5	200.0
D026	Cresol		200.0
D016	2#4-D	94-75-7	10.0
D027	1,4-Dichlorobenzene	106-46-7	7.5
D028	**1,2-Dichloroethane**	**107-06-2**	**0.5**
D029	**1,1-Dichloroethylene**	**75-35-4**	**0.7**
D030	2,4-Dinitrotoluene	121-14-2	0.13
D012	Endrin	72-20-8	0.02
D031	Heptachlor (and its epoxide)	76-44-8	0.008
D032	Hexachlorobenzene	118-74-1	0.13
D033	Hexachlorobutadiene	87-68-3	0.5
D034	Hexachloroethane	67-72-1	3.0
D008	Lead	7439-92-1	5.0
D013	Lindane	58-89-9	0.4
D009	Mercury	7439-97-6	0.2
D014	Methoxychlor	72-43-5	10.0
D035	Methyl ethyl ketone	78-93-3	200.0
D036	Nitrobenzene	98-95-3	2.0
D037	Pentrachlorophenol	87-86-5	100.0
D038	Pyridine	110-86-1	5.0
D010	Selenium	7782-49-2	1.0
D011	Silver	7440-22-4	5.0
D039	**Tetrachloroethylene**	**127-18-4**	**0.7**
D015	Toxaphene	8001-35-2	0.5
D040	**Trichloroethylene**	**79-01-6**	**0.5**
D041	2,4,5-Trichlorophenol	95-95-4	400.0
D042	2,4,6-Trichlorophenol	88-06-2	2.0
D017	2,4,-TP (Silvex)	93-72-1	1.0
D043	Vinyl chloride	75-01-4	0.2

Section 7 Data Management and Analysis

Introduction

Nearly all the activities outlined in this section will be performed by SNL. As part of this demonstration, SNL will establish a data management system that will include computerized data files as well as hard copy data, such as field and laboratory notebooks. This data management system will be used to store sample and analytical data obtained from each technology and the onsite analytical laboratory.

Field Data Categories

Site Environmental

Meteorological data that are pertinent to the demonstration periods. Other site data of interest in terms of technology performance (e.g. terrain where deployed, availability of power, water, etc.)

Groundwater Sample Collection/Distribution

Field logbook data describing sampling procedures, deviations from SOP, well purge times, bulk sample mixing and dispensing operations. A complete record of sample numbers and chain of custody forms are included here.PE Sample Preparation/Distribution
Field logbook data describing: PE sample preparations procedures, PE mix certificates of analysis, mixing and dispensing operations.

Technology Audit Results

A written narrative of the time spent by the auditors with each participating technology. The narrative will assess the various qualitative aspects of each technology and its performance as described in Section 6.

Experimental Plan Deviations

A written record of where deviations occurred in the actual demonstrations as compared to that called out in the demonstration plan.

Laboratory Data Categories

Laboratory Sample Analysis Results

Analytical data similar to that provided by each technology.

Laboratory QC Data

The accompanying QC data such as spike recovery, continuous calibration checks, lab precision checks, etc.

Laboratory Audit Results

A written narrative of sample analysis results from the portable GC/MS system performed prior to the demonstration.

Sample and Data Management

The verification organization will be responsible for all sample custody until the samples are delivered to the onsite laboratory. Sample containers and COC forms will be given to each sampling technology vendor for each particular trial of the experiment. The technology operators will be responsible for verifying the accuracy of sample collection information on the chain of custody form prepared by the verification organization prior to turning the COC and the samples over to the verification organization for analysis.

Field and Laboratory Data Management

All samples will be collected and documented as described in Section 6. The sample number will be a alpha-numeric code that will uniquely identify the sample with regard to the site, trial number and location of its collection.

Data Management

A logbook will be used to document sample receipt for each sample submitted for analysis. Laboratory tracking will be performed by the operator responsible for sample analysis. Samples will be analyzed and the data obtained will be reduced, validated, and reported as described in Section 6. Sample result tables will then be transferred from the report forms generated by the operators to the computerized data management system by computer file transfer or by data entry transcription. In either case, all data transferred to the data management system will be checked for transcription errors before the actual statistical evaluation is performed.

Qualitative and Quantitative Analyses and Evaluations

Samples submitted for chemical analysis will be analyzed by a reference laboratory. Each shipment of samples sent to the laboratory will be accompanied by a chain-of-custody form, which will be completed by the laboratory's sample custodian and returned to the SNL project manager. Samples will be entered into the laboratory's Laboratory Information Management System. This system tracks the progress of sample analysis within the laboratory and provides a reporting format for sample results. After samples are analyzed, the data will be reduced, validated, and reported as described in Section 6.

