EDWARDS AQUIFER
AUTHORITY

Field and Laboratory Tests of Passive Sampling Techniques

Prepared by
Steve Johnson, Gizelle Luevano, Mark Hamilton

February 2018

Report No. 18-01

FIELD AND LABORATORY TESTS OF PASSIVE SAMPLING TECHNIQUES

Prepared by

Steve Johnson, Gizelle Luevano, Mark Hamilton

February 2018

CONTENTS

Tables

Figures

APPENDICES

ACRONYMS AND ABBREVIATIONS

GI	Amplified Geochemical Imaging, LLC
BTEX	benzene, toluene, ethylbenzene, and xylenes
C11, C13, & C15	combined masses of undecane, tridecane, and pentadecane (C11+C13+C15) hydrocarbons (diesel range alkanes)
COC	chain of custody
Combined PAHs	combined polycyclic aromatic hydrocarbons
d	day(s)
DI	de-ionized (water)
DNAPL	dense non-aqueous phase liquid
EAA	Edwards Aquifer Authority
EUWD	Edwards Underground Water District
FD	field duplicate
ft	foot, feet
hr	hour(s)
ITRC	Interstate Technology Research Council
K_{AW}	adsorbent water coefficient
K_{OW}	octanol-water coefficient
LNAPL	light non-aqueous phase liquid
L	liter
µg	microgram
mi	mile(s)
mL	milliliter
MTBE	methyl tert-butyl ether
NA	not analyzed
ND	not detected
NDMA	N-Nitrosodimethylamine
PAH	polyaromatic hydrocarbon
PCE	tetrachloroethene
PDB	polyethylene diffusion bag sampler
PSD	passive sampling device
RPD	relative percent difference
RPPS	rigid porous polyethylene sampler
SVOC	semivolatile organic compound
TB	trip blank
TPH	total petroleum hydrocarbons
TRIDEC	tridecane (C^{13} hydrocarbon)
TWDB	Texas Water Development Board
UNDEC	undecane (C^{11} hydrocarbon)
UPS	universal passive sampler
USGS	United States Geological Survey
US EPA	United States Environmental Protection Agency
VOA	volatile organic analysis
VOC	volatile organic compound

EXECUTIVE SUMMARY

Between 2007 and 2015, the Edwards Aquifer Authority (EAA) evaluated passive sampling devices for improving the collection of representative samples in its water quality monitoring program. Passive sampling techniques involve the placement of a passive sampling devices (PSD) in water over a prescribed time period. While submerged, inorganic constituents and organic compounds diffuse through a porous membrane or sorb onto compatible media. PSDs are then recovered and analyzed for target analytes. Passive samplers offer the ability to monitor for selected analytes over a longer, continuous period of time compared with the ability of grab samples of water. Because PSDs may also have a lower effective detection limit owing to their possible ability to concentrate sorbed compound, they may indicate the presence of analytes that are not detectable by grab samples.

Passive samplers evaluated for this study were a polyethylene diffusion bag sampler (PDB), a rigid porous polyethylene sampler (RPPS), and a universal passive sampler (UPS). For several reasons, UPSs were selected over the PDBs and RPPSs.

Universal passive samplers were tested extensively in the field at seven Edwards Aquifer wells. Four wells are located within the recharge zone surrounded by urban development in Bexar County. One well is located within the recharge zone surrounded by urban development in Hays County. Two wells were considered to be background wells surrounded by agricultural land—one located in Medina County within the artesian zone and the other in Uvalde County within the recharge zone. The wells were systematically sampled using UPSs for exposure periods ranging from 0.25 to 2,043 hr. On a quarterly basis, EAA field staff exchanged the UPSs and collected a grab sample. Results were compared to determine whether direct relationships existed between mass sorbed on the UPSs and grab sample concentrations.

The UPSs consistently detected fuel-related compounds and solvents at low masses, but concentrations were generally below detection limits in accompanying grab samples. Total petroleum hydrocarbons (TPHs), tetrachloroethylene (PCE), chloroform, benzene, toluene, ethylbenzene and xylenes (BTEX), and toluene were the principal contaminants detected by the UPSs. These compounds represented approximately 56% of the detections. A number of the TPH analyses were found to be false positives on the basis of TPH detected in trip blanks, especially early in the study. Only PCE (seven samples), chloroform (27 samples), methyl tert-butyl ether (once), and naphthalene (once) were detected in 238 grab samples.

In general, significantly fewer compounds were detected at the two rural wells, YP 69 35 602 and TD-69-39-504, than at the urban wells. Only one rural sample contained PCE, and all the other detections were fuel-related compounds, in contrast to the frequent detections of PCE in the urban wells. In addition, chloroform was absent from the rural wells.

Detection of solvents, especially PCE, and fuel-related compounds in the Edwards Aquifer was the principal finding from this study. Results indicated that low-level contamination by PCE and fuel-related compounds occurs throughout the aquifer from sources on the recharge zone.

Universal passive samplers, as they were used in this study, were most effective as indicators of the presence or absence of organic compounds, especially at very low concentrations. They also eliminate the need for high-frequency sampling to determine the presence of transient chemicals. However, the mass of organic compounds sorbed on the UPSs was not directly proportional to the concentration of compounds measured in grab samples.

INTRODUCTION

The Edwards Aquifer Authority (EAA) and its predecessor agency, the Edwards Underground Water District (EUWD), in cooperation with the United States Geological Survey (USGS) and the Texas Water Development Board (TWDB), has maintained a water quality sampling program since 1968. EAA uses the analytical results from the program to assess water quality in the Edwards Aquifer. The sampling program involves analyses of a broad spectrum of parameters in wells, springs, and streams across the region. Currently the routine sampling program includes sampling of a minimum of 76 wells, eight streams, and major springs across the region at frequencies ranging from monthly to annually and, in some wells, once every three years.

Water quality samples may be divided into three categories: active (or grab), discrete level, and passive. For this report, only active and passive sampling techniques will be discussed. For the active water quality sampling method, a technician collects a specific volume of water by pumping or another method and pours the water into one or more containers for subsequent chemical analysis. This “grab” sample provides a “snapshot” of the water quality at the time of sampling. The passive water quality sampling method involves diffusion and adsorption technologies that can be utilized for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and metals. Passive sampling devices (PSDs) are deployed in wells for extended periods of time. The long deployment period allows for development of equilibrium between chemicals in the water and the passive samplers and enhances the possibility of transient contaminants present between grab sampling events being detected. PSDs may also continue to accumulate mass of some analytes efficiently, even when the analyte’s dissolved concentrations are very low. This accumulation property can improve sensitivity for detection.

