FINAL

Results Report for the Demonstration of No-Purge Groundwater Sampling Devices at Former McClellan Air Force Base, California

Prepared For

U.S. Army Corps of Engineers Omaha District

and

Air Force Center for Environmental Excellence

and

Air Force Real Property Agency

U.S. AIR FORCE

Contract F44650-99-D-0005
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LIST OF ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFRPA	Air Force Real Property Agency
AFCEE/ERT	Air Force Center for Environmental Excellence, Technology Transfer Division
BRAC	Base Realignment and Closure
CAS	Columbia Analytical Services
cm	centimeter
CRWQCB	California Regional Water Quality Control Board
°C	degrees Celcius
DO	dissolved oxygen
DoD	Department of Defense
gpm	gallon(s) per minute
HDPE	high-density polyethylene
IDW	investigation-derived waste
ITRC	Interstate Technology and Regulatory Council
LDPE	low-density polyethylene
LTM	long-term monitoring
MDL	method detection limit
mL	milliliter(s)
McClellan	former McClellan Air Force Base
MS/MSD	matrix spike/matrix spike duplicate
MTBE	methyl tert-butyl ether
ND	not detected
NTU	nephelometric turbidity unit
OD	outside diameter
ORP	oxidation-reduction potential
Parsons	Parsons Engineering Science, Inc.
PDBS	passive diffusion bag sampler
PDS	passive diffusion sampler
PFA	perfluoroalkoxy
PQL	practical quantitation limit
PsMS	polysulfone membrane sampler
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
R^2	goodness-of-fit parameter/correlation coefficient
RCS	regenerated cellulose sampler
redox	reduction-oxidation
RPD	relative percent difference
RPO	remedial process optimization
RPPS	rigid porous polyethylene sampler
Sequoia	Sequoia Analytical Services
SOP	standard operating procedure
SVOC	semi-volatile organic compound
TAL	target analyte list
TCE	trichloroethene

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

URS	URS Corporation
USACE	US Department of the Army, Corps of Engineers
USEPA	US Environmental Protection Agency
USGS	US Geological Survey
VOA	volatile organics analysis
VOC	volatile organic compound

SECTION 1

INTRODUCTION

1.1   PROJECT DESCRIPTION AND LOCATION

On 22 January 2002, Parsons Engineering Science, Inc. (Parsons) was awarded delivery order DK01 under United States Department of the Army, Corps of Engineers (USACE) Contract Number F44650-99-D-0005. The scope of this delivery order is to provide services, technical labor-hours, and materials to support Remedial Process Optimization (RPO) evaluations and demonstrate the effectiveness of Passive Diffusion Bag Samplers (PDBSs) for sampling volatile organic compounds (VOCs) in existing groundwater monitoring programs at selected Base Realignment and Closure (BRAC) installations administered by the Air Force Real Property Agency (AFRPA). The former Technology Transfer Division of the Air Force Center for Environmental Excellence (AFCEE/ERT) initiated the PDBS demonstration to introduce this technology to multiple Department of Defense (DoD) installations and to improve the cost effectiveness of groundwater monitoring programs for VOCs.

This report describes the activities and results of a field demonstration of six different diffusion and grab groundwater sampling devices at the former McClellan Air Force Base (McClellan), located in Sacramento, California. Analytical results from these samplers are compared to 'baseline' analytical results from samples collected using conventional (low-flow and three-casing-volume purge) techniques for all analytes. As described at the beginning of Section 6, conventional techniques represent baseline data only in the sense that they are the commonly-used sampling methods that are generally accepted by the regulatory community. They do not necessarily represent the *correct* answer (only a *different* answer). The activities described in this report were performed in accordance with the *Final Work Plan for the Demonstration of Passive Groundwater Sampling Devices at Former McClellan AFB, California* (Work Plan) (Parsons, 2004a). The geology and hydrogeology of McClellan are briefly described in the Work Plan (Appendix E).

This demonstration project included an assessment of diffusion and grab samplers (i.e., no-purge samplers) for collection of groundwater samples to be analyzed for VOCs, metals, and selected contaminants listed as California emergent chemicals (California Regional Water Quality Control Board [CRWQCB], 2003), including 1,4 dioxane and hexavalent chromium. The six sampling devices demonstrated were classified as either diffusion or grab samplers depending on the predominant operative mechanism of the sampling device. The group designated as diffusion samplers was comprised of the PDBS, a rigid porous polyethylene sampler (RPPS), a polysulfone membrane sampler (PsMS), and a regenerated cellulose sampler (RCS). The group designated as grab samplers included the Snap Sampler™ manufactured by ProHydro, Inc. and the HydraSleeve® manufactured by GeoInsight. It should be noted that the membrane pore size of the RPPS and PsMS may be sufficiently large to permit some limited advection of water molecules through the sampler wall. However, diffusion is believed to be the

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dominant mechanism for transport of dissolved constituents into these samplers. All of the diffusion and grab samplers tested at McClellan are "no-purge" sampling devices in that they are intended to be used to collect groundwater samples without prior purging of the well.

The diffusion and grab sampling devices tested are relatively new approaches to groundwater sampling that eliminate the need for well purging. Typically, a capsule (e.g., diffusive membrane or self-sealing "grab" container) is deployed at a specified position within the screened interval of a well. Depending on the type of sampler, the capsule may either be filled with purified water and sealed at the surface prior to deployment (e.g., PDBS, RPPS, PsMS, RCS), or it is deployed empty and filled with groundwater and sealed upon retrieval (e.g., Snap Sampler™ and HydraSleeve®). With the PDBS, RPPS, PsMS, and RCS, the constituents in the groundwater enter the sealed sampler through the process of diffusion, and the water quality inside the sampler reaches equilibrium with groundwater quality in the surrounding well. The sampler is subsequently retrieved from the well, and the water in the sampler is transferred to a sample container and submitted for laboratory analysis. The grab samplers are empty when deployed and, following an equilibration period, they are either closed remotely to trap ambient groundwater (Snap Sampler™) or they are filled and sealed during the retrieval process (HydraSleeve®). Potential benefits of using diffusion or grab sampling methods include reduced sampling costs and reduced generation of investigation-derived waste (i.e., purge water).

1.2   TECHNOLOGY BACKGROUND

To date, the primary application of diffusion samplers has been to sample for VOCs in groundwater using PDBSs. The PDBS technology has been validated through various studies (Vroblesky and Hyde, 1997; Parsons, 1999, 2003b and 2004b; Church, 2000; Hare, 2000; McClellan AFB, 2000; Vroblesky *et al.*, 2000; Vroblesky and Peters, 2000; Vroblesky and Petkewich, 2000), and a guidance document for their use has been developed (Vroblesky, 2001). The Interstate Technology and Regulatory Council (ITRC) has formed a workgroup to expand on the PDBS guidance document and to address technical and regulatory implementation issues as they arise.

Use of the PDBS method can provide significant long-term cost savings compared to conventional sampling methods. However, LTM programs at many sites include sampling and analysis for non-volatile parameters (e.g., metals, semi-volatile organic compounds [SVOCs] inorganic anions and cations, dissolved gases, and other geochemical parameters) that cannot be targeted using PDBSs. In addition, although studies performed to date have indicated that the PDBS method is capable of accurately monitoring concentrations of VOCs dissolved in groundwater in most instances, this method is not suitable for all VOCs. For example, methyl tert-butyl ether (MTBE) does not efficiently pass through the wall of the PDBS, and therefore this method cannot be used to sample for this compound. As a result of these limitations, development and testing of other no-purge samplers that can be used for a wider variety of analytes is desirable to take advantage of the cost effectiveness of this approach, while at the same time meeting sampling objectives for non-volatile analytes.

1.3   OBJECTIVES

The overall objective of this demonstration is to evaluate and demonstrate the use of selected diffusion and grab sampling technologies that potentially represent useful and

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cost-effective alternatives to conventional groundwater sampling approaches (e.g., three-volume purge/sample and low-flow purge/sample) for analytes other than VOCs. Specifically, technologies that potentially can be used to sample for non-volatile constituents such as metals, anions, and 1,4 dioxane are evaluated. Expansion of the suite of accepted no-purge sampling methods could be useful in augmenting or possibly substituting for the PDBS method in certain applications.

In addition, the comparative sampler demonstration at McClellan has the following specific objectives:

- Compare analytical results obtained using each sampling method with analytical results for the same constituents obtained via each of the other sampling methods;

- Evaluate how each diffusion and grab sampler reflects any observed chemical stratification in wells included in the demonstration;

- Identify variables that could explain observed differences in the sampling results obtained using the various sampling methods; and

- Compare the approximate costs of the various sampling methods (including conventional methods).

1.4   SCOPE

The sampling demonstration at McClellan required three field mobilizations to the site as described in Section 3.1.1.

The samplers selected for this demonstration monitor chemical conditions in a well. Conventional sampling methods (e.g., purge and sample) disrupt well and aquifer equilibrium for an unknown period of time. Therefore, for this demonstration an effort was made to target only those wells that were not scheduled to be sampled during the regular April-May 2004 basewide LTM conventional sampling event. In the event that a well was selected for use in this demonstration that also was sampled with conventional methods during the LTM event, a minimum time lag of at least one month between the LTM and no-purge sampling demonstration events was used as a well selection criterion.

A total of 20 wells at McClellan were included in this demonstration project. Parsons coordinated with both McClellan and the base LTM contractor (URS Corporation [URS]) to determine which wells should be included in the demonstration.

1.5   SCOPING GUIDELINES

The following general scoping guidelines were developed for this comparative sampler evaluation:

- Sampling devices selected for field testing will be suitable for at least a sub-group of the analytes of interest, and will yield sufficient sample volume to enable testing for the analytes of interest.

- Sampling devices selected for field testing can be deployed at multiple depths within a single well to evaluate vertical stratification of analytes, and each sampler cluster (consisting of multiple types of samplers) can be deployed at a similar depth. This will allow comparison of sampling results from less-depth-discrete methods (i.e., 3-volume purge and low-flow purge) with results from more depth-discrete methods. This topic is of interest in part because the degree to which low-flow purge provides a depth-discrete sample is not well-defined.

- Time lag between sample collection using different methods will be minimized to avoid bias of the comparative evaluation by temporal fluctuations in groundwater quality.

- Analyte reporting limits specified in the McClellan Quality Assurance Project Plan (QAPP) (URS, 2003) will be met to the extent feasible given sample volume limitations and the capabilities of the selected analytical laboratory.

- One or more 'baseline' sampling methods will be included to provide data against which the results of the alternative passive diffusion samplers (PDSs) and grab samplers can be compared.

- Standard operating procedures (SOPs) will be used that minimize loss or transformation of the analytes of interest during the sample collection, handling, shipping, and analysis process, and that ensure the representativeness of the sample to the greatest degree possible.

- Sufficient data will be collected to allow use of appropriate qualitative and quantitative data analysis methods (e.g., graphs, tables, statistical tests) in order to compare results obtained using the various sampling devices/approaches and determine which alternative samplers can be used in place of the current, conventional sampling methods and therefore warrant further evaluation.

1.6   DOCUMENT ORGANIZATION

This report is organized into eight sections, including this introduction, and six appendices. Section 2 is a brief summary description of the sampling technologies used in this demonstration. Section 3 is a description of field activities and the laboratory analytical approach. Section 4 is a presentation and discussion of analytical results. A cost analysis is presented in Section 5. Conclusions and recommendations are presented in Sections 6 and 7, respectively. References cited in this report are presented in Section 8. Appendix A is a Data Quality Assessment Report. Well-specific plots depicting vertical stratification of various target compounds are included as Appendix B. Appendix C includes results of tests for normality performed on the data sets. Appendix D contains X-Y scatter plots comparing the results of each sampling device/method to each of the other devices/methods. Appendix E is a compact disk containing an electronic version of the analytical data in various formats as well as an electronic version of the Work Plan (Parsons, 2004a). Field notes are contained in Appendix F.

SECTION 2

DESCRIPTION OF TECHNOLOGIES

No-purge samplers rely on the natural flow of groundwater through a well screen, and therefore the results obtained using these devices will not always be comparable to results obtained using conventional sampling methods which induce groundwater flow into a well by creating a hydraulic gradient through well purging. In the absence of vertical flow, the no-purge devices will primarily monitor groundwater migrating through the well screen at the discrete depth intervals at which the samplers are placed. If vertical flow exists in the well, no-purge sampler results likely will be representative of the aquifer zone with the highest hydraulic head. Groundwater flows from high- to low-head zones, and the zone with the highest hydraulic head will be the source for groundwater flowing vertically through the well, and will therefore be the zone monitored by the no-purge sampler.

As described in Section 1, a total of four diffusion (PDBS, RPPS, PsMS, and RCS) and two grab (HydraSleeve® and Snap Sampler™) sampling devices were selected for this demonstration. Additionally, these methods were compared to two conventional sampling methods (low-flow purge/sample and three-volume purge/sample). Specific design and method details for each of these sampling techniques are presented in Table 2.1 and the following subsections. Note that the sampler dimensions and volumes listed in Table 2.1 correspond to the versions used in this McClellan AFB field demonstration; other versions of these samplers may be available.

2.1 DIFFUSION SAMPLERS

For diffusion samplers, chemical constituents in the groundwater diffuse across the membrane over time, and the chemical content of the water inside the sampler reaches equilibrium with the chemical content of groundwater in that interval of the well. The sampler is subsequently removed from the well, and the water in the diffusion sampler is transferred to a sample container and submitted for laboratory analysis. Once a diffusion sampler is placed in a well, it remains in place until chemical equilibrium is achieved between the water in the well casing and the water in the diffusion sampler. There is a time-lag between the time groundwater enters a well and the diffusion of the chemicals in the groundwater into a diffusion sampler. This time-lag is variable depending on several factors such as the groundwater temperature, the physicochemical properties of the compound of interest, and the diffusive membrane used in the sampler. Because of this quality, diffusion samplers are representative of a time-weighted average of chemical concentrations in groundwater.

TABLE 2.1
SUMMARY OF NO-PURGE SAMPLING DEVICES TESTED
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Sampler	Dimensions	Construction Material	Membrane Pore Size (microns)	Liquid Volume Capacity (mL)
PDBS	17.7 inches long by 2 inches OD	LDPE	0.001	350
RPPS	6.2 inches long by 1.5 inches OD	Polyethylene	6 to 15	150
PsMS	2 inches long by 2 inches OD	Polysulfone® (HT Tuffryn)	0.2	108 per canister
RCS	13 inches long by 1 inch OD	PVC, LDPE, regenerated cellulose	0.0018	400
Snap Sampler™	10 inches long by 1.6 inches OD	Glass, Teflon®, perfluoroalkoxy-coated stainless steel	NA	40 per vial[a/]
HydraSleeve®	30 inches long by 2.75 inches OD	Polyethylene	NA	2,000

mL = milliliters, cm = centimeters, LDPE = low-density polyethylene, OD = outside diameter, PVC = polyvinyl chloride, NA = not applicable.

a/ Multiple 40-ml vials can be combined to increase the volume of sample obtained. A 125-ml sampler also has been developed.

2.1.1   Passive Diffusion Bag Sampler (PDBS)

The PDBS used in this demonstration is constructed of a 45-centimeter (cm)-long section of 5.08-cm-diameter, 4-mil-thick, low-density polyethylene (LDPE) tubing that is permanently sealed on one end and sealed on the other end with a high-density polyethylene (HDPE) cap (Figure 2.1). The pore size of the LDPE is approximately 0.001 micron, which does not permit the flux of water molecules (i.e., it does not leak). The sampler, which holds approximately 350 milliliters (mL) of purified water, is placed in "flex-guard" polyethylene mesh tubing for abrasion protection, attached to a weighted rope, and lowered to a predetermined depth within the screened interval of a well. The rope is weighted to ensure that the sampling devices are positioned at the correct depth and that they do not float upward through the water column.

FIGURE 2.1
STANDARD PDBS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Depending on the hydrogeologic characteristics of the aquifer, the diffusion samplers can reach equilibrium within 3 to 4 days (Vroblesky, 2001). Groundwater samples collected using the diffusion samplers are thought to be representative of water present within the well during the previous 24 to 72 hours. However, the recommended minimum equilibration time for water temperatures above 10 degrees Celsius (°C) is two weeks (ITRC, 2004).

PDB samples are not susceptible to matrix interferences caused by turbidity because the membrane used in the device is not permeable to colloids or other particles larger in diameter than approximately 0.001 micron. PDB samples also are not subject to volatilization loss by degassing during effervescence when the samples are acidified for preservation in highly alkaline waters because the alkalinity from the aquifer does not penetrate the membrane.

2.1.2 RIGID POROUS POLYETHYLENE SAMPLER (RPPS)

RPPSs have recently been tested in a laboratory setting by the US Geological Survey (USGS). The tested samplers consisted of a 1.5-inch outside diameter (OD), 6.2-inch-long, rigid polyethylene tube having a pore size of 6 to 15 microns (Figure 2.2). Given the relatively large pore size, the RPPS could potentially be used to sample for a relatively wide variety of volatile and non-volatile analytes. The bench-scale test results indicated that this type of sampler can yield accurate results for VOCs (including MTBE), chromium, and chloride (Vroblesky, 2004). Potential disadvantages of this sampler include the following:

- The porous polyethylene sampler pores tend to retain air even when submerged. Because the entrapped air reduces sampler permeability, the air should be removed prior to use by flushing the samplers with water.

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FIGURE 2.2
STANDARD RPPS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

- Tests performed to date indicate that the maximum feasible sampler dimensions are approximately 1.5 inches OD by 7.5 inches long (volume equal to approximately 175 mL). Use of a longer sampler would result in leakage of water out of the sampler walls due to the higher head pressure present in the sampler (Vroblesky, 2004).

2.1.3 POLYSULFONE MEMBRANE SAMPLER (PsMS)

Testing of 'Peeper' samplers performed by (among others) Dr. Andrew Jackson of Texas Tech University has indicated that dissolved concentrations of non-volatile groundwater constituents can pass through a polysulfone (e.g., HT[®] Tuffryn) membrane having a sufficient pore size (Jackson, 2003). Peeper samplers are rigid structures that can hold volumes of water separated from the environment by porous membranes to monitor dissolved constituents in saturated environments. The same polysulfone material used in some Peeper samplers also can be used to construct PSDs. The samplers constructed for use in the McClellan study were comprised of a rigid 2-inch-long section of 2-inch-OD PVC pipe that was covered on both ends with the flexible polysulfone membrane. The polysulfone membrane was held in place by sliding a PVC coupling over the end of the pipe (Figure 2.3). The coupling was held in place by friction. The samplers were filled with purified water prior to deployment. The pore size of the polysulfone material that was used is 0.2 micron. The volume of each sampler canister was approximately 108 mL, and two of these canisters were deployed at each sample depth. One conclusion from a previous diffusion sampler demonstration at Grissom Air Reserve Base (Parsons, 2004b) was that the orientation of the porous membrane relative to the assumed direction of groundwater flow was potentially an important consideration. Because of this, samplers were deployed in an orientation such that the plane of the

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membrane was positioned orthogonally to horizontal groundwater flow. Due to the lack of field- or bench-scale testing of PsMSs, potential advantages or disadvantages of this sampler have not been quantified.

FIGURE 2.3
STANDARD PSMS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

2.1.4   REGENERATED CELLULOSE SAMPLER (RCS)

Regenerated cellulose samplers have been successfully tested in wells for inorganic and volatile organic constituents in groundwater (Vroblesky *et al*., 2002; Ehlke *et al*., 2004). The sampler used in this investigation consisted of a perforated PVC pipe inside a sleeve of high-grade regenerated cellulose tubular dialysis membrane (Membrane Filtration Products, Inc., Seguin, Texas) with an outer protective LDPE mesh (Figure 2.4). The membranes have a nominal molecular-weight cutoff of 8,000 daltons, or about 0.0018 micron pore size, and a flat width of about 3 inches. The diameter of the filled sampler is about 1 inch and the length is about 13 inches, with a capacity of approximately 400 mL. A potential disadvantage of this sampler is that it may begin to biodegrade in some groundwater systems (Vroblesky and Pravecek, 2002); however, the ability of the samplers to produce chemical concentrations comparable to other methods in previous investigations indicates that, during short-term deployment, the susceptibility of the cellulose membrane to biodegradation does not significantly affect the sampler's usefulness in at least some groundwater environments.

Ehlke *et al*. (2004) found that VOC concentrations in RCSs equilibrated within 3 days and iron and bromide concentrations equilibrated within 3 to 7 days. In an unpublished study, Vroblesky (personal communication) found that VOC and chloride concentrations had reached equilibrium by the first sampling event at 8 days. Vroblesky *et al*. (2002) state that concentrations of inorganic constituents in RCSs equilibrated within 20.5 to 92 hours.

FIGURE 2.4
STANDARD RCS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

2.2   GRAB SAMPLERS

In contrast to the diffusion samplers, grab sampling devices represent more of an equilibrated instantaneous "snap-shot" in time of groundwater conditions. For these devices, the sampler is deployed in a well and is left there until groundwater conditions have re-equilibrated. At that time the groundwater is captured by the device, and the resulting sample is submitted to the laboratory for analysis.

2.2.1   SNAP SAMPLER™

The Snap Sampler™ (patent pending) was developed by ProHydro, Inc. and was initially designed to collect a representative VOC sample *in situ* without the need for purging. Samples collected with the Snap Sampler™ can be analyzed for more than VOCs. Utilizing minimum sample volume requirements, this sampler can also be used for analyzing a larger number of physical and/or chemical water quality parameters.