Validated sample results will be sent to SNL for entry into its data management system. In addition to sample results, SNL will request QA/QC summary forms for the reference analysis. These forms will enable SNL to verify the quality of data generated by these methods. SNL will then transfer this data into its data management system. All data transcribed will be double-checked for accuracy in SNL's data management system.

Data analysis

The following performance parameters will be assessed during the standpipe phase of the experiment: Precision, Accuracy, Representativeness, Completeness and Comparability. Precision is defined as the degree of agreement from independent measurements using a repeated application of a process under specified conditions. Sampler precision will be obtained through the use of replicate samples. The relative standard deviation for each VOC compound reported from the analysis will be used as a measure of sampler precision. This precision estimate will include laboratory variation. Additional statistical tests will be performed to apportion the variability of the replicate measurements between the sampler and the laboratory.

Accuracy is defined as the degree of agreement of a measured value with the true or accepted value of the quantity of concern. Sampler accuracy will be determined relative to the reference samples from the standpipe and will be expressed as percent recovery relative to the reference value.

Representativeness is defined as the degree to which the data from a process accurately and precisely represent the parameters in the entire population being sampled.

Completeness is defined as a measure of the amount of data obtained in a measurement process compared to the amount of data that was expected to be collected under the conditions of the measurement. The completeness of the sampling system will be expressed as a ratio of the number of samples delivered versus the number of samples specified in the verification plan.

Comparability is defined as the confidence with which one data set can be compared to another reference data set. A measure of the comparability of the technology data with the reference data will be done using statistical techniques. A 3-way analysis of variance approach will be used to evaluate the effects of the independent variables (technology type, sampling depth, and compound volatility) on overall performance sampler performance at high and low VOC concentrations. The analysis of variance approach allows a comparison of the variance encountered between groups and among groups to assess whether observed differences in technology results can be explained by random variability or by a real effect. Additional post-hoc tests such as Tukey's Honest Significant Differences Test will be used be used to further identify which sampling technologies significantly differ from the reference method.

Section 8 Quality Assurance Project Plan

The QAPP for this demonstration specifies procedures that will be used to ensure data quality and integrity. Careful adherence to these procedures will ensure that data generated from the demonstration will meet the desired performance objectives and will provide sound analytical results.

Purpose and Scope

The primary purpose of this QAPP is to outline steps that will be taken by the operators of the various ground water sampling technologies and the common analytical technology to ensure that data resulting from this demonstration is of known quality and that a sufficient number of measurements are taken for a credible technology performance assessment. The QAPP also details the QA/QC criteria that will be used to validate the reference laboratory results. This project-specific QAPP is based upon the guidance contained in two documents. The first is the Environmental Technology Verification Program Quality Management Plan for the Pilot Period 1995-2000 [EPA, 1998a], and the second is the Environmental Technology Verification Program Quality Management Plan for the Site Characterization and Monitoring Pilot [EPA, 1998b].

The scope of the QAPP includes a comparison of ground water sampling technology results to those generated by a reference sampling method. The collected samples from the various participating technologies and the reference technology will undergo analysis by a common field analytical GC/MS procedure. During the verification testing, each technology operator follow a formal written sampling procedure that has been prepared by the developer and submitted to the VO prior to the start of the verification test. The field analytical laboratory will use a modified EPA SW-846 Method 8260 that incorporates gas Chromatography/mass spectrometry for VOCs in water via headspace analysis. The complete analytical method is included in Appendix D.

Data generated by each technology will be evaluated to determine the level of data quality it is capable of generating. Each technology is expected to produce data quality that parallels the results from SW-846, Method 8260. An additional means of technology performance evaluation is afforded by the inclusion of many Performance Evaluation samples (of known content) in the experimental design. Adherence to the QA/QC requirements of this QAPP will ensure that definitive level data quality is generated by the reference laboratory.

Quality Assurance Responsibilities

SNL as the Verification Organization is responsible for the preparation of this QAPP for the demonstration. The guidelines in the Site Characterization and Monitoring Pilot Quality Management Plan and the overarching ETV Quality Management Plan cited previously have been used in the preparation of this plan.

It is important that the project principals understand and agree on the experimental approach. For this reason, the Technology Demonstration Plan Approval Form must be signed by all key personnel. These signatures, which must be obtained before the final Demonstration Plan is submitted, indicate that the key personnel have read the appropriate sections of the Demonstration Plan and are committed to full cooperation and implementation of the study design elements.

The QA/QC oversight of all demonstration activities will be provided by Tom Burford, the QA/QC officer at SNL for this demonstration. Many individuals will be responsible for sampling and analysis QA/QC throughout the demonstration. The primary responsibility for ensuring that sampling activities comply with the requirements of the sampling plan (Section 5) will rest with Wayne Einfeld, the SNL demonstration project leader. QA/QC activities for the field demonstration will incorporate those activities recommended by the developers as well as those specified by the EPA or SNL in this QAPP to assure that the demonstration will provide data of the necessary quality.