Purpose and Scope

Between 2007 and 2015, EAA evaluated passive sampling devices for improving the collection of representative samples within its water quality monitoring program. Historically, EAA’s water quality sampling has been limited to the collection of grab samples from wells, streams, or springs in compliance with requirements of its *Groundwater Quality Monitoring Plan*. An excerpt of the *Groundwater Quality Monitoring Plan* is included in Appendix C of this document. However, because of the karstic nature of the Edwards Aquifer, grab samples may not fully represent aquifer conditions. Water quality may change quickly owing to rapid groundwater velocities, and grab samples provide only a representation of water quality at the sample point and time. Passive samplers are exposed to water for longer periods of time. They may therefore adsorb transient compounds that appear infrequently or for time periods shorter than the grab sample frequency. Because passive sampling devices commonly adsorb compounds onto a solid sorbent phase, analytical results are reported in units of mass desorbed. EAA would like to determine what types of water quality information may be collected using UPSs to complement the information collected by grab samples.

The purpose of this study is to examine the effectiveness of collecting passive samples when compared with that of the collection of grab samples for the Edwards Aquifer. With passive sampling, constituents diffuse across a membrane or sorb onto appropriate media. Whereas many passive sampling technologies exist, not all are applicable to groundwater. For the purposes of this study, three passive sampling devices were selected for evaluation. Two of the devices collected samples by diffusion across a membrane, and the third sampler involved diffusion and subsequent sorption to solid media.

Diffusion-based samplers are the Polyethylene Diffusion Bag Sampler (PDB) and the Rigid Porous Polyethylene Sampler (RPPS). Each functions via diffusion of dissolved compounds across a semipermeable membrane. Both devices are filled with deionized (DI) water prior to deployment. The resulting concentration gradient between formation water in the well and DI water inside the sampler drives the diffusion process. The PDB is limited to detection of certain non-polar VOCs, whereas the RPSS has a wider range of analytes, including metals and SVOCs.

The third passive sampling device is the Universal Passive Sampler (UPS; formerly known as the GORE- SORBER® Module). It consists of sorbent beads encased in a Gore-Tex® membrane and utilizes diffusion and sorption to accumulate analytes. The membrane prevents water from contacting the sorbent at head pressures of up to 34 ft of water. This sampler provides a cumulative record of all compatible VOC, pesticide, and SVOC compounds present during the exposure period because sorbed compounds cannot diffuse back into the water. The UPS is also unique from other devices because analytical costs are included in the cost of the sampler. Amplified Geochemical Imaging, LLC (AGI), manufactures and analyzes UPSs using proprietary methods.

Adsorption

Adsorption, the accumulation of chemical constituents (in solid, liquid, or gas form) on a solid surface, is typically facilitated by favorable surface charge or the presence of surface functional groups that attract chemical constituents. The magnitude of adsorption is generally controlled by the availability of adsorption sites on the solid surface. In the case of the UPS, AGI inserts a granular adsorbent into the membrane of the sampler during the manufacturing process. Polymeric and carbonaceous resins are utilized because of their ability to adsorb a broad range of VOCs and SVOCs. The membrane is hydrophobic and allows vapor but not water to pass through.

Diffusion

Diffusion refers to the process by which molecules intermingle as a result of their kinetic energy of random motion. Molecules diffuse from solutions of higher concentration to solutions of lower concentration. The direction and rate of diffusion can be driven by differences in concentration across a permeable or semipermeable barrier. As a rule, diffusion rates are higher when the concentration gradient is steeper. For PSDs, DI water is used to create an initial concentration gradient between the groundwater and the sampler's interior. In the PDB and RPPS, polyethylene serves as the semipermeable membrane that allows VOCs and other constituents to diffuse into the samplers. As the concentrations of VOCs or other constituents increase within the sampler, the diffusion rate slows until the interior and exterior concentrations are equal. Because this process represents a dynamic equilibrium, analyte concentrations in the bag are generally representative of well conditions over the previous several days prior to device removal.

Aliasing

The EAA strives to evaluate passive sampling technologies systematically to determine whether PSDs may improve EAA's water quality sampling program, especially with respect to detecting transient chemicals or the presence of chemicals below laboratory detection limits for compounds dissolved in water. Historical sampling results indicate that many contaminants in the aquifer are transient. That is, analyses of Edwards Aquifer water rarely detect the same organic compounds in consecutive samples from the same location. Failure to detect contaminants in successive sampling events is difficult to interpret. The original detection might have been a laboratory artifact or reporting error, or it could reflect a contaminant that moved quickly past the sampling location, such speed being common in karst aquifers where groundwater velocities may be high.

In hydrogeology, the improper characterization of chemical concentrations because of sampling frequencies being too low to detect rapid changes in water compositions is known as *aliasing.* Aliasing can also occur during water level and spring discharge measurements, as well as water quality measurements.

Figure 1 is a graphical representation of aliasing in a water quality sample. Because of rapid groundwater velocities, short-duration, transient chemicals may never be detected if they pass the sampling location, e.g., well or spring, between sampling events. Utilization of passive samplers may help to detect the presence of contaminants between grab sampling events. Whereas a grab sample provides an instantaneous record of compounds present, PSDs provide time-weighted concentrations of compounds and a cumulative record of potential contaminants present during the deployment period.

PSDs may also concentrate some contaminants that are normally below laboratory detection limits for water samples. While exposed to water, PSDs collect chemicals until chemical gradients are flat or sorption sites are saturated. The contaminant mass collected is a function of exposure time, source concentration, and collection rate of the PSD. Consequently, because PSDs accumulate mass from chemicals in solution, they offer detections at concentrations that are lower than those of grab samples.

Lack of Detections in Most Grab Samples

Most grab samples from the Edwards Aquifer contain few, if any, detections of potential contaminants. Grab sample target analytes for this study were identified on the basis of chemical constituents that were detectable by the passive samplers, along with additional parameters valuable to an understanding of long-term trends in water quality. Grab sample frequencies were selected in an effort to detect temporal changes in water quality at a single sample point. Because of the suspected transience of contaminant pulses in the wells, pulses may be difficult to capture using grab samples.