The Snap Sampler™ employs standard-sized 40 mL glass volatile organics analysis (VOA) vials with double end-openings (Figure 2.5). Specialty Teflon® end closure caps seal water within the Snap Sampler™ vial with an internal closure spring. The closure spring is made of perfluoroalkoxy (PFA Teflon®)-coated stainless steel. To deploy the sampling device, the VOA vial is placed inside the Snap Sampler™, and the end closure caps are attached to the sampler's trigger mechanism in an open position. Both ends of the VOA vial are open to the well environment during the deployment period.

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FIGURE 2.5
STANDARD SNAP SAMPLER™
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Up to three Snap Samplers™ can be connected in series with a single suspension/trigger cable. The suspension/trigger cable consists of a 1/32-inch-diameter stainless steel wire rope within ¼-inch HDPE tubing. The HDPE tubing attaches to the samplers and the wire rope attaches to the release mechanism of the sampler. The samplers are lowered into the well to a predetermined depth using the suspension/trigger cable. The suspension/trigger cable is secured at the surface at a well-head docking station that does not interfere with well-head locks or water level measuring devices.

The Snap Sampler™ is left for an appropriate length of time to allow the well to return to equilibrium with the surrounding groundwater. When ready to collect samples, the internal trigger cable is manually pulled at the wellhead to activate the sampler release mechanism. The trigger releases the vial caps, which close onto the VOA vial by action of the internal closure spring. The vial caps and spring seal the groundwater within the sampling container.

The samplers are then retrieved from the well, VOA bottles are removed from the Snap Sampler™, preservative is added (if necessary) using a method that does not require the sample bottle to be uncapped (Parsons, 2004a [SOP can be accessed via vendor website at www.snapsampler.com]), and end caps are secured with standard VOA vial screw caps. The VOA vials can be used with standard laboratory autosampling equipment designed for 40 mL vials. From the well to the autosampler, water samples are never exposed to ambient air. A 125-ml sample bottle is currently in development to accommodate larger volume needs. Other sampler and bottle material compositions are available or are being developed to accommodate different sampling needs. For example, a fully non-metallic sampler is now available for metals sampling.

The diameter of the sampler apparatus used at McClellan was 1.6 inches. The length of the device was approximately 10 inches with a single sampler and vial, 17 inches with two samplers and two vials, and 23 inches with three samplers and three vials. The longest distance between the end openings of the three-vial configuration was 17 inches.

The current configuration uses a new connector that changes these dimensions slightly as follow: diameter = 1.66 inches, length = 8 inches with a single sampler and vial, 16

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inches with two samplers and two vials, and 24 inches with three samplers and three vials. The longest distance between the end openings of the current three-vial configuration is 19 inches.

2.2.2 HYDRASLEEVE® SAMPLER

The HydraSleeve® sampler (US patents #6,481,300 and #6,837,120), manufactured by GeoInsight (www.hydrasleeve.com), is designed to collect a representative sample for most physical and chemical parameters without purging the well. It collects a water sample from a defined interval within the well screen without mixing fluid from other intervals. Physically, it is a section of lay-flat polyethylene tubing, sealed at the bottom end, and built with a polyethylene reed-valve at the top end (Figure 2.6).

FIGURE 2.6
STANDARD HYDRASLEEVE®
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA
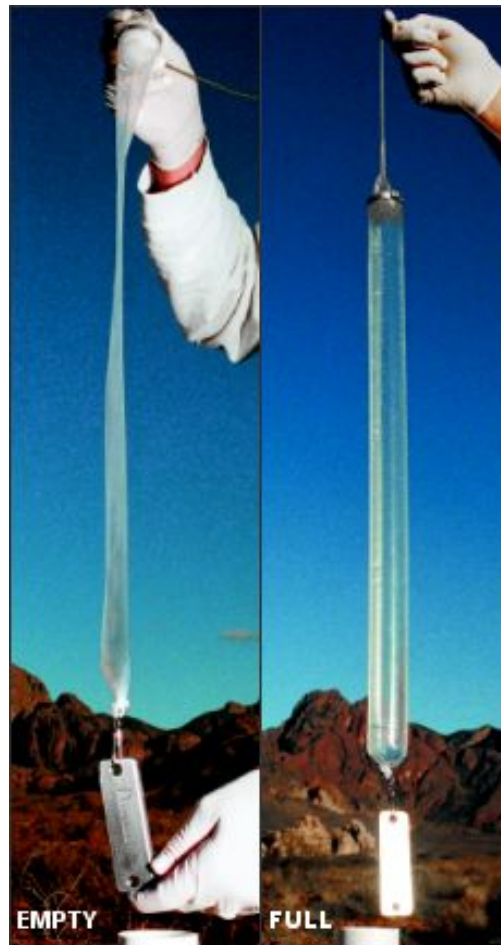
The empty sampler is weighted at the bottom, attached to a line, and then lowered to a predetermined depth within the well screen. It is typically left in the well for a period of

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time to allow the well to re-equilibrate following sampler deployment. Once the well has re-equilibrated, the sampler can be activated for sample collection. Prior to activation, the sampler remains in a collapsed (i.e., empty) state and therefore takes up minimal space within the well. To activate, the sampler is pulled up a distance equal to 1 to 2 times the sampler length (2.5 to 5 feet for a 30-inch-long sampler). As the sampler rises through the water column, the reed valve opens, allowing the sampler to "core" the water column through which it is being raised. Once full, the reed valve closes, which prohibits any more water from entering the sampler. An alternate approach to activating the sampler is to raise and lower it multiple times over a distance equal to the sampler length. However, this approach is less attractive because the raising and lowering of the sampler can result in increased agitation of the water in the well and higher turbidity levels in the sample.

The 24- to 30-inch-long sampler can be purchased in either 1.5- or 2.5-inch diameter models; the 30-inch sampler has volumes of 1,000 mL and 2,500 mL for these diameters, respectively.

2.3   CONVENTIONAL SAMPLING METHODS

One of the scoping guidelines described in Section 1.5 was to have results from at least one other traditional sampling method that could serve as a "baseline" for comparison purposes to the diffusion and grab sampling technologies. In order to address this scoping guideline, conventional sampling methods used as "baseline" measurements were:

1. Sampling following low-flow/minimal drawdown purging , and

2. Sampling following conventional purging of at least three well-casing volumes of water and stabilization of water quality parameters.

The objective of low-flow sampling is to remove a small volume of water at a low flow rate from a small portion of the screened interval of a well without mixing water among vertical zones. Ideally, by placing the inflow port of a pump at a prescribed depth within the screened interval of a well, and by withdrawing water at a slow rate, groundwater will be drawn from the aquifer into the well only in the immediate vicinity of the pump. This theoretically depth-discrete sampling allows for vertical definition of contamination in the aquifer. In practice, however, when a low-flow sample is collected, determining the portion of the screened interval of the aquifer that contributed water to the sample can be problematic.

Groundwater sampling using the three-volume purge method involves removing a large volume of water (three to five well-casing volumes) from the well over a short time. The objective of this method is to remove all stagnant water present within the well casing, as well as groundwater present in the surrounding well filter pack. Theoretically, by removing this water quickly, the "stagnant" water that resided in the well and filter pack will be replaced with "fresh" groundwater from the surrounding formation with minimal mixing. The "fresh" groundwater that is then sampled is considered to be representative of the local groundwater. Rapid drawdown of the water level in a well is not uncommon, and wells are often purged dry using this method.

Conventional sampling at McClellan that is part of regularly scheduled LTM is performed using both low-flow and three-volume purge techniques. Low-flow sampling is only performed at wells in which dedicated bladder pumps have been installed, while

three-volume sampling is performed using submersible pumps that are moved from well to well. McClellan is in the process of installing dedicated bladder pumps in all of their regularly sampled wells so that all future conventional sampling will be performed using the low-flow technique.

In order to maximize consistency and comparability between the historical conventional sampling record for McClellan and the conventional sampling performed as part of this demonstration, similar procedures were followed to the extent possible. However, as described in the Work Plan (Parsons, 2004a) the presence of dedicated pumps in a well automatically excluded that well for use in this demonstration. Therefore, the low-flow sampling that was performed during this demonstration did not strictly adhere to the SOP for low-flow sampling provided in the McClellan QAPP (URS, 2003).

A submersible pump (i.e., Grundfos RediFlo2®) and new, clean dedicated LDPE tubing were used to perform all purging and sampling of the wells. The pump intake was positioned at the midpoint of the saturated portion of the well screen, and the flow rate was controlled to minimize drawdown in the well (during low-flow purging only). Average pump rates varied from approximately 0.09 to 0.19 gallon per minute (gpm) for the low-flow purge and from approximately 0.71 to 4.0 gpm for the three-volume purge. Drawdown was monitored throughout the low-flow purge using a water-level probe. Field parameters including temperature, pH, conductivity, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity also were monitored in a flow-through cell during both low-flow and three-volume purging. Once well stabilization was achieved, as demonstrated by stabilized field parameters (described in the Work Plan [Parsons, 2004a]), samples were collected. For the low-flow technique, sample bottles were filled directly from the pump discharge. For the three-volume purge, samples were collected using a bailer following completion of the purge, as specified in the McClellan QAPP (URS, 2003).

For all wells, the low-flow sample was collected first, after which time the pump rate was increased and the three-volume purge sample was collected following evacuation of the required purge volume and field parameter stabilization.

SECTION 3

FIELD ACTIVITIES AND
LABORATORY ANALYTICAL APPROACH

3.1   FIELD ACTIVITIES

A total of 251 primary samples and 34 quality assurance/quality control (QA/QC) samples were collected from 20 wells at McClellan as part of this demonstration. Details of the field activities are discussed below.

3.1.1   SAMPLING STRATEGY

Concurrent deployment of multiple types of samplers at the same depth in each well is desirable to obtain comparative data. However, the 4-inch well diameter imposed a physical limitation on the number of samplers that could be concurrently deployed at the same depth in each well. Therefore, sampling occurred in three phases as described below.

- Phase 1 – During this phase, which occurred from May 17 through 21, 2004, the diffusion samplers (PDBS, RPPS, PsMS, and RCS) were deployed in the 20 selected monitoring wells at three different depths per well. No more than 3 different types of diffusion samplers were deployed in each well.

- Phase 2 – After an approximate 3-week equilibration period, the diffusion samplers deployed in Phase 1 were retrieved (from June 7 through 9, 2004). The grab samplers (Snap Sampler™ and HydraSleeve®) were subsequently deployed at the same depths as the samplers deployed in Phase 1. Only one type of grab sampler was deployed in each well; concurrent deployment of both the Snap Sampler™ and HydraSleeve® in the same 4-inch well would have made deployment and retrieval difficult and may have compromised the function of one or both of the devices..

- Phase 3 – After an approximate 1-week equilibration period, the grab samplers were retrieved (from June 14 through 17, 2004). Following this retrieval, conventional sampling (i.e., low-flow purge/sample and three-volume purge/sample) of all 20 wells was performed. Both low-flow purge/sample and three-volume purge/sample techniques were used at each well.

Table 3.1 is a summary of the types of sampling techniques that were used in each well.

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<p style="text-align:center">TABLE 3.1
SAMPLING TECHNOLOGIES DEMONSTRATED IN EACH WELL
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA</p>

Well ID	Sampling Technology Demonstrated in Each Well							
	PDBS	RPPS	PsMS	RCS	Hydra-Sleeve®	Snap Sampler™	Low-Flow Purge	Three-Volume Purge
MW-1050	X	X	X		X		X	X
MW-1065	X	X		X		X	X	X
MW-136		X	X		X		X	X
MW-148	X	X	X		X		X	X
MW-173	X	X		X		X	X	X
MW-174	X	X		X		X	X	X
MW-19D		X	X		X		X	X
MW-211		X		X	X		X	X
MW-225	X	X	X		X		X	X
MW-241		X		X		X	X	X
MW-242	X	X		X		X	X	X
MW-333	X	X		X		X	X	X
MW-38D	X	X	X		X		X	X
MW-400	X	X		X		X	X	X
MW-411	X	X	X		X		X	X
MW-424	X	X	X		X		X	X
MW-427	X	X		X		X	X	X
MW-437	X	X	X		X		X	X
MW-453		X	X			X	X	X
MW-72	X	X		X		X	X	X

3.1.2   FIELD MEASUREMENTS

The depth to water was measured in each well prior to deployment during Phase 1, prior to retrievals during Phase 2, and prior to conventional sampling during Phase 3. Additionally, the total well depth was measured prior to deployment during Phase 1. Target sampler deployment depths were calculated after measuring the depth to water and the total well depth at the beginning of Phase 1, taking into consideration the reported screened interval of the well. Of the three sampling depths monitored per well, the intermediate interval was generally defined as the center of the saturated screened interval, the shallow interval was generally defined as being approximately 1 foot below the top of the saturated screened interval, and the deep interval was generally defined as being approximately 1 foot above the bottom of the open (i.e., non-buried) saturated screened interval. Table 3.2 is a summary of the depth to water measurements, the total depth measurements, the screened interval depths, and the sampling intervals for each well.

TABLE 3.2
WATER LEVEL MEASUREMENTS, WELL DETAILS, AND DEPLOYMENT DEPTHS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well ID	Measured Well Depth (ft btoc)[a/]	Measured Well Stickup (ft ags)[b/]	Measured Well Depth (ft bgs)[c/]	Reported Depth to Top of Screen (ft bgs)	Reported Depth to Bottom of Screen (ft bgs)	Depth to Water (ft btoc) Phase 1[d/]	Phase 2[d/]	Phase 3[d/]	No-Purge Sampler Deployment Depths[e/] (ft bgs) Deep Interval	Middle Interval	Shallow Interval
MW-1050	173.4	-1.1	174.5	165	175	101.75	102.33	102.93	172.9	169.9	166.9
MW-1065	129.7	-0.9	130.6	121	131	111.64	NM[f/]	112.54	129	126	123
MW-136	253.2	1.1	252.1	230	245	103.02	103.22	103.5	240.5	237.5	234.5
MW-148	300.7	1.9	298.8	288	298	107.15	108	108.68	296	293	290
MW-173	165.8	-0.9	166.7	156	166	114.93	NM	115.78	164.9	161.9	158.9
MW-174	218.8	-0.8	219.6	208.5	218.5	112.24	NM	113.14	217.3	214.3	211.3
MW-19D	150.1	1.0	149.1	139	149	96.48	96.52	96.66	147	144	141
MW-211	161.1	-1.4	162.5	151	161	108.5	109.18	110.09	159	156	153
MW-225	167.6	NM	167.6[g/]	157.6	167.6	113.39	NM	113.5	165.6	162.6	159.6
MW-241	137.6	2.5	135.1	114	134	102	101.93	102.08	131	124	117
MW-242	137.8	2.2	135.6	120	135	104.85	104.79	104.85	132.5	127.5	122.5
MW-333	168.0	-0.3	168.3	160	170	111.58	110.35	112.49	166.9	164.1	161.4
MW-38D	122.9	2.1	120.8	120.03	130.03	99.5	99.53	99.76	120.3[h/]	None[h/]	None[h/]
MW-400	121.4	-0.4	121.8	111	121	103.65	NM	105.1	119.4	116.4	113.4
MW-411	120.7	-0.9	121.6	102	122	92.42	92.26	92.51	118.25	112	105.75
MW-424	147.2	-0.4	147.5	137	147	104.45	NM	105.71	145	142	139
MW-427	124.0	-0.4	124.4	114	124	105.75	NM	106.48	122	119	116
MW-437	170.2	NM	170.2[g/]	160	170	110.21	110.84	111.04	168	165	162
MW-453	120.0	-0.4	120.4	100	120	94.54	92.51	92.78	117	110	103
MW-72	138.9	2.7	136.2	121.03	131.03	102.53	102.47	102.2	129.03	126.03	123.03

[a/] ft btoc = Feet below top of casing.

[b/] ft ags = Feet above ground surface. A negative value indicates that the top of casing was below the ground surface.

[c/] ft bgs = Feet below ground surface.

[d/] Phase 1 measurements were made from 5/17/04 through 5/20/04.
   Phase 2 measurements were made from 6/7/04 through 6/9/04.
   Phase 3 measurements were made from 6/14/04 through 6/17/04.

[e/] Depths shown are the midpoints of each no-purge sampler group.

[f/] NM = Not measured.

[g/] Well depth shown is actually ft btoc since no stickup was measured.

[h/] Only one depth interval was monitored in this well due to the shortened screened interval.

Measurements of traditional well stabilization parameters were made during conventional sampling. These parameters included groundwater temperature, pH, conductivity, DO, ORP, and turbidity. These measurements along with the total volume purged, the time spent purging, and the average pump rate for each well are summarized in Table 3.3.

A maximum of three different types of diffusion samplers and one type of grab sampler were deployed in each well. The distribution of diffusion and grab samplers in each well was designed to facilitate inter-sampler comparisons while maintaining an overall deployment of RPPS in 20 wells; RCS, PsMS, HydraSleeve®, and Snap Samplers in 10 wells each; and PDBS in only those wells that were targeted for VOC analysis.

Table 3.4 is a summary of the sample dates, deployment lengths, and time lags between all sampling events.

3.2   LABORATORY ANALYTICAL APPROACH

3.2.1   TARGET COMPOUNDS

The following compounds were targeted for analysis in the priority listed below during the technology demonstration.

- 1,4 dioxane;

- Hexavalent chromium;

- McClellan target analyte list (TAL) for metals, total and/or dissolved phases depending on sample turbidity (see below and Section 4.2 of Work Plan [Parsons, 2004a]) including: aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc;

- Anions including sulfate, nitrate, and chloride; and

- VOCs (refer to Table 4.11 of the McClellan QAPP [URS, 2003] for a list of specific analytes).

With the exception of VOCs, these compounds were targeted because they are not able to be monitored using the PDBS method, but are contaminants of concern at some DoD installations. VOCs were included in the target compound list to verify that all no-purge sampling devices also would be capable of accurately monitoring for these compounds.

The final measurements of turbidity made during both types of conventional sampling were used to determine whether or not the samples should be field-filtered for TAL metals analysis using a 0.45-micron disposable filter. If the final turbidity measurement made immediately before sample collection was less than or equal to 5 Nephelometric Turbidity Units (NTUs), the samples were not filtered in the field and were submitted for total metals analysis. If the final turbidity measurement was greater than 5 NTUs, the samples were filtered according to procedures described in SOP #6 of the Work Plan (Parsons, 2004a), and were scheduled for dissolved metals analysis. All conventionally sampled wells that were analyzed for metals were field-filtered with the exception of well

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TABLE 3.3
SUMMARY OF CONVENTIONAL SAMPLING FIELD PARAMETER MEASUREMENTS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well ID	Sampling Method	Temperature (ºC)[a]	pH	Conductivity (µS/cm)[b]	DO (mg/L)[c]	ORP (mV)[d]	Turbidity (NTU)[e]	Total Volume Purged (gallons)	Time Spent Purging (minutes)	Average Purge Rate (gpm)[f]	Average Purge Rate (Lpm)[g]	Samples Field Filtered?
MW-1050	Low-Flow	19.37	7.64	264	6.29	142	15	2	19	0.11	0.40	Yes
	Three Volume	19.06	7.91	268	7.62	149.6	7	144	36	4.00	15.14	Yes
MW-1065	Low-Flow	24.20	7.20	621	7.41	353	58.7	3.5	19	0.18	0.70	Yes
	Three Volume	21.32	7.31	578	9.12	332	10	35	21	1.67	6.31	Yes
MW-136	Low-Flow	21.05	6.43	310	0.53	412	86.5	3.8	22	0.17	0.65	Yes
	Three Volume	21.04	6.34	333	7.33	467	15.3	290	88	3.30	12.47	Yes
MW-148	Low-Flow	20.88	7.00	598	4.24	364	5.5	3.3	19	0.17	0.66	Yes
	Three Volume	21.57	7.29	616	4.42	358	8.1	380	128	2.97	11.24	Yes
MW-173	Low-Flow	22.40	6.81	200	6.66	281.8	171.6	1.5	15	0.10	0.38	Yes
	Three Volume	20.84	7.51	195	7.55	229	NM[h]	99	33	3.00	11.36	Yes
MW-174	Low-Flow	23.95	7.09	458	5.42	313	56.3	2.5	18	0.14	0.53	Yes
	Three Volume	23.12	6.83	459	5.67	432	7.8	205	61	3.36	12.72	Yes
MW-19D	Low-Flow	23.47	7.41	249	1.85	372	16.5	3	19	0.16	0.60	--[j]
	Three Volume	21.99	6.55	239	2.52	423	4.2	97	37	2.62	9.92	--
MW-211	Low-Flow	21.08	7.16	520	7.71	339	35.2	2.5	17	0.15	0.56	Yes
	Three Volume	20.00	7.31	499	8.90	323	74.9	105	35	3.00	11.36	Yes
MW-225	Low-Flow	24.40	7.12	234	6.71	213.3	26.8	4.5	24	0.19	0.71	--
	Three Volume	22.16	7.60	257	7.12	166.6	21	105	35	3.00	11.36	--
MW-241	Low-Flow	24.23	7.29	249	6.27	356.8	49.8	2.4	19	0.13	0.48	--
	Three Volume	22.57	7.41	151	6.89	355	1.2	70	24	2.92	11.04	--
MW-242	Low-Flow	22.37	6.99	258	2.75	NM	3.8	4	30	0.13	0.50	--
	Three Volume	20.28	6.65	224	5.99	338.8	1.3	63	19	3.32	12.55	--
MW-333	Low-Flow	23.85	7.09	226	6.50	174.2	194	2.5	21	0.12	0.45	--
	Three Volume	21.51	7.09	209	9.83	207.3	86	112	30	3.73	14.13	--
MW-38D	Low-Flow	23.37	7.66	277	0.61	-134.8	180.4	2.5	20	0.13	0.47	--
	Three Volume	22.80	7.49	283	NM	77.8	140.6	21	29	0.72	2.74	--
MW-400	Low-Flow	23.89	7.26	646	7.59	352	1.1	4.5	29	0.16	0.59	No
	Three Volume	21.60	7.08	621	8.62	374	4.9	33	47	0.70	2.66	No
MW-411	Low-Flow	23.30	7.36	393	2.37	106.7	158.1	1.5	16	0.09	0.35	Yes
	Three Volume	21.01	7.49	352	5.60	159.5	54	53	22	2.41	9.12	Yes
MW-424	Low-Flow	23.96	8.87	330	6.01	55.8	59.3	3	24	0.13	0.47	Yes
	Three Volume	21.10	8.71	311	2.64	75.6	101	84	21	4.00	15.14	Yes
MW-427	Low-Flow	23.11	6.61	693	7.04	282.6	82.2	2	19	0.11	0.40	Yes
	Three Volume	21.84	7.03	683	9.81	258.7	223	33	37	0.89	3.38	Yes
MW-437	Low-Flow	21.68	6.91	202	5.91	282.8	190.5	3	19	0.16	0.60	--
	Three Volume	20.40	7.24	201	8.34	257.7	24	120	30	4.00	15.14	--
MW-453	Low-Flow	19.33	7.24	797	8.09	157.8	27	2	21	0.10	0.36	Yes
	Three Volume	18.76	7.63	668	9.05	148	7.3	56	14	4.00	15.14	Yes
MW-72	Low-Flow	25.86	7.73	551	0.95	34.5	28.9	NM	16	NA[i]	NA	--
	Three Volume	22.01	7.36	510	2.84	68.4	10.8	69	49	1.41	5.33	--

[a] ºC = Degrees Celsius.