QA/QC activities for the onsite field analytical laboratory analysis of samples will be the responsibility of Craig Crume, the lead analyst of the field analysis team. If problems arise or any data appear unusual, they will be thoroughly documented and corrective actions will be implemented as specified in this QAPP or in the written analytical method in Appendix D. The QA/QC measurements made by the field analytical laboratory are dictated by the analytical methods being used. This QAPP includes additional QA/QC guidance which must be followed during the analysis of demonstration samples.

Data Quality Parameters

The data obtained during the ground water sampling technology demonstration will be thoroughly documented and included in a Technology Verification Report along with conclusions drawn on individual technology performance parameters. For all measurement and monitoring activities conducted for EPA, the agency requires that data quality parameters be established based on the proposed end uses of the data. Data quality parameters include five indicators of data quality: representativeness, completeness, comparability, accuracy, and precision.

Representativeness

Representativeness refers to the degree to which the data accurately and precisely represents the conditions or characteristics of the parameter represented by the data. For the purposes of this demonstration, representativeness will be defined as the collection and analysis of samples that adequately represent the characteristics of those that would be collected under typical field applications of the participating technologies. In this demonstration, representativeness will be ensured by selecting commonly encountered target analytes for spiking into the standpipe, as well as, the collection of GW samples from actual GW monitoring wells at the NASA-SSC complex.

Completeness

Completeness refers to the amount of data collected from a measurement process compared to the amount that was expected to be obtained. For this demonstration, completeness refers to the proportion of valid, acceptable samples collected by each technology relative to the expected sample count. Completeness is expressed as a percentage of the number of samples collected versus the number of samples expected from each technology vendor.

Comparability

Comparability refers to the confidence with which one data set can be compared to another. One of the important objectives of this demonstration is to evaluate how well the various sampling technologies perform in comparison to a reference sampling method. The study design incorporates a high number of blind replicate PE samples of known composition to assist in this determination of data comparability. By this provision, QC samples are built into the study design and are not left to the discretion of the technology operators.

Accuracy

Accuracy is a parameter that describes systematic differences between sample results and the true value or reference method results for a particular sample or a group of samples. A related term, bias, is a measure of the departure from accuracy and can be caused by such processes as systematic volatile losses in sample collection or handling, chemical adsorption on or reaction with components of the sampler, or interferences and/or systematic carryover of contaminats from one sample to the next. Accuracy and bias will be assessed for the monitoring technologies using sample data compared to reference sampling methods and measurements made on the PE samples. Accuracy will also be evaluated for the reference sampling method through the use of PE samples. PE samples used during this demonstration will provide the best estimate of accuracy because they are of known composition while the reference sampling method results are themselves estimates. Accuracy for the PE sample results will be evaluated through the comparison of percent recoveries for each target analyte. The study design calls for more than 50% of all samples provided to the developers to be PE samples to insure that reliable accuracy estimates can be obtained for each technology.

Precision

Precision refers to the degree of mutual agreement among individual measurements and provides an estimate of random error. Precision for this demonstration will be expressed in terms of the relative standard deviation (RSD) between replicate sample measurements.

Precision for each technology will be assessed using replicates sample collections of both standpipe PE samples and ground water samples. The replicate samples will provide an estimate of overall data precision and will include such influential factors as: sample collection, field preparation, handling, and transportation procedures, as well as analytical procedures.

The confidence interval of the mean is another measure of analytical precision and provides a range in which the true mean of a population would be expected to fall with a given probability. For example, a 95% confidence interval implies that the repeated samplings and measurements of a particular sample or mixture will yield a value that lies within the stated interval 95 times out of 100 trials.

Calibration Procedures, Quality Control Checks, and Corrective Action

Calibration procedures, method-specific QC requirements, and corrective action associated with non-conforming QC for the GC/MS technology and the reference method are described in the following subsections.

Initial Calibration Procedures

The initial calibration of ancillary equipment used for measurements of water quality parameters associated with a particular sampling technology will be the sole responsibility of the vendor. Similarly, the calibration of ancillary equipment used in the collection of reference method samples will be the responsbility of the VO. The methods of equipment calibration are included in Appendicies A, B, and C. Calibration of the onsite GC/MS systems will be performed in accordance with the written analytical procedure which a modified version of SW846-Method 8260A and included in Appendix D. The types of standards used and the acceptance criteria for the initial calibration or calibration curve also will be those outlined in the written field analytical method.