Table 1 presents analytical results of volatile organic compounds (VOCs) in grab samples collected by EAA staff. Few VOCs were generally detected in grab samples collected for this study. Of the 120 grab samples, 31 contained detectable organic compounds. However, the compounds were limited to chloroform, naphthalene, methyl tert-butyl ether (MTBE), and tetrachloroethene (PCE). These were detected in samples from five of the eight wells that were sampled approximately quarterly. Chloroform is a byproduct of water chlorination, and naphthalene and MTBE are related to fuels. PCE is a solvent used in dry cleaning

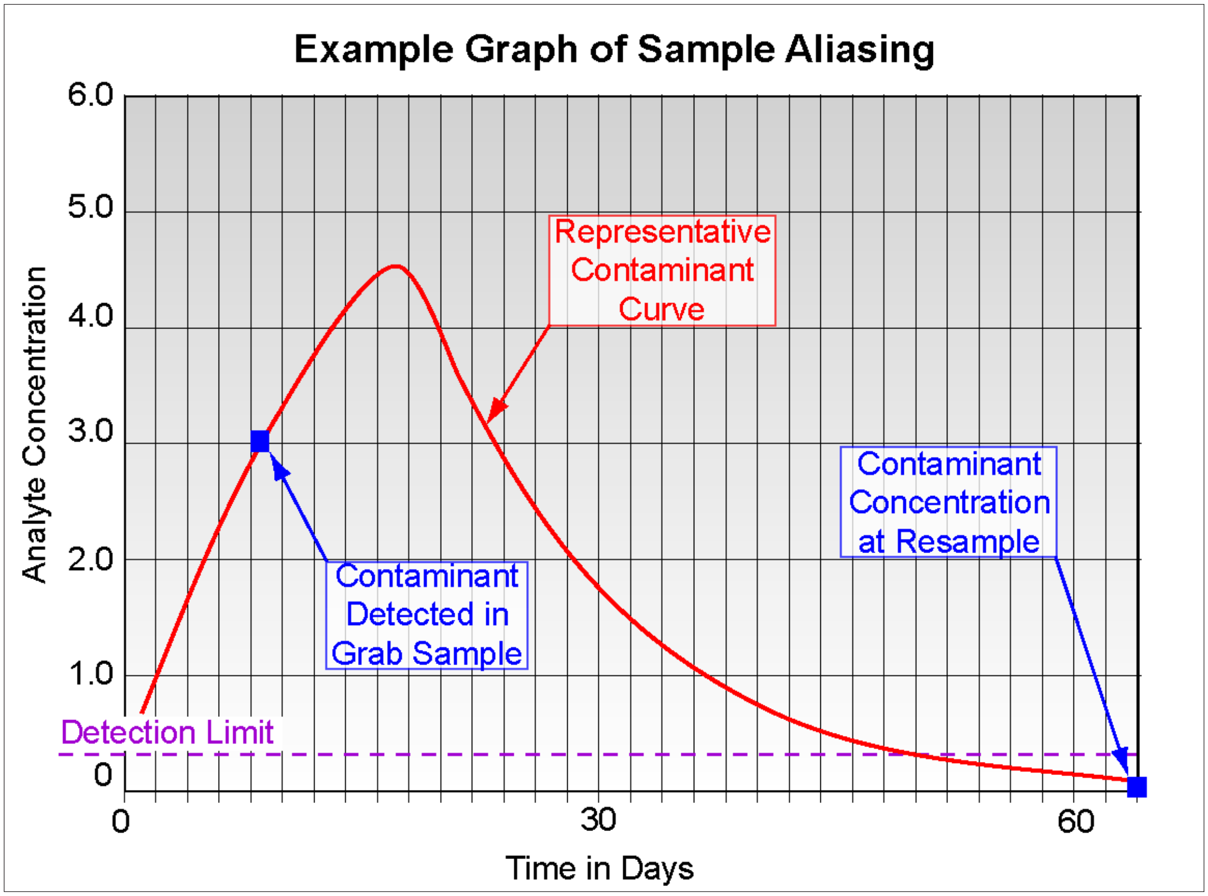


Figure 1. Graphical Explanation of Problem of Aliasing in Groundwater

and degreasing. All five wells, except YP-69-35-602, are located on the recharge zone in Bexar County. YP-69-35-602 is located on the recharge zone in Uvalde County and was included as a background well.

Alternatives to Passive Samplers

Two other solutions to capturing transient potential pollutants are to increase the frequency of sample collection using additional grab samples or automatic samplers. More frequent collection of grab samples requires additional labor and travel costs that become prohibitive as the number of monitoring sites or samples increases. For a large-scale monitoring program such as the one that the EAA operates, a tradeoff always exists between sample frequency and the number of sites sampled. Automatic samplers consist of a programmable pump and multiple sample containers, which can be used to collect samples at a high frequency (e.g., hourly, daily) unattended. However, they are not suitable for target analytes that involve refrigeration, short holding times, or zero head space in the sample container. Because these requirements greatly limit the utility of autosamplers for routine sampling, they were not considered further in this study.

Table 1. Organic Compounds Detected in Grab Samples

State Well No	Sample Date	Compound	Concentration (µg/L)
AY-68-28-608	03/20/2012	Chloroform	0.728
AY-68-28-608	05/22/2012	Chloroform	0.383
AY-68-28-313	03/16/2011	Chloroform	1.86
AY-68-28-313	06/30/2011	Chloroform	1.8
AY-68-28-313	12/07/2011	Chloroform	1.57
AY-68-28-313	02/10/2012	Chloroform	1.39
AY-68-28-313	05/24/2012	Chloroform	0.99
AY-68-28-313	02/28/2013	Chloroform	1.19
AY-68-28-313	05/21/2013	Chloroform	1.28
AY-68-28-313	04/28/2014	Chloroform	2.33
AY-68-27-303	03/16/2011	Chloroform	0.339
AY-68-27-303	07/06/2011	Chloroform	0.403
AY-68-27-303	02/21/2012	Chloroform	0.436
AY-68-27-303	02/27/2013	Chloroform	0.519
AY-68-27-303	05/21/2013	Chloroform	0.544
AY-68-27-303	04/23/2014	Chloroform	0.56
AY-68-27-303	03/16/2011	Chloroform	0.293
AY-68-27-303	07/06/2011	Chloroform	0.399
AY-68-27-303	12/20/2011	Chloroform	0.51
AY-68-27-303	02/21/2012	Chloroform	0.385
AY-68-27-303	02/27/2013	Chloroform	0.699
AY-68-27-303	05/21/2013	Chloroform	0.628
YP-69-35-602	03/14/2011	Naphthalene	0.0358
AY-68-29-113	01/04/2011	Methyl tert-butyl ether	0.991
AY-68-29-418	04/04/2011	Chloroform	0.411
AY-68-29-418	04/04/2011	PCE	2.02
AY-68-29-418	05/31/2012	Chloroform	0.511
AY-68-29-418	05/31/2012	PCE	3.43
AY-68-29-418	12/19/2012	Chloroform	0.242
AY-68-29-418	12/19/2012	PCE	4.34
AY-68-29-418	05/22/2013	PCE	4.33
AY-68-29-418	10/01/2013	Chloroform	0.292
AY-68-29-418	10/01/2013	PCE	4.59
AY-68-29-418	05/01/2014	PCE	4.21
AY-68-29-418	03/31/2015	Chloroform	0.202
AY-68-29-418	03/31/2015	PCE	2.53