[b] µS/cm = Microsiemens per centimeter.

[c] mg/L = Milligrams per liter.

[d] mV = Millivolts.

[e] NTU = Nephelometric turbidity units.

[f] gpm = Gallons per minute.

[g] Lpm = Liters per minute.

[h] NM = Not measured.

[i] NA = Not applicable.

[j] -- = Target analyte list metals not analyzed, therefore field filtering was not required.

TABLE 3.4

SAMPLE DATES AND TIME LAGS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Well	No-Purge Samplers Used						Diffusion Sampler			Grab Sampler			Conventional Sampling Date	Days Between Conventional and Diffusion Sampling	Days Between Conventional and Grab Sampling
	PDBS	RPPS	PsMS	RCS	Hydrasleeve	Snap Sampler	Deployment Date	Retrieval Date	Days Deployed	Deployment Date	Retrieval Date	Days Deployed			
MW-1050	X	X	X		X		05/21/04	06/08/04	18	06/08/04	06/15/04	7	06/17/04	9	2
MW-1065	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/15/04	6	06/17/04	8	2
MW-136		X	X		X		05/20/04	06/08/04	19	06/08/04	06/15/04	7	06/15/04	7	0
MW-148	X	X	X		X		05/21/04	06/08/04	18	06/08/04	06/15/04	7	06/16/04	8	1
MW-173	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/14/04	5	06/16/04	7	2
MW-174	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/14/04	5	06/16/04	7	2
MW-19D		X	X		X		05/19/04	06/07/04	19	06/07/04	06/15/04	8	06/15/04	8	0
MW-211		X		X	X		05/20/04	06/07/04	18	06/07/04	06/15/04	8	06/17/04	10	2
MW-225	X	X	X		X		05/19/04	06/09/04	21	06/09/04	06/15/04	6	06/16/04	7	1
MW-241		X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/15/04	8	1
MW-242	X	X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/14/04	7	0
MW-333	X	X		X		X	05/21/04	06/08/04	18	06/08/04	06/14/04	6	06/15/04	7	1
MW-38D	X	X	X		X		05/19/04	06/07/04	19	06/07/04	06/15/04	8	06/15/04	8	0
MW-400	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/16/04	7	06/17/04	8	1
MW-411	X	X	X		X		05/19/04	06/08/04	20	06/08/04	06/15/04	7	06/15/04	7	0
MW-424	X	X	X		X		05/19/04	06/09/04	21	06/09/04	06/16/04	7	06/17/04	8	1
MW-427	X	X		X		X	05/20/04	06/09/04	20	06/09/04	06/15/04	6	06/16/04	7	1
MW-437	X	X	X		X		05/20/04	06/08/04	19	06/08/04	06/15/04	7	06/16/04	8	1
MW-453		X	X			X	05/19/04	06/08/04	20	06/08/04	06/14/04	6	06/17/04	9	3
MW-72	X	X		X		X	05/21/04	06/07/04	17	06/07/04	06/14/04	7	06/14/04	7	0
Minimum									17			5		7	0
Maximum									21			8		10	3
Median									19			7		8	1

MW-400 where the measured turbidity was less than 5 NTUs. Additionally, all metals samples collected using the HydraSleeve® were field-filtered. Samples for hexavalent chromium analysis were not field-filtered.

3.2.2   LABORATORIES

Two analytical laboratories were used during this demonstration to perform all of the required analyses. Columbia Analytical Services, Inc. (CAS) in Kelso, Washington performed the metals and 1,4 dioxane analyses. Sequoia Analytical (Sequoia), based in Sacramento, California performed the hexavalent chromium, anion, and VOC analyses. Sequoia used two different facilities to perform the requested analyses; hexavalent chromium and anions were analyzed in their Morgan Hill, California facility while VOCs were analyzed in their Petaluma, California facility.

The maximum holding time permitted for hexavalent chromium is 24 hours. Therefore, samples were sent twice per day (once at approximately noon, and again at approximately 5 pm) to Sequoia using a hand-delivery courier. Samples were shipped daily each afternoon to CAS via overnight express courier.

3.2.3   SAMPLE VOLUME

As described in the Work Plan (Parsons, 2004a), the diffusion and grab samplers do not collect large volumes of groundwater (relative to conventional sampling methods), and the available sample volume does not always fulfill normal laboratory and/or analytical method recommendations. This characteristic is not necessarily a critical limitation since most analytical methods do not actually require the larger sample volumes recommended in standard analytical procedures. An ITRC Diffusion Sampler subteam has estimated the minimum sample volumes required for common environmental analytical methods; details are available on the ITRC diffusion sampling website at http://64.203.146.40/news.asp#41. Prior coordination with the analytical laboratories enabled use of smaller sample volumes to perform the required analytical methods while still maintaining required detection limits. Table 3.5 is a summary of the approximate maximum volume capacities of each type of no-purge sampling device used in this study per sample depth (some sampling devices required more than one sampler per depth interval). The volumes listed in Table 3.5 are the maximum obtainable with the configuration used at McClellan; larger volumes can potentially be obtained in some cases by reconfiguring the samplers (e.g., using more PsMS canisters). It should be noted that a larger-volume Snap Sampler™ and HydraSleeve® are now available. Table 3.6 summarizes the minimum sample volume requirements (per analysis) specified by the analytical laboratories.

Groundwater samples from each well were analyzed for only a subset of the target analyte list. The minimum sample volumes shown in Table 3.6 were used for diffusion, grab, and low-flow samples to maintain consistency and to facilitate comparison of the results. However, in order to maintain consistency between the three-volume purge method historically used for these wells as part of LTM and the conventional samples collected as part of this demonstration, normal sample volumes specified in the McClellan QAPP (URS, 2003) were collected for the three-volume purge method.

TABLE 3.5
VOLUMETRIC CAPACITIES OF SAMPLING DEVICES
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Sampling Device	Volumetric Capacity (mL)
PDBS	350 (1 sampler)
RPPS	300 (2 samplers)
PsMS	216 (2 samplers)
RCS	400 (1 sampler)
Snap Sampler™	120 (3 vials)
HydraSleeve®	2,000 (1 sampler)

TABLE 3.6
MINIMUM VOLUME REQUIREMENTS
NO-PURGE SAMPLER DEMONSTRATION
MCCLELLAN AFB, CALIFORNIA

Analyte	Analytical Method(s)	Minimum Volume Required (mL)
Hexavalent chromium	SW7199	5
Metals	SW6020, SW6010, SW7740	25
1,4 dioxane	SW8270C	100
Anions	E300.0	5
VOCs	SW8260B	20

One or more additional sets of sample bottles were filled and submitted to the analytical laboratory along with the primary sample whenever sufficient sample volume was available. This practice allowed the laboratory to reanalyze samples as necessary due to the need for sample dilution or other circumstances.

3.3   DEVIATIONS FROM WORK PLAN

The field activities generally occurred in accordance with the Work Plan (Parsons, 2004a). However, the following notable deviations occurred during this evaluation.

- While measuring the total depth of MW-1031, the depth sounding device continually became caught on the inside of the well. Due to concerns of having the no-purge samplers stuck or damaged inside the well during deployment and/or retrieval, MW-1031 was replaced with the first alternate well (MW-424) listed in the Work Plan (Parsons, 2004a).

- Upon retrieval of the HydraSleeve® samplers from well MW-148, a knot was observed in the rope used for deployment approximately 10 to 30 feet above the top of the upper (i.e., shallow) sampler. Approximately 10.8 feet of rope was tangled as part of this knot, which presumably meant that all HydraSleeve® samplers in this well were actually deployed approximately 10.8 feet higher in the well than anticipated. Additionally, upon retrieval the deepest HydraSleeve® sampler from this well had a hole in it and no water was recovered. Because of these issues, only the intermediate depth sampler was sent to the laboratory for analysis.

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- The trigger mechanism of the Snap™ Sampler was not pulled hard enough at two wells, resulting in no Snap™ Samples being collected from well MW-242 and no deep Snap Sample being collected from well MW-427.

- In order to evaluate the ability of PDBS to monitor 1,4 dioxane, this analysis was requested for one PDBS during the demonstration (the shallow PDBS deployed in well MW-72).

- The measured total depth in well MW-38D was 120.8 ft bgs (Table 3.2). The reported values for the top and bottom of the screened interval for this well were 120.03 and 130.03 ft bgs, respectively. Based on these values, only approximately 0.8 foot of screen was open in this well. Accordingly, only one depth interval was monitored (defined as the deep interval) at 120.3 ft bgs.

- The water level indicator used during the Phase 2 activities malfunctioned during the afternoon of June 8, 2004. Accordingly, no water level measurements were obtained for the last 1.5 days of Phase 2 activities.

- Hexavalent chromium was analyzed using US Environmental Protection Agency (USEPA) Method SW7199 as opposed to SW7196M as described in the Work Plan (Parsons, 2004a). Use of SW7199 permitted a lower detection limit than would have been possible with SW7196M.

- Metals were analyzed using USEPA Methods SW6010, SW6020, and SW7740 as opposed to only SW6020 as described in the Work Plan (Parsons, 2004a).

- Typically, at least two 20-mL VOA vials were shipped to Sequoia for VOC analysis. The expectation (based on prior discussions with the laboratory) was that Sequoia would use one sample bottle for the initial analysis and would use any additional sample bottles as back-up samples in the event that re-analysis was necessary (e.g., dilutions). However, for most analyses Sequoia composited the two 20-mL VOA vials into one 40-mL VOA vial for analysis using their autosampler. Parsons discussed this issue with Sequoia after realizing that the procedure was being used, and Sequoia clarified that the procedure that was used was consistent with USEPA guidance. Nonetheless, the potential for volatilization of VOCs during the compositing process is a potential concern.

- Due to a field oversight, hexavalent chromium was not analyzed in either the Low-Flow or the three-Volume samples collected from wells MW-38D and MW-424.

3.4 QA/QC SAMPLE COLLECTION

A total of 34 samples were collected for QA/QC purposes. The number and type of each of these samples is summarized in Table 3.7. Generally QA/QC sample collection followed the schedule described in the Work Plan (Parsons, 2004a). However, some variances did occur as described below.

Sequoia did not provide trip blank samples as part of the Phase 2 bottle order. However, one trip blank sample was provided via courier by Sequoia on June 9, 2004. This was the only trip blank sample collected during the Phase 2 activities. This sample was sent to Sequoia along with the daily shipment of VOC samples on June 9, 2004. However, Sequoia did not analyze this sample. No explanation was available from Sequoia as to why this sample was not analyzed. Trip blank samples were provided by Sequoia for the Phase 3 activities, and one of these samples was shipped along with each

TABLE 3.7
QA/QC SAMPLES COLLECTED
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sample Type	PDBS	RPPS	PsMS	RCS	Hydra-Sleeve®	Snap Sampler™	Low-Flow	Three-Volume Purge
Field Duplicate	2	0	0	1	0	0	4[a/]	4[a/]
Matrix Spike/Matrix Spike Duplicate	0	0	0	0	0	0	1[b/]	1[b/]
Equipment Rinseate	1	1	1	1	1	1	1 from pump and tubing	2 Total: -1 from bailer only -1 from bailer and filter
Source Water Blank[c/]	1				NA[d/]	NA[d/]	NA[d/]	NA[d/]
Purified Water[e/]	1							
Trip Blank	7 Total:	1 during Phase 2 which was never analyzed 1 per cooler containing VOC samples collected during Phase 3						

[a/] Although four samples were collected with the intention of being used as field duplicates, a fifth field duplicate sample was available for the analyses performed by Sequoia (see Note [b/] below).

[b/] These samples were designated for MS/MSD analyses on the chains of custody. However, Sequoia treated them as primary samples and did not spike them. They therefore are considered field duplicate samples for analyses performed by Sequoia only. Although no other samples were designated by the field scientists as MS/MSD samples, both Sequoia and CAS chose other samples at random upon which to perform MS/MSD analyses (see Appendix A).

[c/] Source water blank was comprised of the water used to fill the diffusion samplers prior to deployment.

[d/] NA = not applicable.

[e/] Purified water blank was comprised of the water used for decontamination.

cooler containing samples intended for VOC analysis. As a result of the lack of trip blanks during Phase 2, the degree to which low-level VOC detections may be attributable to cross-contamination during sample shipping and handling cannot be fully confirmed.

Two of the samples collected with the intent of being used by the laboratories as matrix spike/matrix spike duplicate (MS/MSD) samples were not treated as MS/MSD samples by Sequoia although they were by CAS. Instead, Sequoia analyzed these samples as primary samples. They are therefore considered duplicate samples for QA/QC purposes. These samples were MW173-3VOL-MS/MSD and MW225-MICRO-MS/MSD. Despite this oversight, other samples were selected at random by Sequoia for MS/MSD analysis (see Appendix A). In the instances where field samples designated as MS/MSDs were not analyzed as such, measurements of accuracy and analytical precision based on MS/MSD results were not developed for samples collected using a given sampling method.

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In the Work Plan (Parsons, 2004a), two field duplicates and two MS/MSD samples were scheduled for collection with the HydraSleeve[®]. However, due to an oversight, no field duplicates or MS/MSD samples for this sampler type were collected. Therefore, information regarding precision of the HydraSleeve® sampling process based on MS/MSD results and the impact of potential matrix effects on the analytical testing is not available.

A total of four field duplicate samples were collected for both the low-flow and three-volume purge sampling methods while only two were scheduled according to the Work Plan (Parsons, 2004a).

Although only one equipment rinseate was scheduled for the three-volume purge method (Parsons, 2004a), two were actually collected; one from the bailer only, and another from both the bailer and the in-line filter.

SECTION 4

SAMPLING RESULTS AND COMPARISON

4.1   DATA PRESENTATION

Field measurements collected during this demonstration are summarized in Tables 3.2 and 3.3. Laboratory analytical results are included on CD as an attachment to this report.

4.2   DATA VALIDATION

A project-specific "Level III" data validation protocol was performed, which evaluated sample data and QC data and results summarized on AFCEE reporting forms. In performing the data validation, it was assumed that the laboratory's documentation was acceptable and that the data reported by the laboratory were an accurate representation of the raw data. The raw data were not reviewed. A complete review of the applicable data was performed, and the project-specific QAPP and the McClellan QAPP 5.0 were used as the primary tools in the validation of the data.

The data quality assessment report (Appendix A) is based on the reviewed information, and on the data quality specifications of the project QAPP, as well as Sections 1-17 of the McClellan AFB QAPP 5.0 and the appended SOP McAFB-028 ("Data Review Procedures") and SOP McAFB-029 ("Data Validation Standard Operating Procedures").

In accordance with the Work Plan (Parsons, 2004a) and as described in Section 3.4, QA/QC samples were collected during this demonstration. These samples included field duplicate, MS/MSD, equipment rinseate, source water blank, purified water, and trip blank samples. A brief summary of the data validation results is provided in the following paragraphs, and more complete details are presented in Appendix A.

- Accuracy is considered acceptable for all VOC, 1,4 dioxane, and anion results, all but one hexavalent chromium result, and all metals results with the exception of the aluminum result in several samples.

- Overall precision (sampling and analysis) is considered to be acceptable for all parameters, recognizing that, as shown in Table 3.7, a field duplicate HydraSleeve® sample was not collected. Therefore, information regarding precision of the HydraSleeve® sampling process is not available.

- Analytical precision is considered to be acceptable, recognizing that in the instances where project samples were not analyzed as MS/MSDs, measurements of accuracy and analytical precision based on MS/MSD results were not developed for samples collected using a given sampling technology.

- Representativeness is considered to be acceptable for all parameters, with the exception of many of the extremely low (below or near the practical quantitation limit [PQL]) results for VOCs, anions, and metals that have been qualified as

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undetected ("U") due to associated contamination of laboratory method blanks or field blanks.

- Completeness is considered to be acceptable for all parameters.

Some data quality issues were noted either in the laboratory case narratives or during the data validation process. Despite these issues, nearly all of the validated data were deemed usable for the intended purposes (only one result was rejected) based on this validation. The reader is directed to Appendix A for a detailed discussion of the data validation results.

4.3   WELL-SPECIFIC DATA PLOTS

Figures were prepared that present the concentrations of selected analytes in each well, as reported for each sampling method used and for each sampling depth (shallow, intermediate, and deep). These figures are included in Appendix B. Graphs were prepared for one VOC of concern (trichloroethene [TCE]), one anion (sulfate), one reduction-oxidation (redox)-sensitive metal (iron), one metal that is less redox-sensitive (zinc), 1,4 dioxane, and hexavalent chromium. Results for the three-volume purge are shown using a vertical line across all depths since that method is not depth specific. Results for the low-flow purge are shown as a single point located at the intermediate depth, despite uncertainty about the depth-discrete nature of a low-flow sample. When a low-flow sample is collected, determining the portion of the screened interval of the aquifer that contributed water to the sample can be problematic. As noted in Section 4.4, for instances where more than one value was available per comparison, the maximum value was used in the sampling results comparison.

4.4   SAMPLING RESULTS COMPARISON

Numerous potential methods of data evaluation are possible due to the relatively large amount of analytical data and number of comparisons. For this report, three different types of evaluation processes were used to compare the data sets:

- Conventional statistical methods,

- Other quantitative comparative tools, and

- Holistic qualitative data evaluation.

Each of these processes was applied with the objective of identifying general trends or tendencies present in the data sets. After all of the processes were applied, overall conclusions related to sampler performance were made. In this comparative analysis, the results for each sampler type were compared to the corresponding results (i.e., same well, same depth, same analyte) for each of the other sampling methods. Additionally, the analytical data set was subdivided into the following six categories for comparison purposes:

1. All data combined,
2. 1,4 dioxane,
3. Anions,
4. Hexavalent chromium,
5. Metals, and
6. VOCs.

Each sampler-to-sampler comparison was performed for each of the analytical subgroups listed above, resulting in a total of 113 dataset comparisons. The quantitative evaluation processes described in Sections 4.4.1 and 4.4.2 (Conventional Statistical Methods and Other Quantitative Comparative Tools, respectively) were applied to each of these 113 comparison instances. The results of these quantitative comparisons were then considered using a holistic qualitative review to derive final conclusions about each specific comparison.

Prior to applying the statistical analysis tools, the datasets used for comparison were "pared down" through the application of several logical filters. These filters are described below.

- Instances where both results being compared were not detected (e.g., TCE was not detected in both low-flow purge and PDB samples) were excluded from the data set.

- If a result was qualified as non-detect (U) based on data validation only, it was excluded from the comparative analyses. This alleviates any concerns about skewing the dataset comparisons due to biases that may be caused by laboratory or field contamination.

- One result was rejected based on the data validation; this value was not used in the statistical analyses.

- For instances where more than one value was available per comparison (i.e., multi-depth sampling versus single-point sampling, primary and duplicate samples), the maximum value was used in the statistical analyses.

- For instances where a result was not detected (ND) at the method detection limit (MDL) using one sampling method, and the corresponding result using the other sampling method was a detected value, a value of one-half of the MDL was used for the ND measurement in the statistical analyses. This permitted use of a log-log scale to plot results, whereas if a value of zero had been assigned to the result instead, it would not plot on that type of scale. One exception to this filter was applied however. In circumstances where one result was ND and the other result being compared was detected but had a lower MDL, the comparison was excluded from the statistical analyses. This prevented the comparison from being biased, because one-half of the MDL for the non-detected analyte may have been greater than the detected result.

- One PDB sample was analyzed for 1,4 dioxane to see if that compound would diffuse through the membrane. Although 1,4 dioxane was detected in other samples from the same well, it was not detected in the PDB sample. This indicates that the PDBS method is not suitable for monitoring 1,4 dioxane. Therefore, the PDBS results for 1,4 dioxane were excluded from the statistical analyses.

Tables 4.1 through 4.6 show the number of data pairs that were available for each comparison after all filters had been applied to the data set. For the quantitative evaluation processes, a lower confidence or meaning was ascribed to comparisons with fewer data pairs. In Tables 4.1 through 4.6, instances where less than 10 data pairs were available for a particular comparison were highlighted in red in the "Number of Comparisons" column.