The initial calibration for the field analytical method consists of the analysis of five concentration levels of each target analyte along with a calibration blank. The low-level calibration standard will be at a concentration which defines the Lower Recovery Limits (LRLs) of the method. The remaining calibration standard levels will be used to define the linear range of the instrument. The initial field analytical calibration is used to establish calibration curves for each target analyte to be used in the demonstration.

Continuing Calibration Procedures

Continuing calibration checks of the field analytical method will be performed according to the written procedure. Normally, continuing calibration checks specify a maximum error tolerance for the repeated measurement of a stable calibration mixture over an extended (days or weeks) analysis interval. Continuing calibration of the field GC-MS instruments to be used in this study is performed at least every 24 hours. The check frequency, the standard levels used, and the acceptance criteria for continuing calibrations also will be those outlined in the written procedure in Appendix D. Continuing calibration acceptance criteria and corrective actions are also specified in the written method.

Field and Method Blanks

The collection and analysis of field blank samples by the various sampling technologies is incorporated into the study design. Field blank samples will be collected by all participants and will be analyzed using the same procedure used for all other samples. The field analytical method also specifies the periodic analysis of method blanks in accordance with the specifications of SW-846 Method 8260A.

PE Samples

A critical element of this demonstration's experimental design in the preparation of performance evaluation (PE) samples in the standpipe for collection by the various technologies participating in the test. These samples are critical to the success of the demonstration since they provide the only absolute check of sampling technology and accompanying analysis accuracy and precision during the demonstration.

Data Reduction, Validation, and Reporting

To maintain a high level of data quality, specific procedures will be followed during data reduction, validation, and reporting. These procedures are detailed below.

Data Reduction

Data reduction refers to the organization of all demonstration data into a data base or spreadsheet to facilitate further analysis and reporting. Data reduction will be performed by the verification organization following the chemical analysis of all the collected samples from all the participanting technologies. Supplementary data, such as that collected in field logbooks during standpipe or well sampling will also be used in the data reduction process.

Data Validation

Each technology operator will cross check and verify the list of samples collected by their technology and as provided to them by the verification organization. The verification organization will also review calculations and inspect field logbooks and data sheets as necessary to verify accuracy, completeness, and adherence to the specific analytical method protocols. Calibration and QC data will also be regularly examined by the field analytical instrument operators to ensure acceptable GC/MS performance. Chemical analysts will verify that all instrument systems are within established control limits and that QA objectives for accuracy, completeness, and method detection limits have been met. These QA data will be reported along with the sample analytical results.

Analytical outlier data are defined as those QC data lying outside a specific QC objective window for precision and accuracy for a given analytical method. Should QC data be outside of control limits, the chemical analysts will investigate the cause of the problem. If the problem involves an analytical problem, the sample will be reanalyzed if possible. If the problem can be attributed to the sample matrix, the result will be flagged with a data qualifier. This data qualifier will be included and explained in the Technology Verification Report.

Data Reporting

Analytical data will be reported using the onsite laboratory's standard data report form. At a minimum, the forms will list the results for each sample and include the detection limits, reporting units, sample numbers, results, and qualifiers.

Calculation of Data Quality Indicators

The following calculation will be used by all methods for determining precision for the reference laboratory. This calculation is used to determine the precision between sample results and duplicate sample results.

$$\mathbf{RSD = SD \div MEAN \times 100} \qquad \textbf{Equation 1}$$

where

RSD = relative standard deviation
SD = standard deviation
Mean = average concentration of analyte in replicate sample measurements
Standard deviation is determined through the following calculation:

$$\mathbf{SD = [\{\Sigma\ (x_i - mean)^2\} / (n-1)]^{1/2}} \qquad \textbf{Equation 2}$$

SD = standard deviation
x_i = concentration of analyte in specific replicate sample
Mean = average concentration of analyte in all replicate samples
n = total number of replicate sample measurements

The following calculation is used to determine PE sample recovery, which can be used to assess the accuracy of the analytical method.

$$\mathbf{\%\ Rec = (Measured\ value \div True\ value) \times 100} \qquad \textbf{Equation 3}$$

where

% Rec = percent recovery
Measured value = Result from field instrument measurement
True value = The certified value as provided in the PE sample documentation

The following calculation is used to determine the 95% confidence interval for a population mean.

$$\mathbf{confidence = x \pm \{(t_n) \times [s / (n)^{1/2}]\}} \qquad \textbf{Equation 4}$$

where

confidence = 95% confidence interval for a population mean
x = mean value
t_n = multiplicative constant for a standard t distribution that will yield a 95% confidence interval with n samples
s = standard deviation
n = sample size

Performance and System Audits

The following audits will be performed during this demonstration. These audits will determine if this demonstration plan is being implemented as intended.