HYDROLOGY OF THE EDWARDS AQUIFER

The San Antonio Segment of the Balcones Fault Zone Edwards Aquifer in south central Texas (Figure 2) is one of the largest and most important karst aquifer systems in the United States. The aquifer extends through parts of Kinney, Uvalde, Medina, Frio, Atascosa, Bexar, Comal, Guadalupe, and Hays counties and covers an area approximately 180 mi long and five to 40 mi wide. The aquifer is the primary water source for much of this area, including the City of San Antonio. The cities of Uvalde, San Antonio, New Braunfels, and San Marcos were founded around large springs that flow from the aquifer. As the region grew, wells were drilled into the aquifer to supplement water supplied by the springs. In addition, the Edwards Aquifer, the principal source of water for agriculture and industry in the region, provides springflow required for endangered species habitat, as well as for recreational purposes and downstream uses in the Nueces, Medina, Guadalupe, and San Marcos River basins. Water quality in the aquifer is generally good and adequate for human consumption.

The Edwards Aquifer is contained within the Cretaceous-age Edwards Group limestone (Edwards Limestone) and associated units. The aquifer is capped by the Del Rio Clay and overlies the Glen Rose Formation (upper unit of the Trinity Aquifer). The Edwards Limestone and associated units range from 450 to more than 600 ft in thickness in the region. The Edwards Limestone is exposed at the surface along the southern boundary of the Texas Hill Country. A series of faults in the Balcones Fault Zone has dropped the Edwards Limestone to great depths below the surface along the aquifer's southern and eastern boundaries.

Water circulates through the Edwards Aquifer as part of the hydrologic cycle from recharge areas to discharge points (springs and wells). The approximately 1,250 square mi of Edwards Limestone exposed at the ground surface composes the recharge zone of the aquifer. Streams flow south from the drainage area (the Texas Hill Country) and lose all or most of their base flow as they cross the recharge zone (see Figure 2). In addition, part of the rain that falls directly on the recharge zone also enters the aquifer. Groundwater moves through the aquifer and ultimately discharges from a number of locations, such as Leona Springs in Uvalde County, San Pedro and San Antonio springs in Bexar County, Hueco and Comal springs in Comal County, San Marcos Springs in Hays County, and Barton Springs in Travis County. In addition, domestic, livestock, municipal, agricultural, and industrial wells throughout the region withdraw water from the aquifer. The residence time of water in the aquifer ranges from a few hours or days to many years, depending on depth of circulation, location, and other aquifer parameters.

The Edwards Aquifer is a karst aquifer, characterized by the presence of sinkholes, sinking streams, caves, large springs, and a well-integrated subsurface drainage system. It is one of the most productive groundwater systems in the United States, characterized by extremely high capacity water wells and high spring discharges. The aquifer exhibits extremely high (cavernous) porosity and permeability, which are characteristic of many karst aquifers. In contrast, aquifers that occur in sand and gravel or in other rock types, such as sandstone, have much lower permeability.

PREVIOUS RESEARCH

Environmental Technology Verification Report— Groundwater Sampling Technologies

To date, research on utilizing passive samplers in groundwater monitoring programs is limited. When the United States Environmental Protection Agency (EPA) investigated the UPS in groundwater monitoring wells (EPA, 2002), its scope of study was to determine the accuracy and precision of the UPS in five shallow wells over an exposure time of 48 hr. The water depth of these wells ranged from two to 10 ft, and each well had a history of containing VOC-contaminated groundwater. These conditions were ideal for UPSs because they were designed to sorb VOCs and SVOCs while minimizing the loss of gasses.

After retrieval of the UPSs, the EPA shipped the samplers to AGI for analysis. AGI utilized thermal desorption by GC-MS followed by a modification of EPA SW846 methods 8260 and 8270 to analyze for VOCs and SVOCs (EPA, 2002). Results from the UPSs were reported in units of mass instead of concentration. AGI used an empirical algorithm to convert the mass values into concentration values.

Results from the EPA (2002) study indicated that UPSs could detect concentrations of contaminants in groundwater that were lower than those of grab samples. Data from the study established a direct correlation between UPSs and grab samples. The EPA determined that UPSs were adequate for studying changes in groundwater quality and that they would detect contaminant changes in areas of interest.