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TABLE 4.1
STATISTICAL SUMMARY - ALL DATA
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f]		
						Sign[b]	Wilcoxon[c]	Median RPD[d]	X-Y Scatter Slope (R²)[e]	Sampler A		Sampler B
Low-Flow	3-Volume	379	190	174	15	57% (48%)	47%	1.0	0.99 (0.95)	Low-Flow	=	3-Volume
Low-Flow	HydraSleeve®	175	82	85	8	12% (51%)	20%	0.0	0.96 (0.94)	Low-Flow	=	HydraSleeve®
Low-Flow	PDBS	92	31	57	4	99% (65%)	100%	-22.0	1.41 (0.79)	Low-Flow	<	PDBS
Low-Flow	PSMS	171	92	74	5	81% (45%)	51%	2.8	0.95 (0.97)	Low-Flow	=	PSMS
Low-Flow	RCS	168	93	69	6	93% (43%)	79%	5.3	0.93 (0.97)	Low-Flow	=	RCS
Low-Flow	RPPS	336	178	140	18	96% (44%)	73%	3.5	0.94 (0.98)	Low-Flow	=	RPPS
Low-Flow	Snap Sampler™	52	7	41	4	100% (85%)	100%	-21.7	1.22 (0.99)	Low-Flow	<	Snap Sampler™
3-Volume	HydraSleeve®	180	79	93	8	68% (54%)	83%	-1.3	1.04 (0.98)	3-Volume	=	HydraSleeve®
3-Volume	PDBS	99	50	49	0	0% (49%)	53%	5.1	0.76 (0.58)	3-Volume	=	PDBS
3-Volume	PSMS	173	82	89	2	35% (52%)	45%	-1.2	1.02 (0.97)	3-Volume	=	PSMS
3-Volume	RCS	168	104	61	3	100% (37%)	100%	10.6	0.85 (0.98)	3-Volume	>	RCS
3-Volume	RPPS	338	178	148	12	89% (45%)	81%	2.4	0.92 (0.96)	3-Volume	=	RPPS
3-Volume	Snap Sampler™	53	15	33	5	99% (69%)	94%	-6.9	1.08 (0.99)	3-Volume	<	Snap Sampler™
HydraSleeve®	PDBS	95	51	40	4	71% (44%)	73%	12.8	0.98 (0.39)	HydraSleeve®	=	PDBS
HydraSleeve®	PSMS	359	186	151	22	94% (45%)	95%	1.8	0.91 (0.93)	HydraSleeve®	=	PSMS
HydraSleeve®	RCS	49	35	14	0	100% (29%)	99%	7.9	1.00 (1.00)	HydraSleeve®	>	RCS
HydraSleeve®	RPPS	413	213	174	26	95% (45%)	91%	0.9	0.94 (0.98)	HydraSleeve®	=	RPPS
PDBS	PSMS	120	59	55	6	22% (48%)	92%	0.0	0.41 (0.3)	PDBS	=	PSMS
PDBS	RCS	122	80	30	12	100% (27%)	100%	7.7	0.90 (0.96)	PDBS	>	RCS
PDBS	RPPS	232	146	65	21	100% (31%)	100%	11.6	0.81 (0.71)	PDBS	>	RPPS
PDBS	Snap Sampler™	72	9	61	2	100% (87%)	100%	-21.7	1.27 (0.95)	PDBS	<	Snap Sampler™
PSMS	RPPS	471	234	198	39	91% (46%)	96%	0.0	0.99 (0.98)	PSMS	=	RPPS
PSMS	Snap Sampler™	3	1	2	0	0% (67%)	71%	-27.3	1.20 (-16.2)	PSMS	<	Snap Sampler™
RCS	RPPS	457	177	232	48	99% (57%)	85%	-0.7	1.00 (1.00)	RCS	=	RPPS
RCS	Snap Sampler™	132	9	113	10	100% (93%)	100%	-26.3	1.13 (0.96)	RCS	<	Snap Sampler™
RPPS	Snap Sampler™	134	17	107	10	100% (86%)	100%	-17.0	1.11 (0.96)	RPPS	<	Snap Sampler™

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.2
STATISTICAL SUMMARY - 1,4 DIOXANE
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons a/	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests Sign b/	Wilcoxon c/	Median RPD d/	X-Y Scatter Slope (R²) e/	Holistic Conclusion f/ Sampler A		Sampler B
Low-Flow	3-Volume	7	3	4	0	0% (57%)	50%	-1.5	1.41 (0.97)	Low-Flow	=	3-Volume
Low-Flow	HydraSleeve®	3	1	2	0	0% (67%)	41%	0.0	1.11 (1.00)	Low-Flow	=	HydraSleeve®
Low-Flow	PSMS	4	3	1	0	38% (25%)	73%	7.7	0.94 (0.99)	Low-Flow	=	PSMS
Low-Flow	RCS	3	0	3	0	75% (100%)	89%	-7.4	1.11 (1.00)	Low-Flow	<	RCS
Low-Flow	RPPS	7	5	2	0	55% (29%)	82%	6.1	0.92 (0.99)	Low-Flow	=	RPPS
Low-Flow	Snap Sampler™	3	0	3	0	75% (100%)	89%	-20.7	1.26 (1.00)	Low-Flow	<	Snap Sampler™
3-Volume	HydraSleeve®	3	1	2	0	0% (67%)	71%	-5.4	1.05 (1.00)	3-Volume	=	HydraSleeve®
3-Volume	PSMS	4	2	2	0	38% (50%)	53%	5.2	0.90 (0.99)	3-Volume	=	PSMS
3-Volume	RCS	3	2	1	0	0% (33%)	71%	30.3	0.74 (0.99)	3-Volume	=	RCS
3-Volume	RPPS	7	5	2	0	55% (29%)	82%	28.6	0.64 (0.99)	3-Volume	>	RPPS
3-Volume	Snap Sampler™	3	2	1	0	0% (33%)	71%	17.1	0.84 (0.99)	3-Volume	=	Snap Sampler™
HydraSleeve®	PSMS	6	6	0	0	96% (0%)	97%	27.6	0.83 (1.00)	HydraSleeve®	>	PSMS
HydraSleeve®	RPPS	7	6	1	0	87% (14%)	96%	25.0	0.69 (0.99)	HydraSleeve®	>	RPPS
PSMS	RPPS	9	4	3	2	0% (43%)	69%	0.0	0.85 (0.97)	PSMS	=	RPPS
PSMS	Snap Sampler™	3	1	2	0	0% (67%)	71%	-27.3	1.20 (-16.2)	PSMS	<	Snap Sampler™
RCS	RPPS	9	4	4	1	28% (50%)	6%	0.0	0.90 (0.95)	RCS	=	RPPS
RCS	Snap Sampler™	6	0	6	0	96% (100%)	97%	-21.8	1.35 (0.86)	RCS	<	Snap Sampler™
RPPS	Snap Sampler™	9	0	9	0	99% (100%)	99%	-28.6	1.50 (0.95)	RPPS	<	Snap Sampler™

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
   Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
   A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
   A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
   Values between -10 and 10 indicate that the two populations are similar.
   Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
   Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
   Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
   R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
   R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
   Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
   Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
   Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.3
STATISTICAL SUMMARY - ANIONS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f]		
						Sign[b]	Wilcoxon[c]	Median RPD[d]	X-Y Scatter Slope (R^2)[e]	Sampler A		Sampler B
Low-Flow	3-Volume	42	11	20	11	85% (65%)	94%	0.0	1.06 (0.98)	Low-Flow	=	3-Volume
Low-Flow	HydraSleeve®	18	6	7	5	0% (54%)	45%	-9.5	1.06 (0.96)	Low-Flow	=	HydraSleeve®
Low-Flow	PSMS	16	3	12	1	96% (80%)	98%	-6.2	1.07 (0.99)	Low-Flow	=	PSMS
Low-Flow	RCS	24	12	7	5	64% (37%)	3%	0.7	1.00 (1.00)	Low-Flow	=	RCS
Low-Flow	RPPS	41	13	15	13	15% (54%)	85%	0.0	1.01 (0.99)	Low-Flow	=	RPPS
Low-Flow	Snap Sampler™	19	3	13	3	98% (81%)	99%	-5.1	1.22 (0.99)	Low-Flow	<	Snap Sampler™
3-Volume	HydraSleeve®	18	6	7	5	0% (54%)	42%	0.0	1.09 (0.94)	3-Volume	=	HydraSleeve®
3-Volume	PSMS	17	4	11	2	88% (73%)	76%	-8.0	1.02 (0.93)	3-Volume	=	PSMS
3-Volume	RCS	24	16	6	2	94% (27%)	64%	6.7	0.88 (0.99)	3-Volume	=	RCS
3-Volume	RPPS	42	19	13	10	62% (41%)	51%	0.0	0.92 (0.96)	3-Volume	=	RPPS
3-Volume	Snap Sampler™	19	5	9	5	58% (64%)	90%	0.0	1.08 (0.99)	3-Volume	=	Snap Sampler™
HydraSleeve®	PSMS	44	9	21	14	96% (70%)	75%	0.0	0.86 (0.77)	HydraSleeve®	=	PSMS
HydraSleeve®	RPPS	49	19	19	11	13% (50%)	60%	0.0	0.94 (0.97)	HydraSleeve®	=	RPPS
PSMS	RPPS	50	32	4	14	100% (11%)	100%	6.3	0.98 (0.87)	PSMS	=	RPPS
RCS	RPPS	70	14	33	23	99% (70%)	99%	0.0	1.01 (1.00)	RCS	=	RPPS
RCS	Snap Sampler™	57	5	43	9	100% (90%)	100%	-10.0	1.13 (0.94)	RCS	<	Snap Sampler™
RPPS	Snap Sampler™	59	11	40	8	100% (78%)	99%	-6.5	1.11 (0.95)	RPPS	<	Snap Sampler™

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.4
STATISTICAL SUMMARY - HEXAVALENT CHROMIUM
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f]		
						Sign[b]	Wilcoxon[c]	Median RPD[d]	X-Y Scatter Slope (R^2)[e]	Sampler A		Sampler B
Low-Flow	3-Volume	13	1	12	0	99% (92%)	100%	-42.0	1.39 (0.14)	Low-Flow	<	3-Volume
Low-Flow	HydraSleeve®	7	1	6	0	87% (86%)	96%	-95.1	2.49 (0.46)	Low-Flow	<	HydraSleeve®
Low-Flow	PSMS	5	1	4	0	63% (80%)	92%	-34.5	1.35 (-2.03)	Low-Flow	<	PSMS
Low-Flow	RCS	8	0	7	1	98% (100%)	98%	-47.0	1.32 (-3.66)	Low-Flow	<	RCS
Low-Flow	RPPS	14	1	12	1	99% (92%)	100%	-52.6	1.46 (-0.38)	Low-Flow	<	RPPS
3-Volume	HydraSleeve®	7	2	5	0	55% (71%)	69%	-32.3	1.43 (0.43)	3-Volume	<	HydraSleeve®
3-Volume	PSMS	5	3	2	0	0% (40%)	11%	16.2	0.83 (-1.49)	3-Volume	=	PSMS
3-Volume	RCS	8	2	6	0	71% (75%)	84%	-12.3	1.05 (-0.05)	3-Volume	=	RCS
3-Volume	RPPS	14	4	10	0	82% (71%)	86%	-20.0	1.05 (0.10)	3-Volume	<	RPPS
HydraSleeve®	PSMS	16	9	7	0	20% (44%)	83%	12.7	0.57 (0.12)	HydraSleeve®	=	PSMS
HydraSleeve®	RCS	3	3	0	0	75% (0%)	89%	47.8	0.62 (-1.90)	HydraSleeve®	>	RCS
HydraSleeve®	RPPS	18	9	8	1	0% (47%)	90%	9.1	0.79 (0.77)	HydraSleeve®	=	RPPS
PSMS	RPPS	21	8	9	4	0% (53%)	51%	0.0	1.06 (0.66)	PSMS	=	RPPS
RCS	RPPS	24	6	14	4	88% (70%)	99%	-7.4	1.06 (0.51)	RCS	<	RPPS

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
  Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
  A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
  A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
  Values between -10 and 10 indicate that the two populations are similar.
  Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
  Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
  Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
  R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
  R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
  Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
  Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
  Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

TABLE 4.5
STATISTICAL SUMMARY - METALS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler A	Sampler B	Number of Comparisons[a]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests		Quantitative Comparative Tests		Holistic Conclusion[f]		
						Sign[b]	Wilcoxon[c]	Median RPD[d]	X-Y Scatter Slope (R^2)[e]	Sampler A		Sampler B
Low-Flow	3-Volume	230	150	76	4	100% (34%)	100%	18.9	0.96 (0.93)	Low-Flow	>	3-Volume
Low-Flow	HydraSleeve®	107	68	37	2	100% (35%)	98%	26.9	0.91 (0.93)	Low-Flow	>	HydraSleeve®
Low-Flow	PSMS	104	66	35	3	100% (35%)	98%	9.2	0.92 (0.97)	Low-Flow	>	PSMS
Low-Flow	RCS	92	62	30	0	100% (33%)	92%	26.1	0.90 (0.95)	Low-Flow	>	RCS
Low-Flow	RPPS	198	121	75	2	100% (38%)	93%	8.0	0.91 (0.97)	Low-Flow	>	RPPS
3-Volume	HydraSleeve®	108	52	55	1	15% (51%)	65%	-0.6	1.01 (0.99)	3-Volume	=	HydraSleeve®
3-Volume	PSMS	100	48	52	0	24% (52%)	34%	-1.2	1.02 (0.97)	3-Volume	=	PSMS
3-Volume	RCS	90	56	34	0	97% (38%)	95%	11.3	0.83 (0.97)	3-Volume	>	RCS
3-Volume	RPPS	192	94	98	0	17% (51%)	23%	-1.8	0.92 (0.96)	3-Volume	=	RPPS
HydraSleeve®	PSMS	203	109	88	6	85% (45%)	97%	1.8	0.94 (0.97)	HydraSleeve®	=	PSMS
HydraSleeve®	RCS	46	32	14	0	99% (30%)	98%	7.5	1.00 (1.00)	HydraSleeve®	>	RCS
HydraSleeve®	RPPS	256	121	125	10	15% (51%)	13%	1.0	0.94 (0.98)	HydraSleeve®	=	RPPS
PSMS	RPPS	288	133	146	9	53% (52%)	31%	-0.5	0.99 (1.00)	PSMS	=	RPPS
RCS	RPPS	243	98	137	8	99% (58%)	7%	-1.8	0.99 (1.00)	RCS	<	RPPS

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
Values between -10 and 10 indicate that the two populations are similar.
Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

Sampler A	Sampler B	Number of Comparisons[a]	Number of Instances Where Sampler A > B	Number of Instances Where Sampler A < B	Number of Instances Where Sampler A = B	Statistical Tests Sign[b]	Wilcoxon[c]	Median RPD[d]	X-Y Scatter Slope (R^2)[e]	Holistic Conclusion[f] Sampler A		Sampler B
Low-Flow	3-Volume	87	25	62	0	100% (71%)	100%	-33.7	1.52 (0.76)	**Low-Flow**	<	**3-Volume**
Low-Flow	HydraSleeve®	40	6	33	1	100% (85%)	100%	-23.4	1.20 (0.96)	**Low-Flow**	<	**HydraSleeve®**
Low-Flow	PDBS	92	31	57	4	99% (65%)	100%	-22.0	1.41 (0.79)	**Low-Flow**	<	**PDBS**
Low-Flow	PSMS	42	19	22	1	25% (54%)	57%	-8.7	0.99 (0.77)	**Low-Flow**	=	**PSMS**
Low-Flow	RCS	41	19	22	0	25% (54%)	54%	-6.9	1.22 (0.96)	**Low-Flow**	=	**RCS**
Low-Flow	RPPS	76	38	36	2	9% (49%)	38%	1.8	1.16 (0.91)	**Low-Flow**	=	**RPPS**
Low-Flow	Snap Sampler™	30	4	25	1	100% (86%)	100%	-53.3	1.77 (0.99)	**Low-Flow**	<	**Snap Sampler™**
3-Volume	HydraSleeve®	44	18	24	2	56% (57%)	42%	-15.7	0.59 (0.50)	**3-Volume**	=	**HydraSleeve®**
3-Volume	PDBS	99	50	49	0	0% (49%)	53%	5.1	0.76 (0.58)	**3-Volume**	=	**PDBS**
3-Volume	PSMS	47	25	22	0	23% (47%)	80%	23.3	0.46 (0.33)	**3-Volume**	>	**PSMS**
3-Volume	RCS	43	28	14	1	96% (33%)	99%	20.6	0.63 (0.75)	**3-Volume**	>	**RCS**
3-Volume	RPPS	83	56	25	2	100% (31%)	100%	35.5	0.63 (0.70)	**3-Volume**	>	**RPPS**
3-Volume	Snap Sampler™	31	8	23	0	99% (74%)	96%	-17.0	1.04 (0.90)	**3-Volume**	<	**Snap Sampler™**
HydraSleeve®	PDBS	95	51	40	4	71% (44%)	73%	12.8	0.98 (0.39)	**HydraSleeve®**	=	**PDBS**
HydraSleeve®	PSMS	90	53	35	2	93% (40%)	99%	21.1	0.90 (0.81)	**HydraSleeve®**	>	**PSMS**
HydraSleeve®	RPPS	83	58	21	4	100% (27%)	100%	42.1	1.16 (0.56)	**HydraSleeve®**	>	**RPPS**
PDBS	PSMS	120	59	55	6	22% (48%)	92%	0.0	0.41 (0.30)	**PDBS**	=	**PSMS**
PDBS	RCS	122	80	30	12	100% (27%)	100%	7.7	0.90 (0.96)	**PDBS**	>	**RCS**
PDBS	RPPS	232	146	65	21	100% (31%)	100%	11.6	0.81 (0.71)	**PDBS**	>	**RPPS**
PDBS	Snap Sampler™	72	9	61	2	100% (87%)	100%	-21.7	1.27 (0.95)	**PDBS**	<	**Snap Sampler™**
PSMS	RPPS	103	57	36	10	96% (39%)	99%	5.9	1.05 (0.35)	**PSMS**	=	**RPPS**
RCS	RPPS	111	55	44	12	69% (44%)	96%	0.0	0.96 (0.97)	**RCS**	=	**RPPS**
RCS	Snap Sampler™	69	4	64	1	100% (94%)	100%	-39.5	1.38 (0.93)	**RCS**	<	**Snap Sampler™**
RPPS	Snap Sampler™	66	6	58	2	100% (91%)	100%	-37.0	1.40 (0.88)	**RPPS**	<	**Snap Sampler™**

a/ Values between 1 and 10 are highlighted in pink. Statistical results of these comparisons are of very low confidence due to the small number of samples.

b/ First value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations are statistically different.
   Value in parentheses indicates the percentage of times Sampler B concentration was greater than Sampler A concentration.

c/ Value is the confidence that the populations are statistically different. Values between 90 and 100 and highlighted in yellow indicate that the two populations being compared are statistically different.

d/ RPD = Relative Percent Difference.
   A positive value indicates that the concentration in Sampler A was typically greater than the concentration in Sampler B.
   A negative value indicates that the concentration in Sampler B was typically greater than the concentration in Sampler A.
   Values between -10 and 10 indicate that the two populations are similar.
   Values not between -10 and 10 and highlighted in yellow indicate that the two populations are different.

e/ Slopes between 0.90 and 1.10 indicate the populations are similar.
   Slopes less than 0.90 and highlighted in yellow indicate that the concentration in Sampler A was typically greater than the concentration in Sampler B.
   Slopes greater than 1.10 and highlighted in yellow indicate that the concentration in Sampler B was typically greater than the concentration in Sampler A.
   R^2 values less than 0.90 indicate a greater degree of scatter and a lower confidence that the slope value is meaningful.
   R^2 values greater than 0.90 indicate a lower degree of scatter and a higher confidence that the slope value is meaningful.

f/ An assessment of all statistical and quantitative comparative tests was performed and a holistic qualitative statement regarding the results was made.
   Conclusions highlighted in green are deemed to be valid since all tests resulted in the same observation.
   Conclusions highlighted in orange are assigned a lower degree of confidence since the results of all tests did not result in the same observation.
   Conclusions highlighted in pink are assigned the lowest degree of confidence since too few data points were available for statistical significance.

4.4.1 CONVENTIONAL STATISTICAL ANALYSES

The distribution of the data was evaluated in order select the most appropriate statistical methods to apply to the data. Conventional statistical methods were then selected and used to evaluate the data sets that were being compared.

4.4.1.1 DATA DISTRIBUTION

Each of the data sets was tested for normality in order to determine whether parametric or non-parametric statistical tests were appropriate for the data analysis. The Shapiro-Wilk's W test was used to determine data distribution. Several groupings of data were evaluated for normality as described below.

Initially, data sets for each of the eight different sampling methods were tested for each of the six different compound groupings (all data combined, 1,4 dioxane only, anions only, hexavalent chromium only, metals only, and VOCs only). Data used for normality testing in this application included both primary and field duplicate sample results; results that were not detected or rejected during data validation were excluded.

Additionally, since the difference between two sampling methods was the end-use of the data for comparison purposes, the Shapiro-Wilk's W test also was applied to the populations of differences between two sampling methods being compared. Data used for this variance of normality testing were taken from the "pared-down" data sets described in Section 4.4. As an example of this variance of normality testing, each time there was an available comparison between two sampling methods (e.g., all VOC concentrations at the shallow sample depth in well MW-1065 obtained using the PDBS and RCS sampling methods), the difference between those two concentrations was calculated. After the differences were calculated for all possible comparisons of analytical results obtained using those two sampling methods, the Shapiro-Wilk's W test was then applied to that population (e.g., PDBS versus RCS for VOCs only). The results of all normality tests are included in Appendix C.