Performance Audit

A performance audit will be carried out during this demonstration through the use of PE samples in the experimental design. PE samples will be prepared from stock solutions and will be diluted to appropriate concentration levels for analysis by the onsite GC/MS systems prior to the demonstration. Percent recovery calculations for the PE samples will be used to evaluate method performance and data acceptability.

On-Site System Audits

On-site technology audits during vendor sampling activities will be conducted. These audits will be scheduled and performed by a representative of SNL. The EPA quality assurance officer may also be present to conduct an audit during the demonstration to determine compliance with the ETV Program and Site Characterization and Monitoring Pilot Quality Management Plans. Audit reports will be completed and included in the subject matter of the Technology Verification Report.

Quality Assurance Reports to Management

QA reports provide management with the necessary information to monitor data quality effectively. It is anticipated that the following types of QA reports will be prepared as part of this demonstration project.

Status Reports

The SNL project manager will prepare periodic reports for the EPA project manager. These reports should discuss project progress, problems and associated corrective actions, and future scheduled activities associated with the demonstration. When problems occur, the SNL project manager will discuss them with the EPA project manager or EPA technical lead, estimate the type and degree of impact, and describe the corrective actions taken to mitigate the impact and to prevent a recurrence of the problems.

Audit Reports

Any QA audits or inspections that take place in the field or at the reference laboratory while the demonstration is being conducted will be formally reported by the auditors to the SNL analytical QC manager and the SNL project manager who will forward them to the EPA project manager.

Section 9 Health and Safety Plan

Introduction

This chapter describes specific health and safety procedures SNL and its contract personnel will use during the field work to be performed at the NASA-SSC demonstration sites. The purpose of the HASP is to define the requirements and designate the protocols to be followed during the field work specified under Occupational Health and Safety Administration (OSHA) 29 CFR 1910.120(b) Final Rule. All SNL personnel, subcontractors, and visitors on site must be informed of site emergency response procedures and any potential fire, explosion, health, or safety hazards related to demonstration activities. This section summarizes information contained in the NASA-SSC Health and Safety Plan, prepared for all field operations at the site. A copy of the NASA-SSC Health and Safety Plan is included in Appendix E. This plan will be provided to all SNL personnel, subcontractors, vendors, and other site visitors who may be exposed to dangerous conditions during the demonstration. This provisions of this site-specific HASP must be reviewed and approved by the SNL project manager, the onsite ES&H officers, and the EPA project officer prior to the start of the demonstration. A HASP compliance agreement form must be signed by all field personnel before they enter the site. Any revisions to this plan must be approved by the same demonstration participants listed above.

Responsible Personnel

The SNL project manager along with the USGS site health and safety officer will be responsible for implementing and enforcing the health and safety provisions of this HASP.

Site-Specific Hazard Evaluation

The field activities to be conducted at the SRS present a variety of chemical and physical hazards. Actual personnel exposure to these hazards are dependent on the specific work tasks, weather conditions, levels of protection utilized, and personal work habits.

The identified potential hazards associated with the GW Sampling demonstration are listed below.

- Chemical exposure
- Physical hazards
- Elevated working surfaces
- Heat Stress
- Mechanical
- Electrical
- Unstable/Uneven Terrain
- Other Environmental Hazards
- Insect and Animal Stings or Bites
- Inclement Weather

Chemical Health Effects, Exposure Pathways and Preventive Measures

Health Effects

Some of the chlorinated and non-chlorinated volatile organic target compounds to be used in this investigation (PCE, TCE, 112-TCA, 1,1-DCE, 1,2-DCA, and benzene) are classified by the National Institute for Occupational Safety and Health (NIOSH) as potential carcinogens. Symptoms of acute (high-level) VOC exposure to the above chemicals include the following: irritation of eyes, nose, and throat, dermatitis, headache, vertigo, visual disturbance, tremors, nausea, vomiting, central nervous system depression, cardiac arrhythmia. Chronic expsoure (long-term low-level exposure) symptoms can include liver damage and blood disorders.

The paragraphs below outline the various routes of potential exposure to chemicals associated with this demonstration. Preventive measures taken to minimize exposure hazards are also described.

Inhalation

The risk of inhalation exposure from chemical contaminants is considered minimal because the concentrations of contaminants being characterized are low and sampling is performed using sealed containment. Furthermore, quantities of pure chemicals used for spiking water solutions at the standpipe will be very small and thus will pose insignificant inhalation hazards to demonstration personnel.

Skin Contact

Personal exposure to chlorinated VOC contaminated water may occur by absorption through the skin or eyes. Such contact will be avoided by the use of protective gloves and safety glasses during sampling activities when the likelihood of skin or eye contact with contaminated water is present.