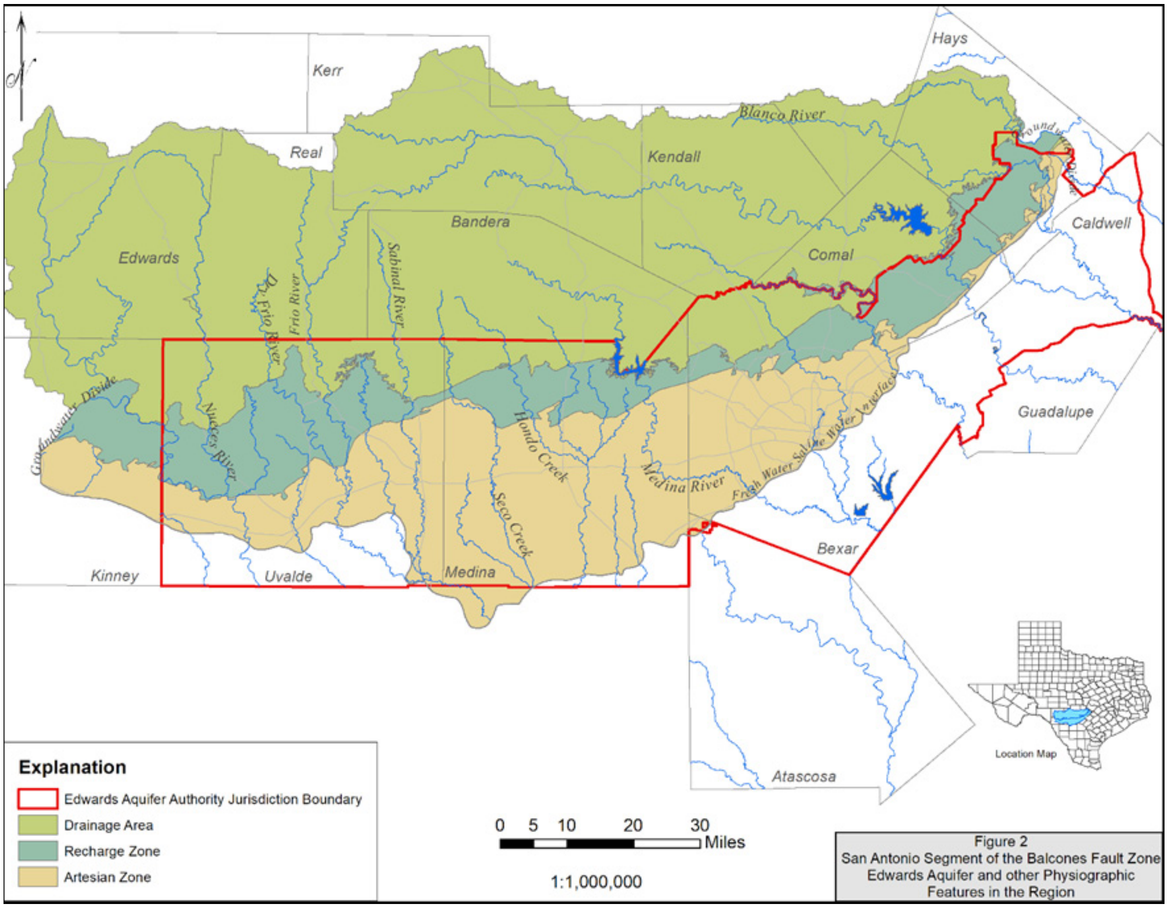


Figure 2. San Antonio Segment of Balcones Fault Zone Edwards Aquifer

METHODS

This section summarizes the three passive sampling devices that were considered for this study: Polyethylene Diffusion Bag Sampler (PDB), Rigid Porous Polyethylene Sampler (RPPS), and Universal Passive Sampler (UPS).

Selection Process

Polyethylene Diffusion Bag Sampler

Developed in the late 1990s, the PDB has become widely accepted for determining VOC concentrations in groundwater. Because they rely on diffusion back and forth across a semipermeable membrane, PDBs do not provide a cumulative representation of analytes present in the well bore for the entire exposure period. However, if deployed back to back, they may be useful in capturing a time-weighted record of site conditions.

PDBs, typically 1.25 inches wide and 24 inches long, are placed in a well for 14 d to allow for adequate diffusion of all potential compounds (diffusion rates vary significantly among VOCs). PDBs are not appropriate for all compounds, but they are suitable for non-polar VOCs with an atomic radius of 10 angstroms or less. They are relatively inexpensive, at approximately $30 each, with an additional one-time cost of an additional $30 that includes weights, tethers, well caps, and miscellaneous expenses. PDBs, as well as other passive samplers, can result in reduced labor costs because no well purging is necessary for sample collection. In addition, PDBs provide a mechanism for vertical profiling in a well, which can be used in wells with known contamination to ascertain potential dilution effects inherent in water quality grab sampling. Available data, as published by the Interstate Technology Research Council (ITRC, 2005), indicates that a two-ft-long PDB will adequately sample five ft of well bore. Table 2 summarizes detectable VOCs applicable to the PDB.

VOCs that were unfavorable for laboratory analyses using the PDB were acetone, methyl iso-butyl ketone, methyl tert-butyl ether, and styrene. These compounds generally were not widely detected in well samples from the Edwards Aquifer between 1986 and 2015. Detections were limited to three of methyl tert-butyl ether and one of styrene during this time period. Note that many of the detectable compounds in Table 2 were detected with greater frequency during this same time frame (1986–2015). The PDBs were therefore useful in detecting VOCs that were more commonly detected in the Edwards Aquifer. Figure 3 shows examples of a PDB and the equipment needed for deployment.

Rigid Porous Polyethylene Samplers

The Rigid Porous Polyethylene Sampler (RPPS) is a diffusion-based sampler similar in function to PDBs but capable of sampling for additional analytes, including SVOCs and metals. Essentially these samplers are capable of monitoring for any dissolved phase constituent in groundwater or surface water. RPPSs contain DI water inside a porous polyethylene material with a pore size of six to 20 microns. Samplers are 3.8 cm (1.5 inch) in diameter by 12.5 cm (five inches) long, yielding a sample volume of 100 mL. Similar to that of PDBs, the diffusion process of RPPSs represents a dynamic equilibrium. That is, concentrations of contaminants in the sampler will change to reflect changes in the borehole water via a concentration gradient. However, concentration changes are not instantaneous because diffusion rates differ for various compounds, with some compounds diffusing faster than others. In general, the literature indicates deployment times of two weeks for most compounds. Field studies indicate that compounds associated with explosives, as well as certain hydrophobic VOCs and SVOCs, require more time for equilibration than do other compounds.

When comparing other passive sampling techniques with these techniques, recent studies indicate good quantitative correlation with RPPSs, which also correlate well with low flow purge sampling (ITRC, 2005). The general advantages of RPPSs include

- Ability to accumulate a wide range of compounds (see Table 3).
- No purging required.
- Ease of deployment/retrieval.
- Supplied field ready.

Table 2. Volatile Organic Compounds Applicable to Polyethylene Diffusion Bag Samplers

Favorable Laboratory Diffusion Testing Results		
Benzene	1, 3-Dichlorobenzene	Naphthalene
Bromodichloromethane	1, 4-Dichlorobenzene	1, 1, 2, 2-Tetrachloroethane
Bromoform	Dichlorodifluoromethane	Tetrachloroethene (PCE)
Chlorobenzene	1, 1-Dichloroethene	Toluene
Carbon Tetrachloride	1, 2-Dichloroethane	1, 1, 1-Trichloroethane
Chloroethane	cis-1, 2-Dichloroethene	1, 1, 2-Trichloroethane
Chloroform	trans-1, 2-Dichloroethene	Trichloroethene (TCE)
Chloromethane	1, 2-Dichloropropane	Trichlorofluoromethane
2-Chlorovinylether	cis-Dichloropropene	1, 2, 3-Trichloropropane
Dibromochloromethane	1, 2-Dibromoethane	Vinyl chloride
Dibromomethane	trans-1, 3-Dichloropropene	Xylenes
1, 2-Dichlorobenzene	Ethylbenzene	

Figure 3. Polyethylene Diffusion Bag Samplers (ITRC, 2005)

Disadvantages include longer equilibration times for less-water-soluble VOCs and SVOCs. Additionally, the samplers must be stored and shipped submerged in DI water, and sample volumes are insufficient for multiple analyses (~100 mL per sampler).

However, data published for these samplers indicate that they should work well for most compounds of interest in this study. Additionally, RPPSs may be a good tool for vertical profiling of wells. Currently the only known supplier of RPPSs is Columbia Analytical, at an approximate cost of $65.00 each. Figure 4 shows RPPSs being prepared for deployment.