Tests for normality failed (i.e., data sets are not normally distributed) for almost all of the data subsets evaluated. Some exceptions were noted (see Appendix C) but were due mostly to small sample populations (e.g., 1,4 dioxane in the difference between PsMS and RPPS results). The overall lack of normally-distributed data sets supports the use of nonparametric statistical tools as described below.

4.4.1.2 WILCOXON MATCHED-PAIRS SIGNED RANKS TEST

The Wilcoxon Matched-Pairs Signed Ranks Test (Wilcoxon test) was applied to determine if two dependent variables (e.g., RPPS and HydraSleeve[®] analytical results) represent two different populations. The Wilcoxon test is a nonparametric procedure used in hypothesis testing when one or more of the assumptions of the students paired t-test (e.g., normal population distributions) are violated. The Wilcoxon test determines if the median of the differences between the pairs of data (e.g., the RPPS measurement and the HydraSleeve[®] measurement for a given well [θ_D]) is equal to zero. If a significant difference is obtained, it indicates that there is a high likelihood that the two data sets represent different populations.

A test statistic (the Wilcoxon T statistic) is calculated and associated with a p-value (and corresponding confidence level). For example, a Wilcoxon T statistic that resulted

in a p-value of 0.03 would correspond to a confidence level of 97 percent that the two samples represent two different populations.

Tables 4.1 through 4.6 include summaries of the results of the Wilcoxon test analyses. Values presented in these tables are the confidence level (i.e., 1 minus the p-value) that the two sampling methods represent different populations. For this analysis, if the confidence was greater than or equal to 90 percent, the two populations were deemed to be different at a statistically significant level, and are highlighted in yellow.

4.4.1.3   SIGN TEST

The sign test is a nonparametric alternative to the students paired t-test for dependent samples. The test is applicable to situations where the researcher has two measures (e.g., under two conditions) for each subject and wants to establish whether or not the two measurements (or conditions) are different.

The only assumption required by this test is that the underlying distribution of the variable of interest is continuous; no assumptions about the nature or shape of the underlying distribution are required. The test simply computes the number of times (across subjects) that the value of the first variable (A) is larger than that of the second variable (B). Under the null hypothesis, which states that the two variables are not different from each other, this is expected to be the case about 50 percent of the time. Based on the number of observed cases where A is greater than B, a p-value and associated confidence level can be calculated for the data set.

Tables 4.1 through 4.6 include summaries of the results of the sign test analyses. Values presented in these tables are the confidence that the two sampling methods represent different populations. For this analysis, if the confidence was greater than or equal to 90 percent, the two populations were deemed to be different at a statistically significant level, and are highlighted in yellow. The results of the sign test also indicate the percentage of times that non-equal values are greater than or less than the comparative set of values (i.e., the percent of times that values in population A were greater than values in population B). These values also are shown in Tables 4.1 through 4.6.

4.4.2   OTHER QUANTITATIVE COMPARATIVE TOOLS

In addition to the traditional statistical tools discussed in Section 4.4.1, two other quantitative tools were used to compare the various combinations of data sets.

4.4.2.1   LINEAR REGRESSION

The results for each sampling method were plotted against the corresponding results for each of the other sampling methods using X-Y scatter plots. Best-fit linear trend lines were then fitted to these data sets, and the slope and goodness-of-fit (R^2) value for each line was calculated. Best-fit linear trend lines were fitted to each of the subgroups of compounds/analytes listed in Section 4.4. These plots are included in Appendix D.

Slopes that are close to 1 suggest that the average correlation between both sampling devices being compared approaches a 1 to 1 ratio, whereas higher or lower slopes suggest that one sampling method is more likely to result in higher or lower concentrations than the other method. Likewise, the closer the R^2 value is to 1, the better the fit of the data to the trend line, and the lower the degree of scatter of data about the best-fit linear trend line.

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Tables 4.1 through 4.6 include summaries of the slope and R^2 values for each of the figures discussed above. The slope and R^2 values shown in Tables 4.1 through 4.6 are highlighted in yellow to indicate when the two populations being compared were deemed to not be similar to each other based on the magnitude of the slope. The following guidelines were followed when applying highlighting to these values:

Slope Guidelines

- If the slope was between 0.90 and 1.10, the two sets of sampling results were deemed to be similar.

- If the slope was equal to or greater than 1.10, the sampling device represented on the Y-axis of the plot was deemed to be more likely to return a higher-magnitude result than the sampling device represented on the X-axis.

- If the slope was equal to or less than 0.90, the sampling device represented on the X-axis of the plot was deemed to be more likely to return a higher-magnitude result than the sampling device represented on the Y-axis.

R^2 Guidelines

- If the R^2 value was greater than or equal to 0.90, the degree of scatter of the data relative to the best-fit linear trend line was deemed to be low; therefore the observation made based on the slope was considered more meaningful.

- If the R^2 value was less than 0.90, the degree of scatter of the data relative to the best-fit linear trend line was deemed to be significant; therefore the observation made based on the slope was considered less meaningful.

The threshold values described above were selected somewhat arbitrarily, but also were based on a qualitative review of the data as described in Section 4.4.3. The guidelines established for R^2 values were used primarily in the qualitative evaluation.

4.4.2.2   MEDIAN RPD

Another quantitative analysis tool applied to the data sets is referred to as the median relative percent difference (RPD). The first step in this analysis is to calculate the RPD of each data pair using the following equation:

$$RPD = 100*[(A-B)/\{(A+B)/2\}]$$

Where:

A = Result from sampling method A; and

B = Result from sampling method B.

A positive RPD indicates that the result from sampling method A is higher than the result from sampling method B, while a negative RPD indicates the opposite. RPDs close to zero generally indicate that results from both sampling methods were similar.

Once all the RPDs were calculated, the median of the RPDs for each data comparison group was calculated by ranking the RPD values from lowest to highest and choosing the middle value of the ranked set of calculated RPDs. If the number of RPD values was even, then the median was selected as the mean RPD of the middle two values. This median RPD was then used as an indicator of the comparability of the two sampling methods for each compound/analyte subset. A positive value for the median RPD

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indicated that sampling method A results were more frequently higher than sampling method B results (the reverse is true for negative values). Additionally, the closer the median RPD was to zero, the more likely the two sampling methods returned similar results (essentially, for every time sampling method A was greater than sampling method B, there were an equal number of times where sampling method B was greater than sampling method A). Conversely, if the median RPD was much greater than or less than zero, the more likely one sampling method was to return results that were significantly greater than the other method. For this analysis, a median RPD that was either greater than or equal to 10 or less than or equal to -10 was considered to indicate that one method was more likely to return a meaningfully higher (or lower) concentration than the other sampling method compared. Median RPD values between 10 and -10 were considered to indicate that both sampling methods returned similar concentrations. As with the guideline values described for the linear regression analysis, these values were selected somewhat arbitrarily, but also were based on a qualitative review of the data as described in Section 4.4.3.

Tables 4.1 through 4.6 include summaries of the results of the median RPD analysis. RPD results greater than or less than 10 are highlighted in yellow.

4.4.3   HOLISTIC QUALITATIVE ASSESSMENT

Each of the statistical analyses described above was applied to the 113 possible comparison combinations. Of the 113 possible comparison combinations, 26 (23 percent) had sufficiently small populations (i.e., fewer than 10 data pairs) that the results of the statistical analyses are not considered to be particularly meaningful.

Of the remaining 87 combinations, there were 41 instances where both the conventional statistical and other quantitative comparison tests resulted in consistent observations. Conversely, there were 46 instances where the results of each of these tests were not internally consistent.

If the results of each of the four quantitative comparisons were consistent for a particular comparison (as shown in Tables 4.1 through 4.6 by having consistent highlighting of all four comparative test results), the resulting observation was validated and deemed correct without further review. The resulting observation is shown in Tables 4.1 through 4.6 under the column titled "Holistic Conclusion".

For those instances where the results of the four quantitative analyses varied, the results of the two populations being compared were scrutinized qualitatively, and a general conclusion regarding the comparison was made based not only on the results of the statistical analyses, but also on professional judgment. For example, some of the following criteria were considered during the holistic qualitative evaluation.

- The paired data sets were reviewed to identify whether outlier points may have contributed to anomalous comparison results.

- The R^2 value calculated as part of the linear regression was reviewed to evaluate the degree of confidence in the linear regression results.

- The median RPD and linear regression results were compared to the threshold values derived for those comparative methods (i.e., 10 and -10 for median RPD and 0.90 to 1.10 for linear regression slope) to determine if the results were close to those values.

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A discussion of the comparison results is presented in Section 6. However, if the reader is interested in better understanding the comparison results for particular analytes and/or sampling methods, they are encouraged to perform a detailed review of all of the comparison results presented in Tables 4.2 through 4.6 rather than limiting their review to the holistic conclusions. For example, the holistic conclusion for comparison of VOC concentrations obtained using the three-volume purge and HydraSleeve® methods is that these methods provided essentially equivalent results. The orange highlight indicates a lower degree of confidence in this conclusion because the results of all of the comparison tests were not internally consistent. Further inspection of the comparison results shown in Table 4.6 indicates that the Sign and Wilcoxon tests both indicated that the two data sets are statistically similar. However, the RPD and X-Y Scatter Slope/R^2 tests both indicate differences in the data sets. The slope result (0.59) indicates that the VOC concentrations obtained using the 3-volume purge method tended to be higher than the concentrations obtained using the HydraSleeve®. However, the relatively low R^2 value (0.50) indicates a high degree of scatter about the best-fit trend line and a correspondingly low confidence that the slope value is accurate and meaningful. Therefore, some comparisons termed "equal" in the holistic sense are more equal than others (i.e., "equal" defines a range of conditions rather than one specific condition).

The combined (i.e., "all data") results presented in Table 4.1 are solely for illustration purposes as a way to provide a summary analysis of the entire evaluation. However, these summary data may be misleading when compared with the results for the individual analytes or analyte groups presented in Tables 4.2 through 4.6. Tables 4.2 through 4.6 should be used to evaluate a particular sampling method's utility for a specific analyte or analyte group.

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SECTION 5

COST ANALYSIS

In addition to the technical capability of a specific sampling method to monitor the medium in question, the potential cost of using any type of sampling method is a significant consideration when devising a sampling strategy. Accordingly, one of the objectives of this demonstration is to evaluate and compare the costs of each different sampling method demonstrated.

Due to the nature of the demonstration performed at McClellan (i.e., deployment and retrieval of multiple sampler types in the same well concurrently), some elements of the cost analysis such as labor costs are difficult to determine based on the actual dollars and hours expended for the demonstration, and must be estimated using professional judgment. To compare the costs of the eight sampling techniques used in this demonstration, the annual cost per well sampled for a given LTM scenario was estimated for each technique. Because other factors in addition to cost are considered in selecting an appropriate groundwater sampling method, it is assumed that each method is technically appropriate and can collect the necessary volume of water required for the target analyses. The following assumptions and expenses were considered in the development of a cost analysis for each different sampling method:

- Only one sample depth per well was assumed for LTM as opposed to the three sample depths scoped in the McClellan demonstration.

- Some of the diffusion and grab sampling devices require more time than others to deploy and retrieve. For LTM using these samplers, it is assumed that new samplers are deployed at the time of sample collection so that only one mobilization is required. A combination of field notes from the McClellan sampling events and professional judgment were used to estimate labor requirements for each of the different sampling methods.

- Each sampling method evaluated requires varying lengths of time at the outset of the LTM program for initial setup (e.g., installing dedicated systems and building sampler strings). This cost analysis does not include those initial setup costs for any of the evaluated methods.

- Some of the sampling methods require a one-time capital expenditure for equipment that is re-used throughout LTM (e.g., dedicated pump, Snap Sampler™ equipment, stainless steel weights). For the cost analysis, the one-time expenditures are amortized over the assumed 20-year duration of the LTM program.

- The LTM program was assumed to be comprised of 20 4-inch-diameter wells sampled semi-annually. Each well was assumed to be 50 feet deep, and the

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bottom 10 feet of each well was assumed to comprise the screened interval. Depth to groundwater at all wells was assumed to be 15 feet.

- All sampling was assumed to be performed by a two-person field crew.

- Since water level measurements would be made regardless of which sampling method was used, costs for this task were not included in the cost analysis.

- Although field filtration of samples was performed in some instances during the McClellan demonstration, this task was not built into the cost analysis.

- Conventional sampling was assumed to be performed in a manner consistent with current practices at McClellan. The low-flow method was assumed to be performed using pumps and tubing that are dedicated to each well. The three-volume purge method was assumed to be performed using non-dedicated pumps and tubing and disposable bailers.

- In order to estimate the labor requirements for conventional sampling, the following assumptions were made:

  − Average low-flow and three-volume purge rates used during this demonstration (summarized in Table 3.3) were used to develop the cost estimates for these methods.

  − For the low-flow method, the average purge volume used during this demonstration (Table 3.3) was assumed.

  − For the three-volume purge method, a per-well purge volume of approximately 69 gallons was assumed, which is approximately three times the volume of water contained in a 4-inch well casing with 35 feet of water.

- Costs associated with disposal and/or management of investigation-derived waste (IDW) at some sites can vary widely depending on the approach used. For this cost analysis, no additional costs were assumed for treatment of IDW since McClellan uses an on-base treatment plant. However, labor and equipment costs to collect and transfer the IDW to the treatment plant were included in the cost analysis. As a qualitative consideration not captured in this cost analysis, IDW disposal and treatment can be significant at some sites where waste water generated must be disposed of off-site. The three-volume purge method would typically be expected to have the highest IDW disposal costs.

- Field mobilization/demobilization costs were assumed to be equal for all methods and therefore were not included in the cost analysis.

- Prices for commercially available products were obtained from product distributors or vendors.

- Three Snap Samplers™ were assumed to be used per well for LTM due to the relatively small volume of a single sampler (40 ml). Depending on the specific sample volume needs, use of a lesser number of Snap Samplers™ may be possible, resulting in a lower cost per sample than calculated for this cost analysis.

- For the RPPS, PsMS, and RCS, which are not commercially available, a retail price was estimated. This price was derived by summing the purchase cost of each individual component of the samplers used for the McClellan demonstration and

factoring in a profit of 400 percent (i.e., multiplying the materials cost by a factor of 4).

- Many of the common sampling supplies (e.g., nitrile gloves, plastic sheeting, sample containers) were assumed to be equal in cost regardless of the sampling method and were not included.

- Sales taxes were not included in the cost analysis.

- Labor is broken out by task in the cost analysis. Estimates of labor required for each task are based on field experience and professional judgment.

- A labor rate of $60 per hour was assumed for a field scientist.

- Laboratory analytical expenses were assumed to be equal regardless of sampling method and therefore are not included in the analysis.

Table 5.1 is a detailed account of the various costs that were considered in this analysis. Table 5.2 is a summary of the calculated per-well-per-event sampling costs using each of the eight methods. The results of this analysis indicate that conventional sampling is more expensive than any of the diffusion and grab sampling techniques. The PDBS and HydraSleeve® were the least expensive sampling methods, with the primary cost difference between the two being the time required to refill a new PDBS that is not necessary when using the HydraSleeve®.

The Snap Sampler™ was more expensive than the other no-purge samplers, but it still was substantially less then the purge methods. The initial purchase of the device and the recurring costs for the specialized sample bottles make the Snap Samplers™ more expensive than the other no-purge sampling devices. However, the Snap Sampler™ is less expensive than both conventional sampling methods. Because the Snap Sampler™ is untested in long-term use, it is difficult to estimate a realistic life expectancy for the device. The manufacturer of the Snap Sampler™ (ProHydro, Inc.) states that the Snap Sampler™ itself seems likely to have an extended life, and that replacing trigger linkage parts or other maintenance may be needed rather than full replacement of the samplers. For the cost calculation we assumed replacement parts and maintenance would be equivalent to replacing 1/3 of the sampler cost over the course of the program. It should be noted that the cost analysis assumed a three-vial configuration as was used at McClellan. In some applications, use of a two-vial configuration would be sufficient, which would reduce the cost of using the Snap Sampler method™ from that shown in Tables 5.1 and 5.2.

The cost for use of the RPPS was relatively high compared to other diffusion samplers and the HydraSleeve® primarily due to the labor required to prepare new samplers for deployment. Specifically, a significant amount of time was taken in purging the samplers of residual air. If the sampler is ever developed commercially, it is reasonable to expect that the degassing could be done more cheaply and efficiently prior to delivery.

If so, the cost to use the RPPS would be significantly reduced, potentially to the point where is would be comparable to the PDBS and RCS costs.

Similar to the RPPS, although to lesser degrees, the PsMS and RCS also were relatively time consuming to construct. Although this resulted in higher costs for the McClellan cost analysis, optimized designs and commercial availability would likely

TABLE 5.1
COST ANALYSIS[a]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

3-VOLUME PURGE

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Sampling Pump (Submersible Electric)	$ 300.00	week	--	1	40	$ 15.00
Pump Tubing	$ 0.50	foot	0.5	100	4000	$ 2.50
Tubing Reel	$ 100.00	each	5	1	4	$ 0.50
Controller	$ 150.00	week	--	1	40	$ 7.50
Generator (3,800 watt)	$ 200.00	week	--	1	40	$ 10.00
Field Meters + Flow-thru Cell	$ 300.00	week	--	1	40	$ 15.00
Field Meter Calibration Solutions	$ 50.00	each	0.5	1	40	$ 2.50
Truck Rental	$ 200.00	week	--	1	40	$ 10.00
500-Gallon IDW Poly Tank and Trailer	$ 3,000.00	each	20	1	1	$ 3.75
Teflon[®] Bailer (1.5" x 36" disposable)	$ 15.00	each	0.5	20	800	$ 15.00
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	0.5	1000	40000	$ 1.00
					Subtotal	$ 82.75

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	20	40	$ 40.00
Purge Time	$ 1.00	minute	2	25	50	$ 50.00
Sample Collection	$ 1.00	minute	2	10	20	$ 20.00
Decontamination	$ 1.00	minute	2	15	30	$ 30.00
IDW Transfer to Treatment Plant	$ 1.00	minute	2	6	12	$ 12.00
					Subtotal	$ 152.00
					TOTAL COST	$ 234.75

TABLE 5.1 (Continued)
COST ANALYSIS[a]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

LOW-FLOW PURGE

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Sampling Pump (Submersible Electric)	$ 1,200	each	10	20	40	$ 60.00
Pump Tubing (dedicated)	$ 0.50	foot	5	900	3600	$ 2.25
Controller	$ 150.00	week	--	1	40	$ 7.50
Generator (3,800 watt)	$ 200.00	week	--	1	40	$ 10.00
Field Meters + Flow-thru Cell	$ 300.00	week	--	1	40	$ 15.00
Field Meter Calibration Solutions	$ 50.00	each	0.5	1	40	$ 2.50
55-Gallon Drums	$ 50.00	each	10	2	4	$ 0.25
Truck Rental	$ 200.00	week	--	1	40	$ 10.00
					Subtotal	$ 107.50

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	10	20	$ 20.00
Purge Time	$ 1.00	minute	2	20	40	$ 40.00
Sample Collection	$ 1.00	minute	2	10	20	$ 20.00
Decontamination	$ 1.00	minute	2	5	10	$ 10.00
IDW Transfer to Treatment Plant	$ 1.00	minute	2	1.5	3	$ 3.00
					Subtotal	$ 93.00

TOTAL COST $ 200.50

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

SNAP SAMPLER[TM]

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Samplers	$ 185.00	each	20	60	60	$ 13.88
Sampler Bottles (3 per sample)	$ 16.00	each	0.5	60	2400	$ 48.00
Docking Stations	$ 35.00	each	20	20	20	$ 0.88
Trigger Line	$ 1.25	foot	20	900	900	$ 1.41
Trigger with reel	$ 40.00	each	20	20	20	$ 1.00
Sampler Equipment Maintenance	$ 60.00	year	--	--	20	$ 1.50
					Subtotal	**$ 66.66**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	10	20	$ 20.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Removal	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Preservation/Prep	$ 1.00	minute	2	7	14	$ 14.00
Sample Bottle Replacement	$ 1.00	minute	2	8	16	$ 16.00
Decontamination	$ 1.00	minute	2	2	4	$ 4.00
					Subtotal	**$ 78.00**

TOTAL COST $ 144.66

TABLE 5.1 (Continued)
COST ANALYSIS[a]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

PDBS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 16.50	each	0.5	20	800	$ 16.50
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 17.76**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Filling and Replacement	$ 1.00	minute	2	6	12	$ 12.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 50.00**

| | | | | | **TOTAL COST** | **$ 67.76** |

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

HYDRASLEEVE®

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 20.00	each	0.5	20	800	$ 20.00
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 21.01**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Replacement	$ 1.00	minute	2	2	4	$ 4.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 42.00**

TOTAL COST $ 63.01

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

RPPS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 33.40	each	0.5	20	800	$ 33.40
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 34.66**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	10	20	$ 20.00
Sampler Filling and Replacement	$ 1.00	minute	2	20	40	$ 40.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 86.00**
					TOTAL COST	**$ 120.66**

TABLE 5.1 (Continued)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

PsMS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 40.00	each	0.5	20	800	$ 40.00
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 41.26**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	8	16	$ 16.00
Sampler Filling and Replacement	$ 1.00	minute	2	14	28	$ 28.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 70.00**
					TOTAL COST	**$ 111.26**

TABLE 5.1 (Concluded)
COST ANALYSIS[a/]
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

RCS

Capital and Recurring Costs

Item	Cost per Unit	Unit	Assumed Life-Span (years)	Number of Units per Sampling Event	Total Number of Units Needed Throughout LTM Program	Cost per Well per Sampling Event
Stainless Steel Weights	$ 19.00	each	20	20	20	$ 0.48
Stainless Steel Hanger	$ 10.50	each	20	20	20	$ 0.26
Well Suspension Cap	$ 10.00	each	20	20	20	$ 0.25
Samplers	$ 32.60	each	0.5	20	800	$ 32.60
Water	$ 1.00	gallon	0.5	5	200	$ 0.25
3/16-inch Braided Polypropylene Rope	$ 0.02	foot	20	900	900	$ 0.02
					Subtotal	**$ 33.86**

Labor Costs

Task	Cost per Unit	Unit	Number of People in Team	Time Needed per Task per Well (minutes)	Total Labor Needed (minutes)	Total Cost per Well per Sampling Event
Set-up and Tear-Down	$ 1.00	minute	2	6	12	$ 12.00
Sampler Retrieval and Redeployment	$ 1.00	minute	2	6	12	$ 12.00
Sample Bottle Filling	$ 1.00	minute	2	6	12	$ 12.00
Sampler Filling and Replacement	$ 1.00	minute	2	12	24	$ 24.00
Decontamination	$ 1.00	minute	2	1	2	$ 2.00
					Subtotal	**$ 62.00**

TOTAL COST $ 95.86

[a/] Assumes that 20 wells are sampled semi-annually for 20 years. See Section 5 for additional details.