Ingestion

Personal exposure to CVOCs may occur by absorption through the gut after ingestion. Ingestion will be avoided. To minimize ingestion, smoking and eating in the vicinity of sampling operations will not be allowed.

Physical Hazards

A number of physical hazards likely to be encountered during the planned tests at the standpipe and the GW monitoring wells are briefly outlined below.

Elevated Surfaces: Sampling activities at the standpipe will be conducted on a platform 100 feet above the ground floor of the Saturn building. The platform is equipped with a railing, however, sampling crews will be required to lift their sampling equipment over the railing for insertion into the standpipe. A minor fall hazard is present under these working conditions. Furthermore, a falling debris hazard is present for those who may be working below. To address these hazards, the following precautions will be taken:

Personnel engaged in sampling activities at the standpipe will be required to wear a body harness that is tethered to a suitable anchor as a fall prevention measure.

The railing face in the vicinity of the standpipe will be covered from the top of the rail to the floor level with a tight mesh nylon netting to prevent the loss of tools etc. that may be lying on the floor surface over the edge through inadvertent kicking by or mishandling by sampling crews.

A tight mesh nylon net will be positioned in a horizontal plane outward from the railing edge in the vicinity of the standpipe. This net will serve to catch any items that may be dropped over the edge of the railing during sampling activities at the standpipe.

The ground floor level zone below the standpipe will be cordoned off from all personnel during work activities at the top of the standpipe. This is to prevent falling debris hazard for personnel on the ground level floor in the vicinity of the standpipe.

Heat Stress: Technology demonstrations are scheduled for the July-August time frame. Heat stress may become a concern during the demonstration period because of elevated air temperature and relative humidity. Personnel will be provided adequate shelter, water, and work/rest regimens as required by environmental conditions. Additionally, sun screen may be used to reduce the risk of sunburn and skin damage caused by UVB solar radiation.

Mechanical: Machinery or equipment capable of movement will be stopped and the power source de-energized or disengaged, and if necessary, the movable parts mechanically locked or blocked to prevent inadvertent movement during cleaning, servicing, or adjusting operations. Controls will be locked in the off position and marked with accident prevention signs and/or tags. If machinery must be able to move during servicing, extension tools must be used to protect personnel from movement.

All other mechanical hazards, such as sharp edges, tripping hazards, bumping hazards, etc., will be identified and guarded or highlighted to ensure visibility and minimize the potential for personal injury.

Electrical: All electrical connections and grounding will be in accordance with the current edition of the Nation Electric Code.

Unstable/Uneven Terrain: Electrical cables represent a potential tripping hazard. When practical cables will be placed in areas of low pedestrian travel. If necessary, in high pedestrian travel areas, covers or bridges will be installed over cables. Site personnel shall attempt to minimize the potential for slips, trips, and falls by providing clean footing. Site personnel shall be aware of uneven terrain and existing ground level piping and conduit, and they shall maintain good housekeeping in the area. Permanent roadways, walkways, and material storage areas will be maintained free of dangerous depressions, obstructions, and debris.

Insect and Other Animal Stings and Bites: A potential for insect or other animal stings or bites exists during the technology demonstration period. Insect repellent may be used to minimize insect bite hazards. In the event of snake or other large animal bite, the injury will be immobilized and immediately reported to qualified medical personnel. All demonstration personnel will be notified of animal hazards at the initial safety meeting. Appropriate clothes should be worn.

Inclement Weather: Severe weather conditions may generate lightning or flooding hazards. If a potential for significant thunderstorm activity exists during demonstration activities, personnel will not be allowed in the field during the threat period. Personnel will take refuge in support shelters. Vehicles will not be driven in potential flood areas.

Preliminary Safety Briefing

Prior to involvement in any field activity, either at the standpipe or at the site monitoring wells, all Sandia, EPA, and vendor personnel will attend a safety briefing. The briefing will include the nature of the chemical contamination likely to be encountered, other physical hazards and their recognition, normal operating procedures, personnel protective measures, and emergency operating procedures. The briefing will be jointly conducted by USGS and Sandia personnel. NASA personnel will also conduct a briefing regarding endangered species at SSC.