Compounds that compare favorably to conventional sampling techniques in laboratory and/or field studies are listed in Table 3. In laboratory tests conducted by Columbia Analytical Services as published by ITRC (2005), known concentrations of compounds were analyzed using traditional (water quality grab) samples versus RPPSs, and many VOCs were detected with greater accuracy than they were using grab sampling. Of significant interest to this study is PCE, which was spiked into a solution at 57 µg/L. PCE was detected at 21 µg/L using RPPSs and at 5 µg/L using the grab sample.

Figure 4. Rigid Porous Polyethylene Samplers (ITRC, 2005)

Compounds that compare favorably to conventional sampling techniques in laboratory and/or field studies are listed in Table 3. In laboratory tests conducted by Columbia Analytical Services as published by ITRC (2005), known concentrations of compounds were analyzed using traditional (water quality grab) samples versus RPPSs, and many VOCs were detected with greater accuracy than they were using grab sampling. Of significant interest to this study is PCE, which was spiked into a solution at 57 µg/L. PCE was detected at 21 µg/L using RPPSs and at 5 µg/L using the grab sample.

Universal Passive Sampler

The UPS works on the principal of diffusion and sorption, resulting in a cumulative representation of sample conditions during the time of deployment. Results are reported in total mass of analytes detected during the exposure period. The UPS has been used in soil, groundwater, surface water, and saltwater, and it consists of a Gore-Tex® membrane sleeve filled with sorbent beads, which allows vapors to pass through while preventing water intrusion to the sorbent. Water may penetrate the membrane when the UPS is submerged to a depth of more than 34 ft; however, compounds will continue to partition to the adsorbent directly from the water but at a lower rate than that of air. Colloidal particles and microbes cannot pass through the membrane. It is possible for the sorbent to become saturated, so the mass level may eventually reach a maximum steady state value at any concentration.

The cost of a UPS ranges between $185 and $285, depending on the selected analyses that are included in the cost of the sampler. AGI ships UPSs in sealed glass vials, with a chain of custody (COC) enclosed in the packaging. Once deployed and retrieved, each UPS is returned to its original vial and shipped back to AGI for analyses. Adding preservatives or chilling during storage or transportation is not necessary. Each UPS has a unique serial number printed below the loop of the sampler and on top of the cap of the glass vial. The sampler and analytical process are proprietary products available only from AGI. Figure 5 displays a UPS and its glass vial.

The UPS is capable of sorbing and detecting most VOCs and a more limited list of SVOCs and pesticide compounds. The method is capable of detecting compounds in a parts per trillion (ppt) range. However, the samplers do not sorb compounds such as metals or nutrients, nor do they function in the presence of free product (light non-aqueous phase liquid or LNAPL or dense non-aqueous phase liquid or DNAPL). They offer the opportunity of detecting transient compounds passing through a well bore because they provide a

Table 3. Successful Results for Rigid Porous Polyethylene Samplers vs. Conventional Sampling Techniques

Analyte(s)	Laboratory Study Completed	Field Study Completed
Water Soluble VOCs	Yes	No
Phenols	Yes	Pending
Explosives	Yes	Yes
MTBE	Yes	Yes
Water Soluble SVOCs	Yes	No
NDMA	Yes	Yes
1, 4-Dioxane	Yes	Yes
Metals	Yes	Yes
Hexavalent Chromium	Yes	Yes
Perchlorate	Yes	Yes
Chloride	Yes	No
Nitrate	Yes	No
Sulfate	Yes	No
Methane, Ethane, Ethene	Yes	No
Dissolved Gasses	Yes	No

(Hamilton, J.M., 2007, Edwards Aquifer Authority, Aquifer Science Program, Passive Sampling Technology Pilot Study, unpublished).

cumulative record of compounds present during the exposure period. Target compounds detectable by AGI are listed in Table 4 (VOCs), Table 5 (PAHs), Table 6 (SVOCs and fuels), and Table 7 (pesticides).

As previously mentioned, analytical results for the UPS are reported as mass. Although contaminant concentrations may be calculated on the basis of sorption rates, they are not used for the purposes of this report. AGI calculates contaminant concentrations from laboratory tests that may not simulate groundwater conditions in the aquifer. For example, contaminant concentrations may vary during the exposure period of the UPS so that grab samples are not representative of groundwater conditions (Figure 6). In addition, some UPSs had to be placed more than 34 ft below the water table. Because the depth of emplacement affects the sorption rate and the sorption rate is used for calculating concentration, varying corrections would be required to make reasonable estimates of contaminant concentrations.

Figure 5. Universal Passive Sampler and Its Glass Vial (ITRC, 2005)

Table 4. VOCs Detectable by Amplified Geochemical Imaging, LLC

trans-1,2-Dichloroethene	Trichloroethene	m,p-Xylenes
1,1-Dichloroethane	1,1,2-Trichloroethane	o-Xylene
cis-1,2-Dichloroethene	Toluene	1,1,2,2-Tetrachloroethane
Chloroform	Octane	1,3,5-Trimethylbenzene
1,1,1-Trichloroethane	Tetrachloroethene	1,2,4-Trimethylbenzene
1,2-Dichloroethane	Chlorobenzene	1,3-Dichlorobenzene
Benzene	1,1,1,2-Tetrachloroethane	1,4-Dichlorobenzene
Carbon Tetrachloride	Ethylbenzene	1,2-Dichlorobenzene

Table 5. PAHs Detectable by Amplified Geochemical Imaging, LLC

Acenaphthene	Fluoranthene	Phenanthrene
Acenaphthylene	Fluorene	Pyrene
Anthracene	Naphthalene	

Table 6. SVOCs and Fuels Detectable by Amplified Geochemical Imaging, LLC

Undecane	2-Methylnaphthalene	TPH
Tridecane	Pentadecane	Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)

Table 7. Pesticides Detectable by Amplified Geochemical Imaging, LLC

Alpha Hexachlorocyclohexane (BHC)	Heptachlor Epoxide	Endosulfan II
Beta Hexachlorocyclohexane (BHC)	Endosulfan I	Endrin Aldehyde
Gamma Hexachlorocyclohexane (BHC)	4, 4'-DDD	Endrin
Delta Hexachlorocyclohexane (BHC)	4, 4' DDE	Endosulfan Sulfate
Heptachlor	4, 4' DDT	Endrin Ketone
Aldrin	Dieldrin	Methoxychlor

Selection of Universal Passive Sampler

The UPS was selected over the PDB and RPPS for the following reasons:

1. Deployment and retrieval of UPSs are simple and thus reduce field labor costs.
2. Handling of UPSs is minimal, which reduces the risk of cross-contamination, as compared with the handling of other samplers.
3. Universal passive samplers are more sensitive than grab samples and can detect a wide range of VOCs and SVOCs. Metals are not an important potential contaminant.
4. UPSs detect contaminants at equivalent concentrations of parts per trillion.
5. UPSs may be deployed in monitoring wells, springs, surface water, and other aqueous settings.
6. UPSs do not require refrigeration and thus reduce shipping and handling costs.