TABLE 5.2
SUMMARY OF COST ANALYSIS RESULTS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampling Method	Per Well, Per Event Cost
3-Volume Purge	$235
Low-Flow Purge	$200
Snap Sampler™	$145[a]
RPPS	$121
PsMS	$111
RCS	$96
PDBS	$68
HydraSleeve®	$63

a/ Assumes use of 3 samplers per well per sampling event.

reduce the construction time needed for both devices and would therefore reduce the overall cost of using them.

Of important note is that this cost analysis did not consider various more subtle aspects of using each of the sampling methods evaluated. For example, fewer QA/QC samples are typically necessary for the diffusion and grab sampling devices compared to conventional methods. This is due in part to the fact that it generally takes longer to sample a given number of wells using conventional methods than using diffusion and grab methods, and that conventional methods may require equipment decontamination. For these reasons, it is presumed that more trip blank and equipment rinseate blank samples would be required for conventional sampling compared to the alternate approaches. In addition, collection of MS/MSD samples may not be required using diffusion sampling given that turbidity would not migrate through the walls of these samplers. Snap Samplers™ are sealed shut while still in the well; therefore, collection of ambient field blanks should not be necessary when using this device (compared to other methods where the sample is transferred into sample bottles above-ground).

Additionally, this cost analysis does not consider the costs required to actually convert from one sampling method to another. Switching from one sampling method to another would probably require approval from one or more regulatory agencies, which could be simple or more complicated, depending on the specific circumstances (e.g., federal or state regulatory requirements, degree of technology "acceptance"). Converting from one sampling method to another also would probably require modification of some site-specific documents (e.g., QAPP, Record of Decision, Sampling and Analysis Plan). In some instances, additional field demonstrations may also be required in which side-by-side comparisons of the results of the proposed sampling method to contemporaneous or historical results of the current sampling method would be performed.

In summary, the cost analysis described above provides a general comparison of the per-well-per-event costs of each of the eight sampling methods demonstrated at McClellan; these costs can be used as an initial screening tool when trying to identify a candidate alternative sampling technology. Accordingly, prior to conversion from one sampling method to another, a more complete cost analysis that takes into account all site-specific cost factors should be performed.

SECTION 6

DISCUSSION

As described in Sections 1.1 and 2.3, one of the objectives of this demonstration was to include one or more "baseline" sampling methods to provide data against which the results of the alternative diffusion and grab samplers can be compared. This was achieved by incorporating the conventional methods (three-volume purge and low-flow purge) into the demonstration. However, these methods utilize inherently different sampling concepts than both the diffusion and grab sampling methods. Most notably, the conventional sampling methods induce groundwater flow into the well by creating an increased hydraulic gradient around the well resulting from the purge. Conversely, the alternative sampling methods rely solely on the natural flow of groundwater through the well. These methods might be expected to provide differing results since they are monitoring different flow conditions and potentially also different volumes of the aquifer. Furthermore, even results from the two conventional methods are expected to vary given the differences in purge volume and rate and the fact that low-flow samples are considered by some to be representative of a more discrete sample interval than samples obtained using a three-volume purge. Accordingly, although they represent "baseline" data in the sense that they are the commonly-used sampling methods that are generally accepted by the regulatory community, they do not necessarily represent the *correct* answer (only a *different* answer).

Because there are many different ways to evaluate a data set as large and robust as the one collected during this demonstration, it is difficult to derive sweeping conclusions about the relative performance of one device compared to all the others. If all methods were measuring the same thing, comparison of the performance of one method to another would be more straightforward. However, in this demonstration, the purge and no-purge sampling methods actually might have measured different things (as described above). Accordingly, the performance of one sampling method relative to another is more difficult to quantify. Nonetheless, the sampling results were compared as described in Section 4.

Sampling method- and analyte-specific conclusions and observations are summarized in the following subsections. These conclusions and observations were derived entirely from the 'holistic conclusions' presented in Tables 4.2 through 4.6. The holistic conclusions are necessarily 'broad-brush' and generalized and were assigned varying degrees of confidence depending on whether all of the quantitative comparisons performed resulted in the same observation. For example, the holistic conclusion that low-flow anion concentrations are less than Snap Sampler™ anion concentrations does not mean that this is always the case. The results of all four comparative tests did not consistently indicate this conclusion; however, the weight of evidence indicated that this was true more often than not. The reader is encouraged to study the more detailed information presented in Section 4 (Tables 4.2 through 4.6) prior to making final

decisions on use of the various samplers tested at McClellan. The summary data presented in Table 4.1 may be misleading when compared with the results for the individual analytes or analyte groups presented in Tables 4.2 through 4.6, and should not be used to evaluate a particular sampling method's utility for a specific analyte or analyte group.

It should be noted that sampling results were quantitatively compared using groupings of analytes rather than specific analytes (e.g., all metals rather than individual metals such as aluminum and zinc, and all VOCs rather than specific VOCs such as TCE). Pooling data for a multitude of analytes provides a general basis for comparison, but the comparison results may not be representative of how each of the individual analytes compared. For example, a more extensive study is being performed by URS that is comparing individual and pooled metals results obtained from more than 250 McClellan wells using both low-flow and three-volume purge methods, and the results of this comparison obtained to date do not agree with the results presented in this report (source: written communication from J. Rogalla [URS]). Therefore, the comparison results presented in this report may not definitively determine comparability among the different sampling methods.

6.1   SUMMARY OF RESULTS BY SAMPLING METHOD

6.1.1   LOW-FLOW PURGE

Generally, results of the low-flow purge are equal to or lower in concentration than corresponding results from most of the other sampling methods. The only notable exception to this observation is with metals (not including hexavalent chromium), where the low-flow purge method typically produced higher concentrations than all of the other sampling methods (Table 4.5). Low-flow results for hexavalent chromium tended to be lower than results obtained using other methods (Table 4.4). Although it is not entirely evident why these trends occurred, the following explanations are proposed.

The three-volume purge samples were collected from a bailer after the purge was complete, while the low-flow samples were collected directly from the pump discharge. As shown in Table 3.3, the final water temperature in the low-flow purge sample was usually higher than for the three-volume purge samples. The temperature differences ranged from 0.01 to 3.8 degrees Celsius (°C) with a mean value of 1.7 °C . This may have resulted from the heat generated by the pump motor and impeller, and could at least partially explain why the VOC concentrations in the low-flow purge samples are frequently lower than the concentrations of the same analytes derived using other sampling methods (i.e., a higher water temperature could result in a higher volatilization rate and correspondingly lower concentrations of VOCs in the sample).

In this particular case study, the final turbidity in the low-flow purge water was generally higher than it was in the three-volume purge water (Table 3.3). This indicates that more particulates were present in the low-flow water than in the three-volume water, and could explain why metals concentrations were usually higher in the low-flow purge samples. While the reasons for this are unclear, it may be due at least in part to the fact that the low-flow purge was performed prior to the three-volume purge and shortly after the sampling pump had been introduced into the well (disturbing the water column and potentially increasing turbidity levels in the well). However, in almost every instance conventional and grab samples collected for metals analysis were field filtered with a

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new 0.45-micron filter to remove particulates. One hypothesis is that elevated quantities of colloidal metals were present in the low-flow samples that passed through the filters. The use of dedicated pumps, rather than newly decontaminated submersible equipment, may result in lower turbidity results during purging, possibly eliminating the need for filtration to remove particulates.

From a cost perspective, the low-flow purge method was the second most expensive method demonstrated (Section 5).

6.1.2   THREE-VOLUME PURGE

From a "performance" perspective, concentrations in samples collected using the three-volume purge technique were generally equal to or greater than corresponding concentrations in other sampling devices. Four exceptions to this trend were noted, including VOC concentrations in the Snap Sampler™, metals concentrations in the low-flow samples, and hexavalent chromium concentrations in the Hydrasleeve® and RPPS samples. In each of these instances, the three-volume purge concentrations tended to be lower. Overall, of the two conventional sampling methods demonstrated, the three-volume purge method produced results that were the most similar to the results for the diffusion and grab sampling devices.

Based on the cost analysis (Section 5), the three-volume purge method was the most expensive method demonstrated. It should be noted that if the cost analysis had assumed use of dedicated pumps for the three-volume purge (similar to what was assumed for the low-flow purge method), the estimated costs of the three-volume and low-flow purge methods would have been more similar.

6.1.3   HYDRASLEEVE®

For VOC concentrations, the HydraSleeve® was most comparable to the three-volume purge and the PDBS. Samples obtained using this device usually had higher concentrations of VOCs relative to the low-flow purge, PsMS, and RPPS methods. For metals, it was comparable to the three-volume purge, PsMS, and RPPS. HydraSleeve® samples typically contained higher concentrations of metals than the RCS and lower concentrations of metals than the low-flow purge samples. For anions, the HydraSleeve® was comparable to all other sampling methods against which it was compared. For hexavalent chromium, the HydraSleeve® was most comparable to the PsMS and RPPS, and was greater than both of the conventional methods and the RCS. For 1,4 dioxane, the HydraSleeve® was most comparable to both conventional methods, and was greater than both the PsMS and the RPPS. The conclusions involving hexavalent chromium and 1,4 dioxane are tentative due to the limited number of comparisons and resulting low statistical power of the tests performed. The HydraSleeve® and Snap Sampler™ were not tested in the same wells; therefore, analytical results for these two samplers were not compared with each other.

The HydraSleeve® was the least expensive method demonstrated according to the cost analysis (Section 5).

6.1.4   SNAP SAMPLER™

For the majority of comparisons, the concentrations in the Snap Sampler™ samples were higher than corresponding concentrations in samples from all other sampling methods. This was true for all comparisons involving VOCs, and for all comparisons of anions and 1,4 dioxane except for the three-volume purge samples, which were roughly

comparable to the Snap Sampler™ concentrations for those constituents. It should be noted that the 1,4 dioxane comparisons included few data points. The Snap Sampler™ was not used to sample for metals or hexavalent chromium. The observed 'high bias' in the Snap Sampler™ concentrations suggests that they may be more representative of the actual concentrations in the well at the time of sample collection, particularly for VOCs as described below.

The fact that water for VOC analysis does not have to be transferred from the Snap Sampler™ into separate sample containers appears to be the most reasonable explanation for the relatively higher VOC concentrations obtained using this method. The lack of sample transfer eliminates the potential for VOC loss as a result of sample transfer. The developer of this sampler reports that results of other tests also exhibit the same higher-concentration trends for VOCs as seen in this study (Britt *et al.*, 2005). For anions and 1,4 dioxane, it is not clear why the Snap Sampler™ concentrations were typically higher than those in samples collected using other methods.

It should be noted that the relatively high VOC concentrations in the Snap Sampler™ may also be due, at least in part, to differences in how these samples were treated at the laboratory. As stated in Section 3.3, most of the VOC samples submitted to the analytical laboratory in 20-ml vials (i.e., samples collected using the PDBS, RPPS, RCS, PsMS, and HydraSleeve®) were composited at the laboratory into one 40-ml vial for analysis. Therefore, most of the VOC samples collected using no-purge techniques, except for the Snap™ samples, underwent two episodes of sample transfer (one in the field and one at the laboratory). These transfers may have resulted in some VOC loss and increased the "noise" or variability in these no-purge VOC data sets. The VOC data indicate that minimizing VOC sample transfer can result in more accurate detection of VOC concentrations present in the well water. The data also indicate that caution is advised when scoping the use of 20-ml VOA vials for VOC sample collection. The ability of the laboratory to analyze VOC samples contained in 20-ml vials without sample transfer should be confirmed, and use of 40-ml vials wherever possible is recommended.

The Snap Sampler™ was more expensive than the other no-purge sampling methods based on the cost analysis described in Section 5, but as described above, it produced the most conservative sample results from a protectiveness standpoint. The cost per sample could be reduced by approximately $16 if two sample vials per sample are used instead of three, as was used at McClellan AFB and assumed in the cost analysis. It should be noted that the volume of water that can be collected using this device is relatively small compared to most of the other methods (Table 3.5). The vendor has developed a 125-ml sample bottle to accommodate somewhat larger sample volume needs.

6.1.5 PDBS

The PDBS was only used to monitor VOCs. This diffusion sampler tended to return higher concentrations of VOCs than the low-flow method, the RCS, and the RPPS. It was most comparable to the three-volume purge, PsMS, and HydraSleeve® methods, and typically returned lower VOC concentrations than the Snap Sampler™.

The PDBS was the second least expensive of the non-conventional samplers and was the least expensive diffusion sampler evaluated, according to the cost analysis described in Section 5. It has been shown in several other studies (e.g., Parsons, 2003b and 2004b) to be a reliable and inexpensive method of monitoring for most commonly-occurring VOCs in groundwater.

6.1.6 RPPS

For VOCs and 1,4 dioxane, the results obtained using the RPPS were generally comparable (i.e., similar concentrations) to those obtained using the low-flow purge, PsMS, and the RCS methods. Conversely, the RPPS results for these analytes were usually less than (i.e., lower concentrations) obtained with the three-volume purge, HydraSleeve®, PDBS, and Snap Sampler™ methods. For anions, the RPPS was generally comparable with all other methods except the Snap Sampler™, which typically yielded higher concentrations. The RPPS results for hexavalent chromium tended to be higher than the low-flow purge, three-volume purge, and RCS results, but were similar to the HydraSleeve® and PsMS results for that analyte. For metals, the RPPS results were most comparable to the three-volume purge, HydraSleeve®, and PsMS; usually less than results obtained with the low-flow purge; and greater than results obtained with the RCS.

In summary, the RPPS seems to have performed well at monitoring for anions, metals, and hexavalent chromium, but not as well at monitoring for VOCs and 1,4 dioxane. It is perhaps noteworthy that the RPPS appears to have performed best for inorganic, non-volatile parameters, and less well for organic parameters (i.e., VOCs and 1,4 dioxane). Considering the relatively large pore size of the membrane used for this sampler relative to some of the other devices (Section 2.1.2), there may be a higher potential for volatilization when using this sampling device.

The RPPS was the most expensive diffusion-based sampler according to the cost analysis (Section 5).

6.1.7 RCS

Based on the statistical analysis results presented in Section 4, the RCS had lower concentrations of metals (not including hexavalent chromium) than all other methods. In contrast, this sampler returned hexavalent chromium concentrations that were similar to or higher than obtained using conventional methods. With the exception of the Snap Sampler™, it was generally comparable to all other methods for anions. The RCS also usually had lower concentrations of VOCs than the other methods except for the RPPS and low-flow purge methods, which produced results that were more similar to the RCS results. Based on limited data, the RCS performed acceptably for 1,4 dioxane. In general, the demonstration results indicate that this sampling device was in a lower bracket in terms of its performance at McClellan AFB. It usually produced concentrations that are comparable to or lower than the other devices. It was relatively inexpensive according to the cost analysis, being the third least expensive device evaluated (Section 5). In addition, the cellulose membrane of the RCS was occasionally observed to become brittle or was more easily torn upon retrieval of the sampler (see also Section 2.1.4).

6.1.8 PsMS

The PsMS results for anions are comparable to anions results obtained using all other methods. Although the data set for 1,4 dioxane is small, the comparative analyses performed indicated that the PsMS is generally comparable to both the conventional methods and the RPPS, and usually produced lower concentrations than the HydraSleeve® and the Snap Sampler™. For hexavalent chromium and metals, the PsMS was comparable to all methods except low-flow purge, which generally returned lower-magnitude concentrations than the PsMS. For VOCs, the PsMS was comparable to the

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other diffusion samplers against which it was compared (PDBS and RPPS) and the low-flow purge, but returned lower-magnitude concentrations than the HydraSleeve® and the three-volume purge. The PsMS was not installed in the same wells as the RCS and Snap Sampler™ except for well MW-453, which was sampled using both the PsMS and Snap Sampler™. Therefore, the PsMS was not compared to these other devices.

This method was relatively expensive compared to the most of the other diffusion-based devices, but it still was significantly less expensive than the conventional methods.

6.2   SUMMARY OF RESULTS BY ANALYTE

6.2.1   1,4-DIOXANE

As indicated in Table 4.2, a low degree of confidence is assigned to the statistical results for this analyte due to the relatively small number of comparisons that could be made (ranging from 3 to 9). Therefore, the following conclusions and observations regarding 1,4 dioxane are tentative.

- In the limited number of cases where two diffusion samplers were compared against each other (i.e., RCS vs.RPPS, PsMS vs. RPPS), the results were found to be generally equivalent.

- 1,4 dioxane concentrations obtained using discrete-interval grab samplers (i.e., Snap Sampler™ and HydraSleeve®) were typically equivalent to or higher than other methods tested for this analyte. The Snap Sampler™ in particular tended to yield concentrations that were relatively high.

- Conventional sampling results were mixed, with low-flow purge results typically equivalent to or lower than other sampling methods and three-volume purge results equivalent to or higher than other sampling methods.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then the HydraSleeve®, Snap Sampler™, PsMS, and RCS appear to produce results that are similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Although similar to low-flow results, the RPPS results tended to be biased low relative to three-volume results; therefore, this sampler can not be wholeheartedly endorsed for use with 1,4 dioxane on the basis of the McClellan results.

6.2.2   ANIONS

The holistic conclusions for anions summarized in Table 4.3 indicate a relatively high degree of parity among the samplers in terms of anion results. Fourteen of the 17 sampler-pair comparisons performed for anions (82 percent) generally yielded comparable results (indicated by an 'equal' sign in the 'Holistic Conclusion' column). In contrast, only 56 percent of 1,4 dioxane sampler-pair comparisons (Table 4.2), 36 percent of hexavalent chromium comparisons (Table 4.4), 43 percent of metals comparisons (Table 4.5), and 38 percent of VOC comparisons (Table 4.6) yielded equivalent results. The three sampler-pair comparisons for anions that did not yield equivalent results involved the Snap Sampler™, which tended to yield anion concentrations that were relatively elevated.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then all of the diffusion and grab samplers tested for anions (i.e., HydraSleeve®, Snap Sampler™, PsMS, RCS, and RPPS) appear to

produce results that are either similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations.

6.2.3   HEXAVALENT CHROMIUM

Similar to 1,4 dioxane, many of the holistic conclusions for hexavalent chromium listed in Table 4.4 are assigned a relatively low degree of confidence because they are based on a small number of comparisons. Therefore, the following conclusions and observations regarding hexavalent chromium are tentative.

- The two conventional methods did not produce equivalent results; concentrations obtained using the three-volume purge method tended to be higher than concentrations obtained using the low-flow purge method.

- The only grab sampler tested for hexavalent chromium (HydraSleeve®) tended to yield concentrations that were higher than those obtained using conventional methods and equivalent to or higher than those obtained using diffusion samplers.

- Diffusion samplers tended to yield concentrations that were higher than those obtained using the low-flow method and equivalent to or higher than those obtained using the three-volume purge method.

- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for hexavalent chromium. While PsMS and RPPS results were generally equivalent, the RCS results tended to be lower than RPPS results.

In summary, if conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then all of the tested grab and diffusion samplers (i.e., the HydraSleeve®, PsMS, RPPS, and RCS) appear to produce results that are similar to or higher than the conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Of the three diffusion samplers tested, the RCS would rank the lowest in terms of monitoring for hexavalent chromium based on the McClellan data.

6.2.4   METALS

The holistic conclusions for TAL metals summarized in Table 4.5 indicate the following general conclusions and observations:

- Despite being field-filtered, metals concentrations in low-flow samples were generally higher than concentrations obtained using other conventional, diffusion, and grab samplers tested for this analyte group. A potential reason for this trend is discussed in Section 6.1.1.

- Metals concentrations obtained using the only discrete-interval grab sampler tested for this analyte group (the HydraSleeve®) tended to be equivalent to or higher than other sampling methods except for low-flow purge.

- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for TAL metals. While PsMS and RPPS results were generally equivalent to each other, the RCS results tended to be lower than RPPS results. The PsMS and RPPS results were also generally equivalent to both the three-volume purge and HydraSleeve® results, while the RCS results tended to be lower than the results obtained from these conventional and grab sampling methods.

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In summary, the McClellan data suggest that the low-flow results for TAL metals are anonymously high relative to results obtained using all of the other tested methods, and therefore they may not be a good indicator of 'baseline' results for comparison purposes. If the three-volume purge results are used as a baseline for comparison purposes, then the HydraSleeve®, PsMS, and RPPS appear to produce results that are similar to or higher than the baseline conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Of the three diffusion samplers tested, the RCS would rank the lowest in terms of monitoring for TAL metals based on the McClellan data. Comparison of metals results for filtered vs. unfiltered samples does not indicate a trend of low bias in the filtered samples relative to the unfiltered samples.