Protective Equipment and Clothing

Protective equipment and clothing will be selected based on known contaminant types, atmospheric concentrations, aqueous concentrations, and known routes of entry into the human body. In situations where the contaminant type, concentration, and exposure potentials are unknown, a subjective decision regarding the assignment of PPE will be made by the site Health and Safety Officers. These individuals may choose to upgrade or downgrade the required PPE depending on work area conditions, atmospheric contaminant concentration, air temperature, or other environmental factors. All field sampling crews should be prepared to work in a modified D level ensemble, as further described below:

Level of protection:	D-modified
Respiratory Protection:	None

Suit:	Coverall (optional)
Boot:	Steel toe
Glove:	Neoprene (or equivalent)
Head:	Hard hat (as appropriate for overhead hazards)
Eye:	Safety glasses/goggles
Hearing:	Muffs/Plugs (as required)

Field/Medical Support

In the event of a chemical exposure injury or illness, the onsite ES&H officers and/or the SNL project manager will promptly initiate the steps necessary to identify the chemical(s) involved in the exposure. Chemical identification will be accomplished through the use of monitoring equipment and any available prior sampling data. The chemical agent(s) information will be made available to the treating physician and other emergency responders.

Any injury or illness not limited to a first-aid response will require notification of the onsite ES&H officer and the SNL project manager. Notification allows the coordination of resources to assist emergency response personnel and the treating physician in rendering appropriate care.

Any person suspected of having an overexposure to chemicals found on-site will be given another complete physical examination.

Periodic Air Monitoring

Personnel exposure determination for each field activity will be made as frequently as deemed necessary by the onsite ES&H officers.

Heat Stress Monitoring

Air temperature and relative humidity will be monitored by appropriate instrumentation and as deemed necessary by the onsite ES&H officers.

Site Control

The onsite ES&H officer(s) will enforce all site control requirements. Communications from the work site to other facilities will be by phone.

A warning barricade will surround the work area and warning signs stating hard-hats and safety glasses with side shields are required for entry will be posted as necessary and appropriate.

Each company will provide the required training and equipment for their vendor personnel on-site to meet safe operating practices and procedures in effect at the SSC. Each company will be responsible for the safety of their workers. All general safety guidelines and procedures will conform to the requirements and provisions of 29 CFR 1910.120.

Health and Safety Plan Enforcement

Failure of any demonstration personnel to comply with the Health and Safety plan may be grounds for expulsion from the site and withdrawal of the associated technology from the demonstration. The designated onsite ES&H officer(s) is the sole determinant of compliance with the Health and Safety Plan.

Equipment Decontamination

Sampling equipment and tools used during sampling activities will be decontaminated using a water solution of Alconox, rinsed with tap water, and rinsed with distilled water. All contaminated site equipment will be decontaminated both before and after site activities. Equipment will also be properly decontaminated between sampling locations to prevent cross contamination. All uncontaminated equipment should be wiped with a wet towel at the close of site activities.

Decontamination materials will be containerized, labeled, and left on-site pending appropriate characterization of the material. These materials will be properly disposed.

The following decontamination equipment and supplies will be used during the tests:

Alconox
Distilled water
Scrub brushes
Towels
Plastic buckets
55-Gallon DOT-17 drums

Emergency Contingency Planning

The objective of the Health and Safety Plan is to minimize chemical and physical hazards and operational accidents. The following directions are provided to ensure personnel respond to emergency situations in a calm and reasonable manner.

During field operations, the existing emergency medical assistance network at SSC will be used. Emergency phone numbers are listed in the attached SSC Health and Safety Plan. A vehicle will be available on-site during all activities to transport injured personnel to the identified emergency medical facility. An ambulance or air-rescue will be on-call at the medical facility to transport seriously injured personnel to the nearest medical facility equipped to handle the specific emergency. Telephone numbers and locations of the nearest emergency room facilities will be posted at the site. At least two people will be present at the demonstration site during all activities.
The onsite ES&H officer(s) will hold the leadership role in all emergency situations. They will also be certified to render first aid and cardio-pulmonary resuscitation (CPR) prior to initiation of field activities. Other provisions are as follows:

- A first aid kit will be available at the demonstration site.
- An emergency eye wash will be available at the demonstration site.
- An adequate supply of potable water will be available at the demonstration site.
- Demonstration personnel will be trained in emergency procedures during the personnel training sessions.
- Evacuation routes as outlined in the SSC Health and Safety Plan will used by the project team and will be communicated to all test personnel during the initial safety conference prior to field activity commencement.
- The onsite ES&H officer(s) will be responsible for ensuring that all personnel understand the specific emergency signals and procedures.

What to do in the event of an emergency

In the event of an emergency, immediately call for emergency medical assistance, notify theonsite ES&H officer and the Sandia project manager. Give first aid as appropriate. In an emergency, the primary concern is to prevent loss of life or severe injury to site personnel. In the event of protective equipment failure when immediate medical treatment is required to save a life, decontamination should be delayed until the victim is stabilized. If decontamination can be performed without interfering with essential life-saving techniques or first aid, or if a person has been contaminated with an extremely toxic or corrosive material that could cause severe injury or loss of life, decontamination must be performed immediately.