Universal Passive Sampler Evaluation and Applications

The objective of this study is to test UPSs under a variety of groundwater conditions to determine their application in the water quality monitoring program for EAA. Wells

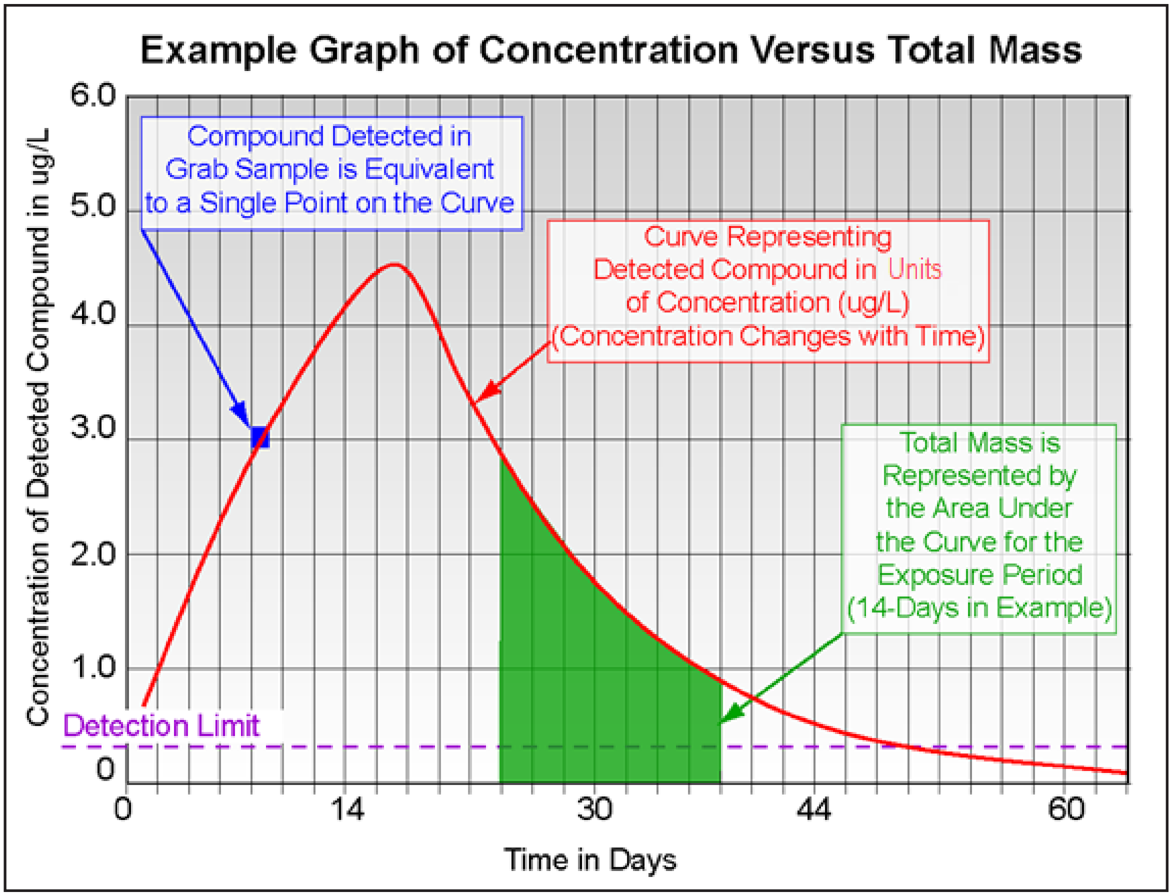


Figure 6. Example Graph Depicting Difference in Concentration vs. Total Mass (Hamilton, J.M., 2007, Edwards Aquifer Authority, Aquifer Science Program, Passive Sampling Technology Pilot Study, unpublished).

were selected for deploying UPSs in the recharge and artesian zones of the Edwards Aquifer. In general, UPSs were positioned in the principal flow zones in the wells, which were identified using geophysical and hydrophysical methods. Flow within the Edwards Aquifer occurs predominately in fractures, conducts, and bedding plane partings. These secondary and tertiary dissolution features were identified by conductivity contrasts, downhole flow meters, and/or by using a borehole video camera. Placements of UPSs are shown schematically in Figure 7.

Wells were selected in both rural and urban areas to capture a variety of compounds and to observe any effects due to contrasting land uses. In addition, UPSs placed in rural settings may reflect background conditions. A comparison of rural and urban settings may also indicate different compounds associated with different land uses, sorption rates, and concentrations.

Finally, exposure durations were varied to observe how detection of sorbed compounds compared with grab sample concentrations. In general, sorbed mass is directly proportional to contaminant concentration and to exposure time (at short to moderate exposure times) and exponentially proportional to temperature following the Arrhenius law (temperature increases sorption rate.) UPSs exposed to high concentrations or long durations may reach a maximum steady state mass and be under reported. These sorption characteristics affect how UPSs may overcome aliasing. Exposure duration tests may determine whether the mass sorbed by UPSs represents the maximum concentration that occurred during deployment. If so, UPSs could preserve important information regarding contaminant movement, such as locations, timing, and concentration. Potential uses include tracking contaminants during storm events or following spills or when used as an early warning device.