6.2.5   VOCs

The holistic conclusions for VOCs summarized in Table 4.6 indicate the following general conclusions and observations:

- VOC concentrations in the low-flow purge samples were typically lower than the concentrations of the same analytes derived using the three-volume purge method, HydraSleeve®, Snap Sampler™ and PDBS. As discussed in Section 6.1.1, this may be due at least in part to heat generated by the pump motor and impeller.

- VOC concentrations obtained using discrete-interval grab samplers (i.e., HydraSleeve® and Snap Sampler™) were generally similar to or higher than concentrations obtained using other methods. In particular, the concentrations in the Snap Sampler™ samples were higher than corresponding concentrations in samples from all other sampling methods. Likely reasons for this occurrence are discussed in Section 6.1.4.

- All tested diffusion samplers do not appear to be equivalent in terms of their ability to monitor for VOCs. PDBS concentrations were generally similar to or higher than concentrations obtained from other diffusion samplers, the three-volume and low-flow purge methods, and the HydraSleeve®. In contrast, the PsMS and RPPS produced concentrations that tended to be lower than the three-volume and HydraSleeve® methods, and the RCS produced concentrations that tended to be lower than the three-volume purge method but was not compared to the HydraSleeve®.

In summary, if the conventional (i.e., low-flow and three-volume purge) results are used as a baseline for comparison purposes, then the Snap Sampler™, HydraSleeve®, and PDBS appear to produce results that are similar to or higher than the baseline conventional results, suggesting that they could be substituted for the conventional methods in at least some situations. Although similar to low-flow results, the RPPS results tended to be biased low relative to three-volume, HydraSleeve®, Snap Sampler™, and PDBS results. Similarly, the PsMS results tended to be biased low relative to the 3-volume and HydraSleeve® results, and the RCS tended to be biased low relative to the 3-volume, PDBS, and Snap Sampler™ results; therefore, these three diffusion samplers can not be confidently endorsed for use with VOCs on the basis of the McClellan results.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

The overall objective of this demonstration was to evaluate and demonstrate the use of selected diffusion and grab sampling devices that potentially represent useful and cost-effective alternatives to conventional groundwater sampling approaches (e.g., 3-volume purge/sample and low-flow purge/sample) for analytes other than VOCs. Specifically, devices that potentially can be used to sample for metals, anions, and 1,4 dioxane were evaluated. Expansion of the suite of accepted no-purge sampling methods could be useful in augmenting or possibly substituting for the PDBS method in certain applications.

From a performance perspective, the HydraSleeve® and Snap Sampler™ methods typically produced results that are most similar to the more conservative (i.e., higher-concentration) results obtained from the two conventional sampling methods. Both of these methods are characterized as grab-type samplers, and although they do allow for well equilibration, they do not use diffusion as the operative mechanism, therefore the results obtained are more of a "snapshot" in time. It should be noted that all of the diffusion and grab samplers collect samples over a 'short' time frame with respect to the groundwater velocity at many sites. Of these two sampling methods, the HydraSleeve® was substantially less expensive based on the assumptions used in the cost analysis, although both methods were less expensive than the conventional approaches. The HydraSleeve® was simpler to deploy and retrieve, and permits a larger volume of water to be collected. Comparisons involving the Snap Sampler™ on the other hand indicate that the VOC data set for this sampler may be more consistently representative of the actual VOC concentrations in the well at the time of sample collection. A fully non-metallic version of the Snap Sampler™ is available in the event that the metal construction of the Snap Sampler™ tested in this study is of concern.

For the diffusion-based methods, the PDBS provided the most conservative results (i.e., highest concentrations) for VOCs, but this device is only appropriate for monitoring most VOCs. The other diffusion-based devices evaluated occasionally produced results that were, on average, lower in concentration than the conventional and/or grab sampler results. Although much less expensive than the conventional sampling methods, these devices were generally more expensive to use than the HydraSleeve® based on the assumptions used in the cost analysis (the PDBS and HydraSleeve® costs were very similar, see Table 5.2).

Finally, although the conventional methods evaluated are well accepted throughout the industry (Newell *et al.*, 2000), they did not always provide the most conservative (i.e., highest-magnitude) results. These methods also were more expensive than the diffusion and grab samplers used in the demonstration.

The American Petroleum Institute (Newell *et al*., 2000) concluded that three-volume purge/sample data are broadly accepted by regulatory agencies, suggesting a consensus that these data are *adequately representative* of formation conditions to ensure protection of human health and the environment. One of the primary objectives of this demonstration is to identify cost-effective alternatives to conventional groundwater sampling approaches for analytes other than VOCs. Accordingly, one critical question is whether the diffusion and grab devices are also *adequately representative* and therefore protective (or more conservative), but not systematically biased low relative to conventional methods. A particular grab or diffusion sampling device was considered to be viable when the analyte concentrations obtained using that device were similar to or higher than those obtained using conventional sampling methods. Conversely, if the results obtained using the grab or diffusion device exhibited low bias relative to the conventional results, then the ability of that device to accurately detect concentrations of that particular analyte group was considered to be suspect. In summary, high bias was considered to be acceptable, but low bias was not. Of the four diffusion and two grab sampling devices evaluated, the following conclusions were derived based on the results of this demonstration. In addition, Table 7.1 contains a summary of key conclusions and observations derived from this technology demonstration.

- The HydraSleeve® appears to be a technically viable method for monitoring all of the compounds included in this demonstration. Concentrations of metals obtained using this device tended to be lower than low-flow-purge concentrations, but the low-flow concentrations appear to be anomalously high.

- The Snap Sampler™ appears to be a technically viable method for monitoring all of the compounds it was tested for in this demonstration (i.e., anions, 1,4 dioxane, and VOCs). This method was not tested for metals and hexavalent chromium.

- The PDBS is a technically viable method for monitoring VOCs only. PDB samples may be advantageous when sampling for VOCs in waters where matrix interferences, such as highly turbid or alkaline conditions, may compromise results.

- The RPPS appears to be a technically viable method for monitoring hexavalent chromium, metals, and anions. Although concentrations of VOCs and 1,4 dioxane obtained using this method are statistically similar to low-flow concentrations of these analytes, they tended to be biased low relative to concentrations obtained using the three-volume-purge method. Further development of this technology may be warranted.

- The RCS appears to be a technically viable method for monitoring anions and possibly 1,4 dioxane and hexavalent chromium. Although other studies have shown that the RCS is appropriate for monitoring VOCs (Ehlke *et al*., 2004; Imbrigiotta *et al*., 2002; Vroblesky *et al.*, 2002), that observation was not validated during this demonstration.

- The PsMS appears to be a technically viable method for monitoring hexavalent chromium, metals, and anions, and may be technically viable for monitoring VOCs (although VOC results using this method were typically less than those obtained using the three-volume purge and HydraSleeve® methods and were not compared with the Snap Sampler™ or RCS results because, with one exception, they were not installed in the same wells). Although all comparative tests indicate

that 1,4 dioxane concentrations in the PsMS are similar to concentrations of this analyte obtained using conventional sampling methods, a more definitive endorsement regarding the use of the PsMS method for dioxane sampling was not reached due to the relatively low number of comparisons. Metal concentrations obtained using the PsMS method tended to be lower than low-flow concentrations, but the low-flow concentrations tended to be anomalously high. Further development of this technology may be warranted.

TABLE 7.1
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS
NO-PURGE SAMPLER DEMONSTRATION
McCLELLAN AFB, CALIFORNIA

Sampler	1,4 Dioxane[a]	Anions	Hexavalent Chromium[b]	Metals	VOCs	Advantages	Disadvantages	Remarks
PDBS	N[c]	N	N	N	Y[d]	--Widely tested for VOCs --Relatively inexpensive --Commercially available --Technical Guidance available --Alkalinity is excluded --No well diameter limitation	--Suitable for VOCs only --Potential for VOC loss during sample transfer --Not suitable for all VOCs	Abundant information available on ITRC website (www.itrc-web.org)
RPPS	?[e]	Y	Y	Y	?	Good results for inorganics	--Most expensive diffusion sampler --May need to de-gas pores prior to use --Size and volume limited by large pore size --Not commercially available --Mixed results for organic compounds at McClellan --Potential for VOC loss during sample transfer	Large pore size may increase potential for VOC loss via volatilization
PsMS	Y	Y	Y	Y	?	Good results for inorganics	--Small volume for some applications --Not commercially available --Mixed results for VOCs at McClellan --Potential for VOC loss during sample transfer	
RCS	Y	Y	Y	N	?	--Relatively inexpensive --Commercially available --Inorganic and organic analytes	--Cellulose membrane may be easily damaged --Relatively poor performance overall at McClellan --Potential for VOC loss during sample transfer	Other studies have had better results for VOCs (e.g., Ehlke *et al.*, 2004; Imbrigiotta *et al.*, 2002; Vroblesky *et al.*, 2002)
Hydra-Sleeve®	Y	Y	Y	Y	Y	--Relatively large sample volumes possible --Works for wide variety of analytes --Relatively inexpensive --Commercially available in multiple sizes	Potential for VOC loss during sample transfer	Detailed information available on Vendor's website (www.hydrasleeve.com)
Snap Sampler™	Y	Y	NT[f]	NT	Y	--No sample transfer required, potentially reducing data 'noise' and VOC loss --Commercially available, including variety of sizes and materials	--Most expensive no-purge sampler tested --More involved field procedure --Small volume for some applications	Detailed information available on vendor's website (www.snapsampler.com)

a/ Comparisons involving 1,4 dioxane are based on a relatively small data set and therefore there is a lower confidence in the associated conclusions.

b/ Some of the comparisons involving hexavalent chromium are based on a relatively small data set and therefore there is a lower confidence in the associated conclusions.

c/ N = Sampler does not appear to be a technically viable method for monitoring that particular analyte or analyte group based on McClellan results.

d/ Y = Sampler appears to be a technically viable method for monitoring that particular analyte or analyte group based on McClellan results.

e/ ? = Mixed results were obtained, and further evaluation is required to reach a more definitive conclusion. See text in Sections 6 and 7 for more details.

f/ NT = Sampler not tested for that analyte or analyte group.

TABLE 7_1.doc   7-4

SECTION 8

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APPENDIX A

DATA QUALITY ASSESSMENT REPORT

Electronic file provided separately

APPENDIX B

WELL-SPECIFIC PLOTS DEPICTING VERTICAL STRATIFICATION OF VARIOUS TARGET COMPOUNDS

Electronic file provided separately

APPENDIX C

NORMALITY TESTING RESULTS

Electronic file provided separately

APPENDIX D

X-Y SCATTER PLOTS

Electronic file provided separately

APPENDIX E

ELECTRONIC DATA DELIVERABLE
AND
ELECTRONIC VERSION OF THE WORK PLAN
(PARSONS, 2004A)

Electronic file provided separately

APPENDIX F

FIELD NOTES

Electronic file provided separately

APPENDIX G

REVIEW COMMENTS AND RESPONSES

Electronic file provided separately

APPENDIX D

X-Y SCATTER PLOTS

Low-Flow Versus 3-Volume Purge

Plot axes:
- Y-axis: 3-Volume Purge Sample Concentration (µg/L)
- X-axis: Low-Flow Purge Sample Concentration (µg/L)

$y = 0.9888x$
$R^2 = 0.9452$ All

$y = 1.411x$
$R^2 = 0.972$ 1,4 Dioxane

$y = 1.0644x$
$R^2 = 0.9803$ Anions

$y = 1.3895x$
$R^2 = 0.1383$ Hexavalent Chromium

$y = 0.9581x$
$R^2 = 0.929$ Metals

$y = 1.5201x$
$R^2 = 0.7625$ VOCs

Legend:
- All Data
- 1,4 Dioxane
- Anions
- Hexavalent Chromium
- Metals
- VOCs
- Trend Line (All Data)
- Trend Line (1,4 Dioxane)
- Trend Line (Anions)
- Trend Line (Hexavalent Chromium)
- Trend Line (Metals)
- Trend Line (VOCs)

Low-Flow Versus Hydrasleeve

$y = 0.9585x$
$R^2 = 0.9405$ — All Data

$y = 1.1067x$
$R^2 = 0.9952$ — 1,4 Dioxane

$y = 1.0619x$
$R^2 = 0.9569$ — Anions

$y = 2.4906x$
$R^2 = 0.4639$ — Hexavalent Chromium

$y = 0.905x$
$R^2 = 0.9291$ — Metals

$y = 1.1974x$
$R^2 = 0.9571$ — VOCs

Hydrasleeve Sample Concentration (µg/L)

Low-Flow Purge Sample Concentration (µg/L)

Legend:
- All Data
- Anions
- Metals
- Trend Line (All Data)
- Trend Line (Anions)
- Trend Line (Metals)
- 1,4 Dioxane
- Hexavalent Chromium
- VOCs
- Trend Line (1,4 Dioxane)
- Trend Line (Hexavalent Chromium)
- Trend Line (VOCs)

Low-Flow Versus PDBS

$y = 1.409x$
$R^2 = 0.7896$

VOCs

PDBS Sample Concentration (μg/L)

Low-Flow Purge Sample Concentration (μg/L)

✳ VOCs

— Trend Line (VOCs)

Low-Flow Versus PSMS

y = 0.952x
R^2 = 0.9741 All Data

y = 0.9433x
R^2 = 0.9903 1,4

y = 1.0699x
R^2 = 0.9893 Anions

y = 1.3509x Hexavalen
R^2 = -2.029 l

y = 0.9249x Metals
R^2 = 0.9733

y = 0.9897x VO
R^2 = 0.7709

PSMS Sample Concentration (μg/L)

Low-Flow Purge Sample Concentration (μg/L)

Legend:
- ◆ All Data
- ✳ 1,4 Dioxane
- ✳ Anions
- ✳ Hexavalent Chromium
- ✳ Metals
- ✳ VOCs
- — Trend Line (All Data)
- — Trend Line (Anions)
- — Trend Line (Hexavalent Chromium)
- — Trend Line (Metals)

Low-Flow Versus RCS

y = 0.9347x
$R^2 = 0.9693$
All Data

y = 1.105x
$R^2 = 1$
1-4 Dioxane

y = 0.9967x
$R^2 = 0.9951$
Anions

y = 1.316x
$R^2 = -3.6611$
Hexavalent Chromium

y = 0.8989x
$R^2 = 0.9544$
Metals

y = 1.2163x
$R^2 = 0.9601$
VOCs

RCS Sample Concentration (µg/L)

Low-Flow Purge Sample Concentration (µg/L)

Legend:
- All Data
- 1,4 Dioxane
- Anions
- Hexavalent Chromium
- Metals
- VOCs
- Trend Line (All Data)
- Trend Line (1,4 Dioxane)
- Trend Line (Anions)
- Trend Line (Hexavalent Chromium)
- Trend Line (Metals)

Low-Flow Versus RPPS

Low-Flow Versus Snap Sampler

y = 1.2153x
R^2 = 0.9916   All Data

y = 1.2582x
R^2 = 0.9991   1,4 Dioxane

y = 1.2153x
R^2 = 0.9891   Anions

y = 1.7719x
R^2 = 0.9949   VOCs

Snap Sample Concentration (µg/L)

Low-Flow Purge Sample Concentration (µg/L)

Legend:
- ◆ All Data
- ✳ 1,4 Dioxane
- ✳ Anions
- ✳ VOCs
- Trend Line (All Data)
- Trend Line (1,4 Dioxane)
- Trend Line (Anions)
- Trend Line (VOCs)

3-Volume Versus Hydrasleeve

3-Volume Versus PDBS

$y = 0.7587x$
$R^2 = 0.5824$

VOCs

PDBS Sample Concentration (µg/L)

3-Volume Purge Sample Concentration (µg/L)

✱ VOCs
—— Trend Line (VOCs)

3-Volume Versus PSMS

PSMS Sample Concentration (µg/L)

$y = 1.0218x$
$R^2 = 0.966$ All Data

$y = 0.902x$
$R^2 = 0.994$ 1,4 Dioxane

$y = 1.0238x$
$R^2 = 0.9253$ Anions

$y = 0.8307x$
$R^2 = -1.4868$ Hexavalent Chromium

$y = 1.0207x$
$R^2 = 0.9692$ Metals

$y = 0.4563x$
$R^2 = 0.3314$ VOCs

3-Volume Purge Sample Concentration (µg/L)

Legend:
- All Data
- 1,4 Dioxane
- Anions
- Hexavalent Chromium
- Metals
- VOCs
- Trend Line (All Data)
- Trend Line (1,4 Dioxane)
- Trend Line (Anions)
- Trend Line (Hexavalent Chromium)
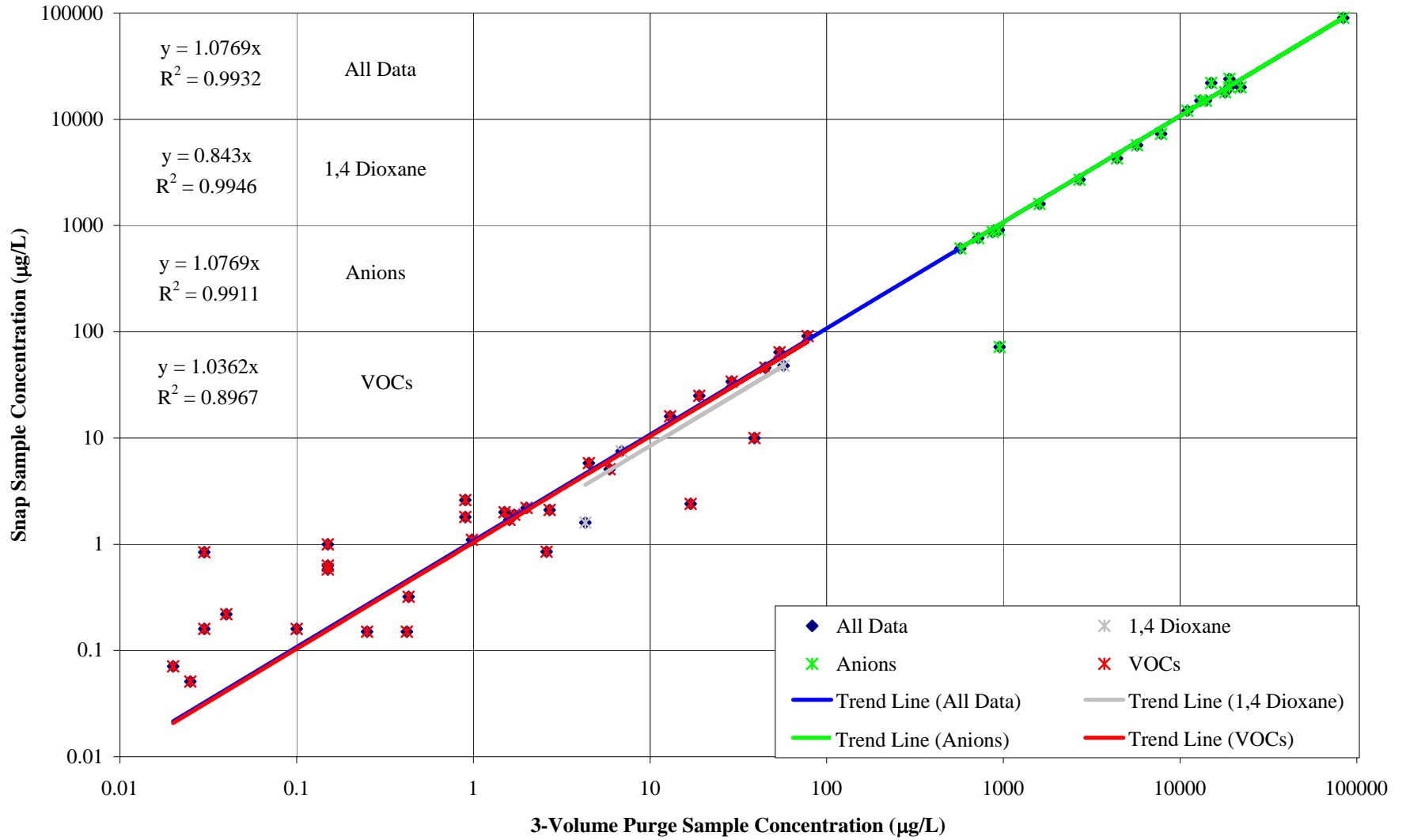- Trend Line (Metals)
- Trend Line (VOCs)

3-Volume Versus RCS

3-Volume Versus RPPS

3-Volume Versus Snap Sampler

y = 1.0769x
R^2 = 0.9932   All Data

y = 0.843x
R^2 = 0.9946   1,4 Dioxane

y = 1.0769x
R^2 = 0.9911   Anions

y = 1.0362x
R^2 = 0.8967   VOCs

Snap Sample Concentration (µg/L)

3-Volume Purge Sample Concentration (µg/L)

Legend:
- ◆ All Data
- ✳ 1,4 Dioxane
- ✕ Anions
- ✳ VOCs
- —— Trend Line (All Data)
- —— Trend Line (1,4 Dioxane)
- —— Trend Line (Anions)
- —— Trend Line (VOCs)

Hydrasleeve Versus PDBS

$y = 0.9831x$
$R^2 = 0.3875$

VOCs

PDBS Sample Concentration (µg/L)

Hydrasleeve Sample Concentration (µg/L)

✻ VOCs

▬ Trend Line (VOCs)

Hydrasleeve Versus PSMS

$y = 0.9085x$
$R^2 = 0.9253$ All Data

$y = 0.8331x$
$R^2 = 0.9963$ 1,4 Dioxane

$y = 0.8635x$
$R^2 = 0.7717$ Anions

$y = 0.5664x$
$R^2 = 0.1235$ Hexavalent Chromium

$y = 0.9352x$
$R^2 = 0.971$ Metals

$y = 0.9017x$
$R^2 = 0.8084$ VOCs

PSMS Sample Concentration (µg/L)