In the event of a fire or explosion, all site work will cease and the site will be evacuated. The oniste ES&H officer and the Sandia project manager will determine the appropriate action following site evacuation.

Emergency Information Telephone Numbers

Person	Title	Phone Number
Wayne Einfeld	SNL Project Manager	tbd (local cell phone)
Ed Ford	USGS Project Manager	tbd
?????	ES&H Officer (USGS)	tbd
?????	ES&H Officer (Johnson Controls)	tbd
?????	SSC Medical Clinic	(601) 688-3810
	Center for Disease Control	(404) 329-3311
		(404) 329-2888
	National Response Center	(800) 424-8802

See also Table 12.1 in the NASA-SSC Health and Safety Plan in Appendix E.

Hospital Route Directions

Directions to the nearest hospital, including a map, are included in the NASA-SSC Health and Safety Plan and will be posted at the site.

Section 10 Deliverables

Several documents and reports will be produced by the SNL as part of this demonstration. Deliverables include a Demonstration Plan and a Environmental Technology Verification Report for each technology participating in the demonstration. Each of these reports is discussed below.

Demonstration Plan

This demonstration plan has been prepared to provide a detailed description of all activities that will take place as part of this demonstration. Key elements of the demonstration plan include the following:

- Test Plan - The test plan includes an overview of the demonstration process (Section 1), a description of the roles and responsibilities of involved parties (Section 3); technology descriptions (Section 4); site descriptions (Section 5); a discussion of the experimental design and sampling protocols (Sections 6 and 7) and an explanation of the methodology for evaluating the performances of the technologies (Sections 8 and 9).

- Quality Assurance Project Plan - This section was prepared according to EPA guidelines listed in the statement of work. The QAPP includes a project description, delineation of QA/QC responsibilities, QA objectives for critical measurements, sampling and analytical procedures, data reduction, validation, and reporting procedures, plans for system and performance audits, and descriptions of internal QC checks, calculation of data quality indicators, plans for corrective actions, and QC reports to management. The QAPP is provided in Section 8.

- Health and Safety Plan - The HASP identifies the key personnel who will be involved with demonstration activities and the minimum training requirements for field personnel, evaluates anticipated hazards associated with field work, and discusses site entry, personal protection equipment, communication, and decontamination procedures to be followed during field work. The HASP is provided in Section 10.

Technology Verification Report

The main product of a completed demonstration under the ETV Program, Site Characterization and Monitoring Pilot is a Technology Verification Report. This report documents the results of the demonstration for each developer and reports on the performance of the technology. The report will include descriptions of sampling and analytical procedures, data collection and management procedures, a data summary and analysis, as well as associated QA/QC requirements.

The report content for this demonstration project is given in more detail as follows:

A demonstration summary.
A description of the technology that was demonstrated including diagrams, operating instructions, and a brief discussion of the theoretical concepts under which the technology operates.
A description of the experimental design for the demonstration including method protocols, sampling and analysis procedures and methods, QA/QC procedures and records, descriptions of the demonstration site, and any other pertinent information about the demonstration.
An interpretation and assessment of the technology that compares results to those obtained using reference or standard methods.
Analytical performance data and data interpretation for the technology including an evaluation of data quality parameters (precision, accuracy, comparability, completeness, representativeness), and a description of the methods used to assess this data.
Limited information on cost of technology acquisition, deployment and maintenance.
Conclusions about the advantages and limitations of each technology on its own merit compared to conventional EPA sample analysis.

Recommendations for the potential use of the technologies for field screening, as well as recommendations for improvements or further testing, if appropriate.

Other Reports

Other reports or documents may also be prepared as directed by the EPA. Examples of other reports which may be required include memorandum trip reports following field activities or visits to developer facilities. In addition, the EPA project manager may require development of technology transfer documents including technology mailers, bulletins, journal articles, or other publications.

Section 11 References

Foster Wheeler, 1998. "Final Hydrogeologic Investigation Report for the National Aeronautics and Space Administration Stennis Space Center, Mississippi," Foster Wheeler Environmental Corporation, Lanham, MD.

EPA, 1998a. "Environmental Technology Verification Program, Quality Management Plan for the Pilot Period 1995-2000," EPA Report No. EPA/600/R-98/064. Available at the ETV Web Site: www.epa.gov/etv/library.htm

EPA, 1998b. "Environmental Technology Verification Program, Quality Management Plan for the Site Characterization and Monitoring Pilot," No EPA report number assigned; contact Eric Koglin, US EPA, Las Vegas for more information.

EPA, 1998c. "Environmental Technology Verification Report, Field-Portable GC/MS, Inficon Inc., HAPSITE," EPA Report No. EPA/600/R-98/142. Available at the ETV Web Site: www.epa.gov/etv/library.htm