Hydrasleeve Sample Concentration (µg/L)

Legend:
- All Data
- 1,4 Dioxane
- Anions
- Hexavalent Chromium
- Metals
- VOCs
- Trend Line (All Data)
- Trend Line (1,4 Dioxane)
- Trend Line (Anions)
- Trend Line (Hexavalent Chromium)
- Trend Line (Metals)
- Trend Line (VOCs)

Hydrasleeve Versus RCS

Chart with axes:
- X-axis: **Hydrasleeve Sample Concentration (µg/L)**
- Y-axis: **RCS Sample Concentration (µg/L)**

Equations shown on chart:

$y = 0.9988x$
$R^2 = 0.9988$ — All Data

$y = 0.617x$
$R^2 = -1.9022$ — Hexavalent Chromium

$y = 0.9988x$
$R^2 = 0.9988$ — Metals

Legend:
- ◆ All Data
- ✕ Hexavalent Chromium
- ✕ Metals
- Trend Line (Metals)
- Trend Line (Hexavalent Chromium)
- Trend Line (All Data)

Hydrasleeve Versus RPPS

PDBS Versus PSMS

$y = 0.4099x$
$R^2 = 0.3003$

VOCs

PSMS Sample Concentration (µg/L)

PDBS Sample Concentration (µg/L)

× VOCs

Trend Line (VOCs)

PDBS Versus RCS

PDBS Versus RPPS

$y = 0.8113x$
$R^2 = 0.7123$

VOCs

RPPS Sample Concentration (µg/L)

PDBS Sample Concentration (µg/L)

VOCs

Trend Line

PDBS Versus Snap Sampler

$y = 1.2659x$
$R^2 = 0.9508$ VOCs

Snap Sample Concentration (µg/L)

PDBS Sample Concentration (µg/L)

✳ VOCs

—— Trend Line (VOCs)
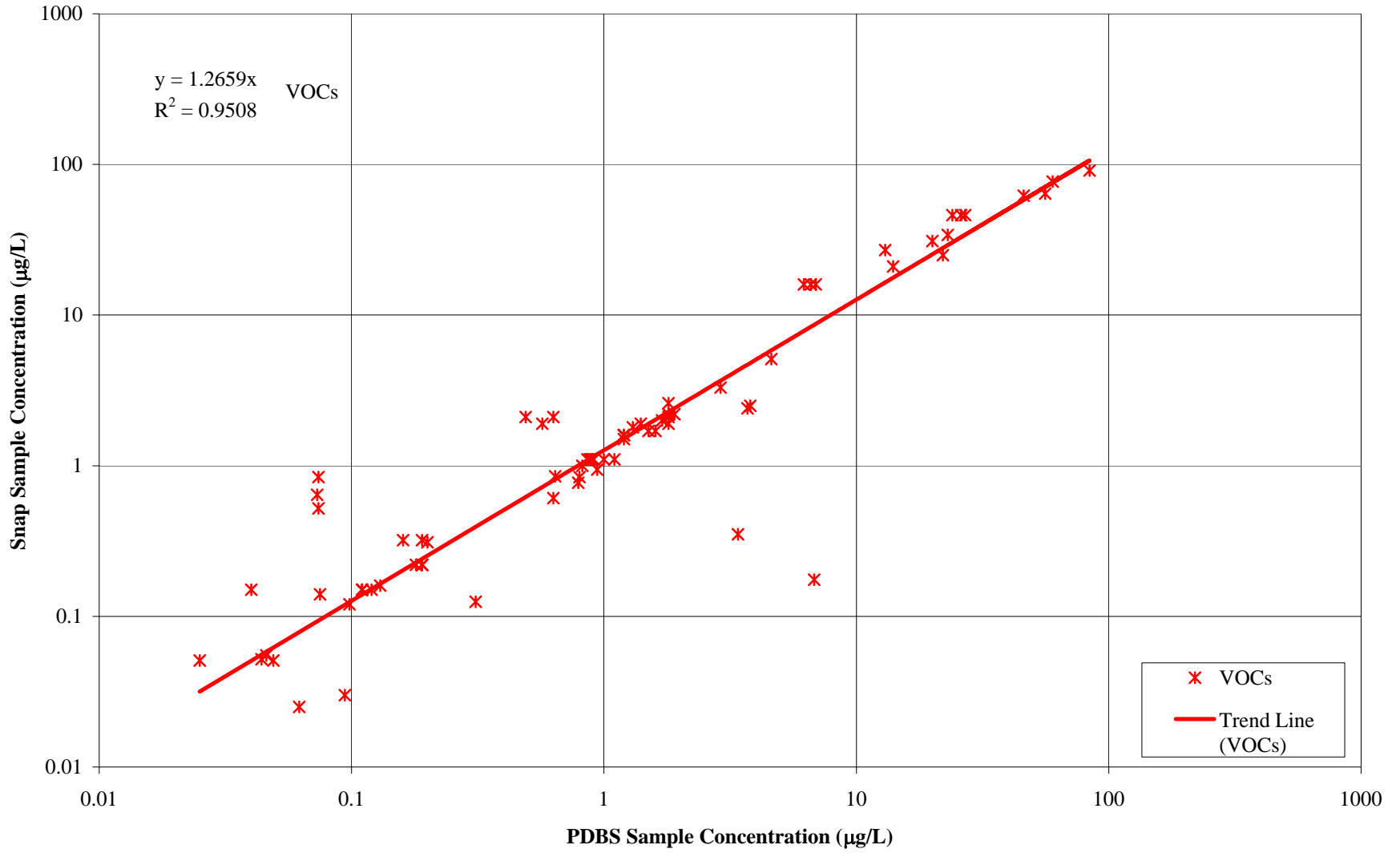
PSMS Versus RPPS

PSMS Versus RPPS

y = 1.1959x
R^2 = -16.281

1,4 Dioxane

Legend:
- ✳ 1,4 Dioxane
- ─── Trend Line (1,4 Dioxane)

X-axis: **PSMS Sample Concentration (µg/L)**

Y-axis: **RPPS Sample Concentration (µg/L)**
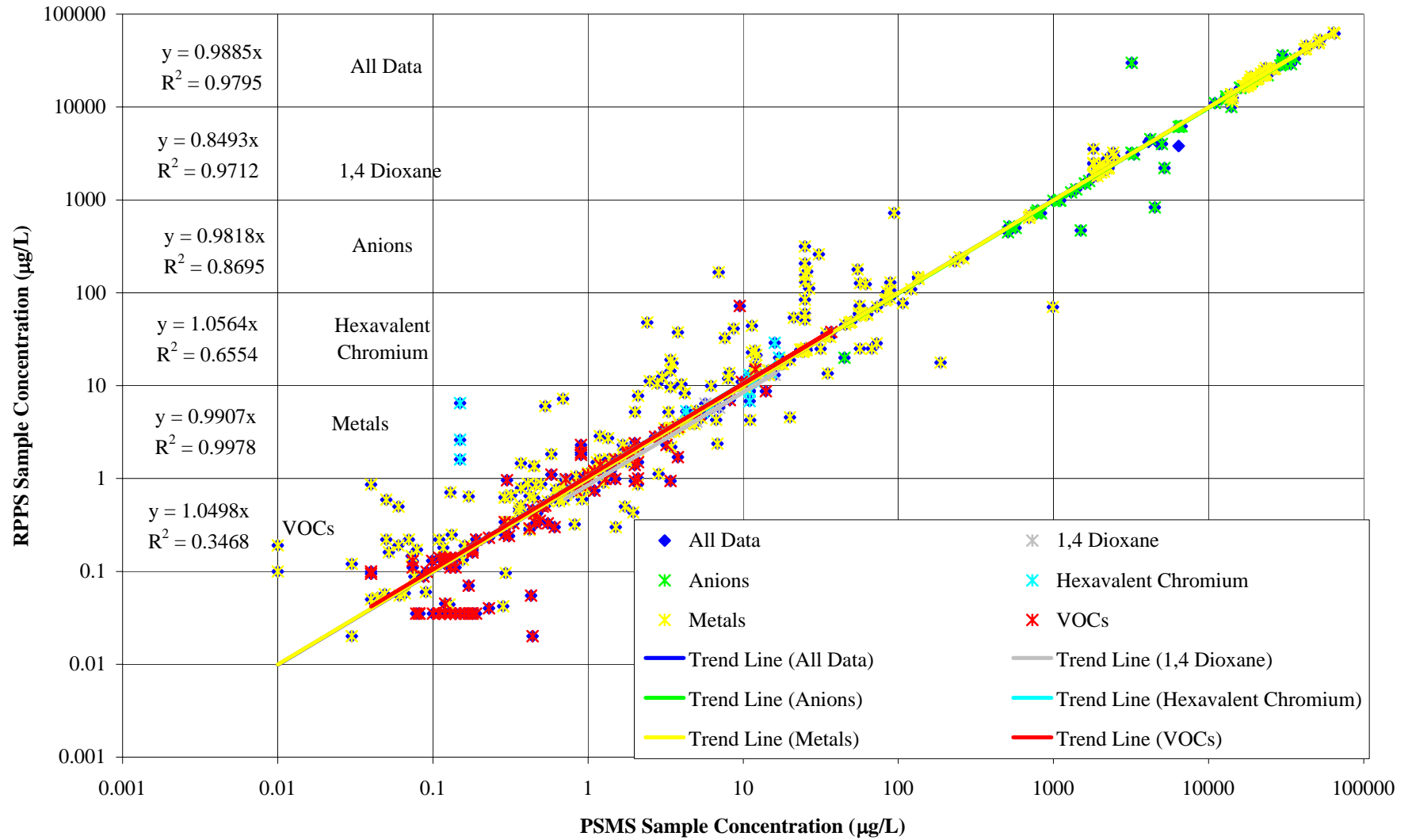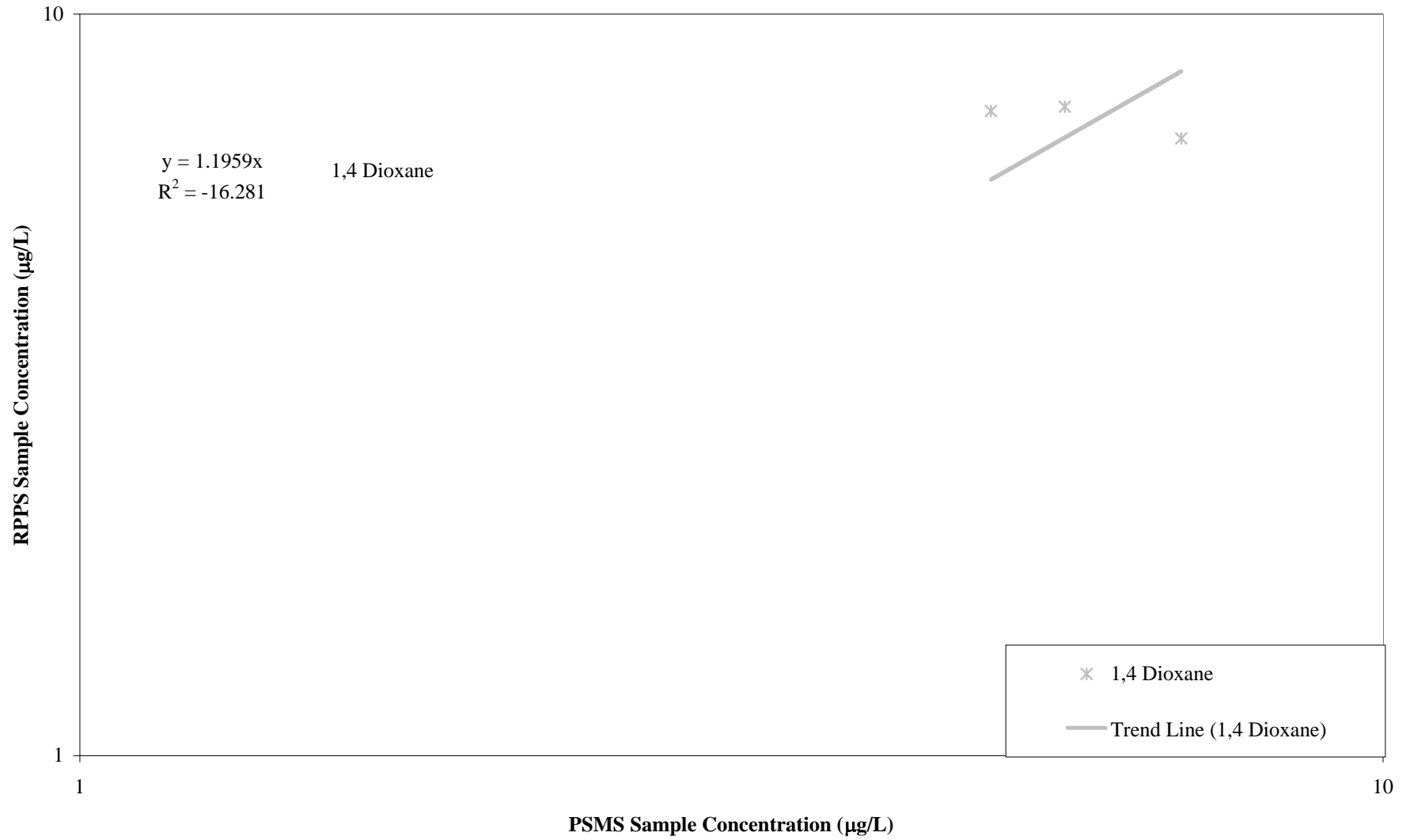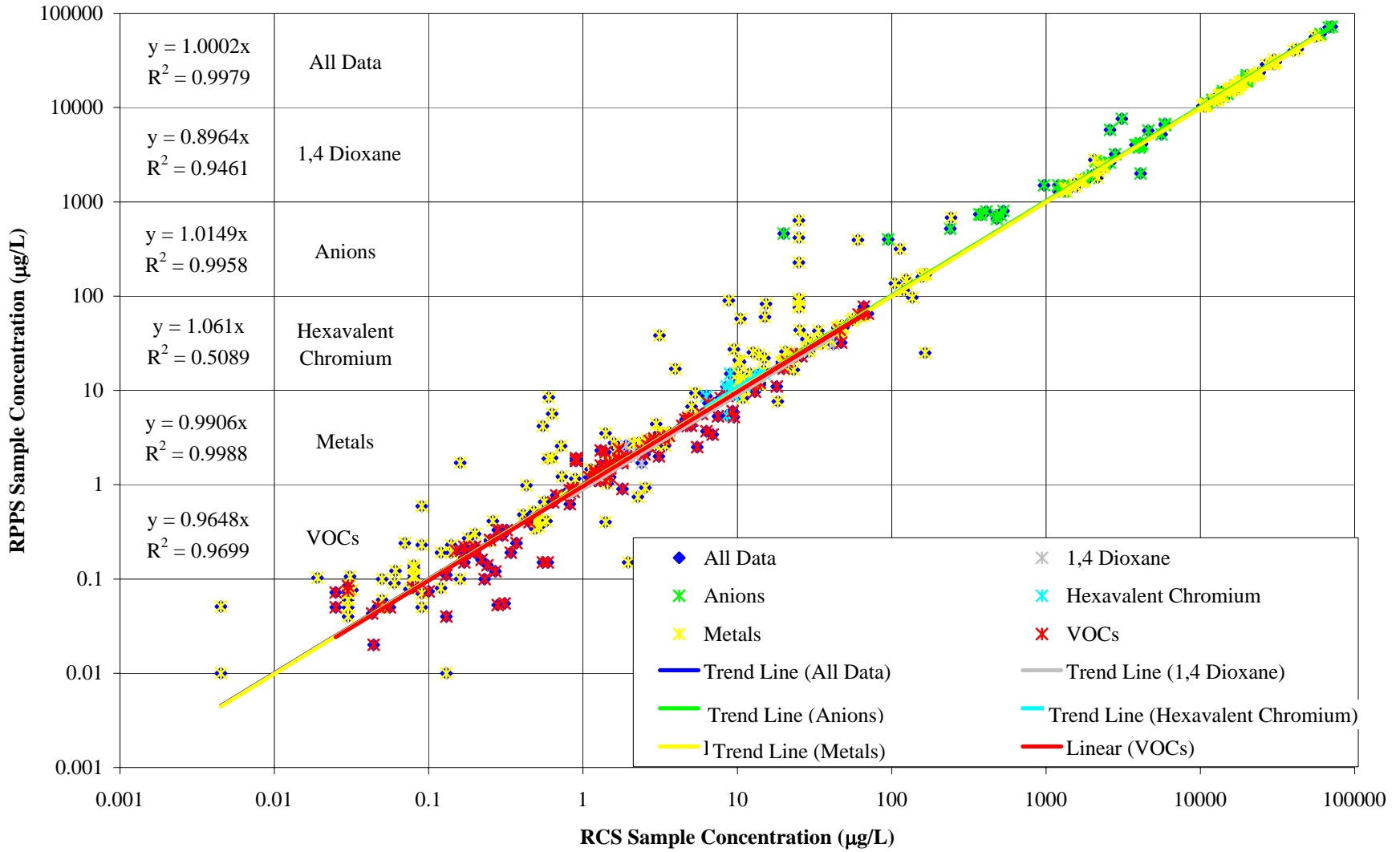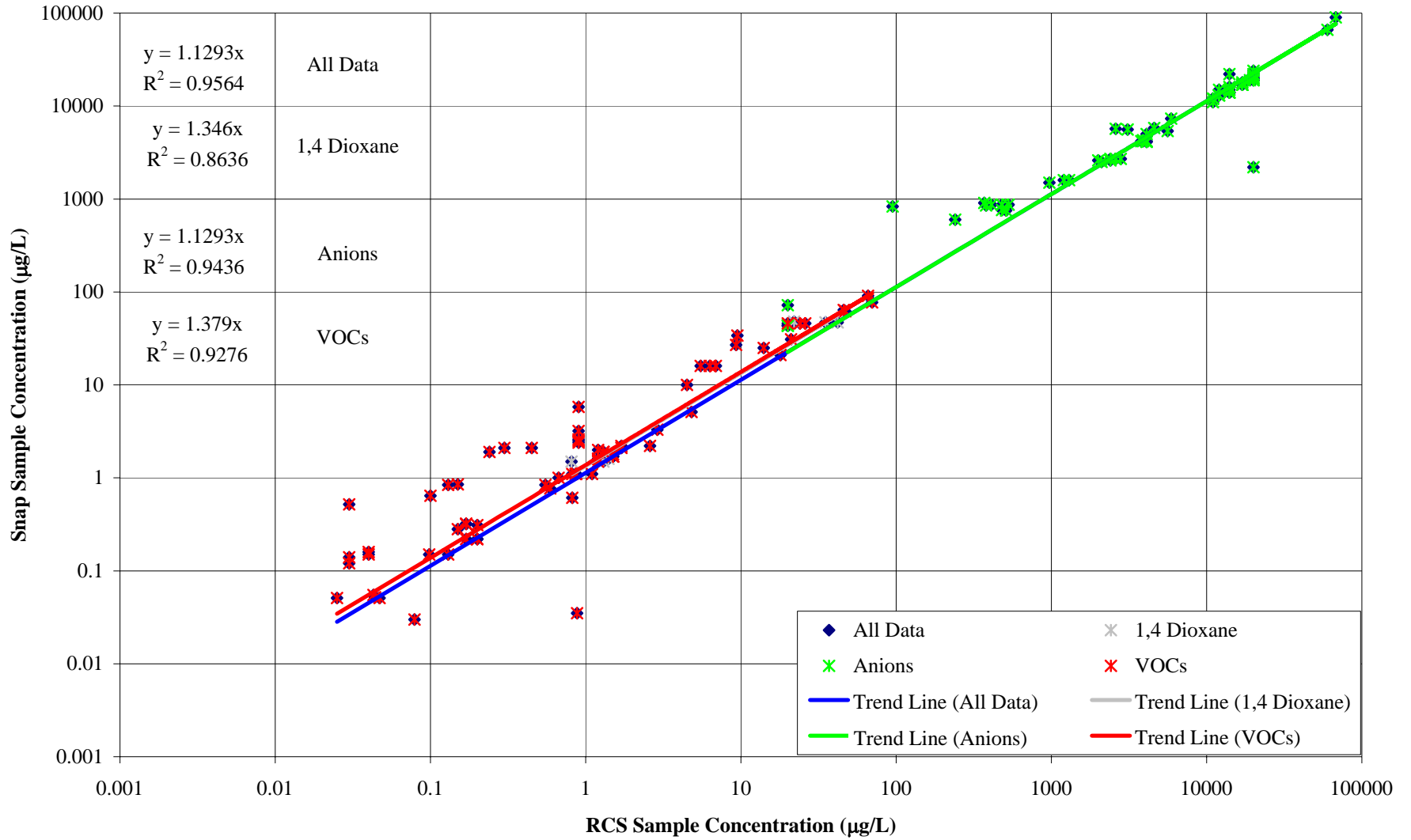
RCS Versus RPPS

RCS Versus Snap Sampler

RPPS Versus Snap Sampler

y = 1.1107x
$R^2 = 0.9628$ All Data

y = 1.5021x
$R^2 = 0.9547$ 1,4 Dioxane

y = 1.1107x
$R^2 = 0.9524$ Anions

y = 1.4003x
$R^2 = 0.8769$ VOCs

Snap Sample Concentration (µg/L)

RPPS Sample Concentration (µg/L)

- All Data
- 1,4 Dioxane
- Anions
- VOCs
- Trend Line (All Data)
- 1,4 Dioxane
- Trend Line (Anions)
- Trend Line (VOCs)