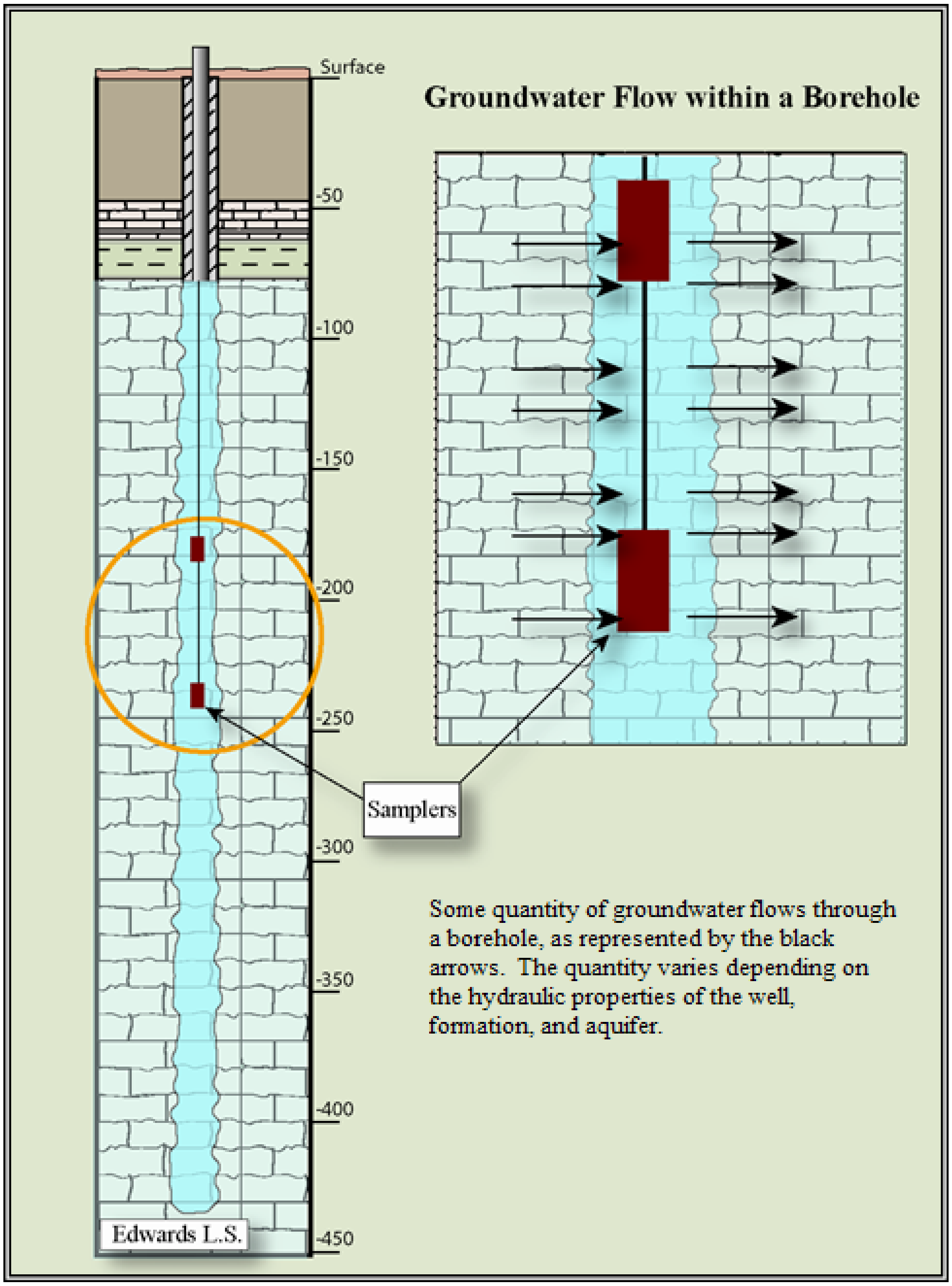


Figure 7. Idealized Groundwater Flow within a Borehole and Placement of UPS Samplers

The solid adsorbent in the UPS is designed to sorb organic compounds that pass through the membrane in vapor phase while submerged. When the depth of submersion exceeds approximately 34 ft (which occurred during this study), water will penetrate the membrane and directly contact the solid adsorbent. At that point, organic compounds partition from the water to the solid at a rate related to the adsorbent water coefficient (K_{AW}). AGI has determined through laboratory tests that the K_{AW} is related to the octanol-water coefficient, K_{OW}, by the equation, $K_{AW} = 0.0082\ K_{OW}$. The sorption rate at depths greater than approximately 34 ft will consequently be slower than at shallower depths.

Table 8. List of Wells Included in Passive Sampling Program

State Well Number	County	Generic Name	Sampling Period	Deployment Depth (feet below ground)
AY-68-27-303*	Bexar	Chase Hill	07/2010–01/2015	235; 253
AY-68-28-313*	Bexar	BexarMet	01/2011–01/2015	250
AY-68-28-608*	Bexar	608	08/2007–07/2014	120–237
AY-68-29-418*	Bexar	Rio Seco	03/2011–04/2015	212
LR-67-09-101-1*	Hays	Crystal Clear 1	11/2007–04/2015	136–152
LR-67-09-101-4*	Hays	Crystal Clear 4	11/2007–04/2015	180–190.5
TD-69-39-504*	Medina	Tarpley Well	03/2013–01/2015	250
YP-69-35-602*	Uvalde	Frio Well	04/2010–02/2013	69
AY-68-28-7FR	Bexar	Fryer	12/5/2013	NA
AY-68-29-103	Bexar	Hill Country Village	8/10/2012	465
AY-68-29-112	Bexar	Donella	01/2011–08/2012	250
AY-68-29-113	Bexar	Mecca	01/2011–08/2012	238
AY-68-29-114	Bexar	Pipestone	08/2012	198
AY-68-29-1SW	Bexar	Fleetwood	08/2012	500
AY-68-29-213	Bexar	Thousand Oaks P O	08/2012	220
AY-68-29-215	Bexar	Mud Creek	08/2012	178
AY-68-29-4MO	Bexar	Moretti	08/2012	350
AY-68-29-506	Bexar	Thousand Oaks	08/2012	470
AY-68-29-5AZ	Bexar	Auto Zone	08/2012	225
AY-68-29-5FL	Bexar	Faith Lutheran	08/2012	75
TD-68-41-303	Medina	City of Castroville	09/2007	NA

* = UPSs continuously deployed and retrieved from these wells.

NA = not available.

Sample Locations

This project involved collecting samples from 21 monitoring wells using UPSs in the Edwards Aquifer. Some wells were sampled once, whereas others were sampled multiple times. Of these wells, seven were systematically sampled up to 90 times using UPSs. Four wells were located within an urban/suburban setting in the recharge zone in Bexar County. One well was located within an urban setting in the recharge zone in Hays County. Two wells, TD-69-39-504 in Medina County and YP-69-35-602 in Uvalde County, are both in the recharge zone in agricultural/ranch settings. EAA staff stopped sampling background well YP 69-35-602 because of travel costs and replaced it with TD-69-39-504. The purpose of the rural wells was to determine the possible presence of compounds of interest and to compare results from those of urban/suburban wells. Rural water samples were also expected to have low or no detections of compounds of concern, thus potentially serving as field blanks to test the analytical process for laboratory or sampling artifacts.

Table 8 lists wells that were sampled using UPSs and the sampling period for each. Figure 8 shows the locations of these wells, and Figure 9 is a detailed map of Bexar County and passive sampling well locations.

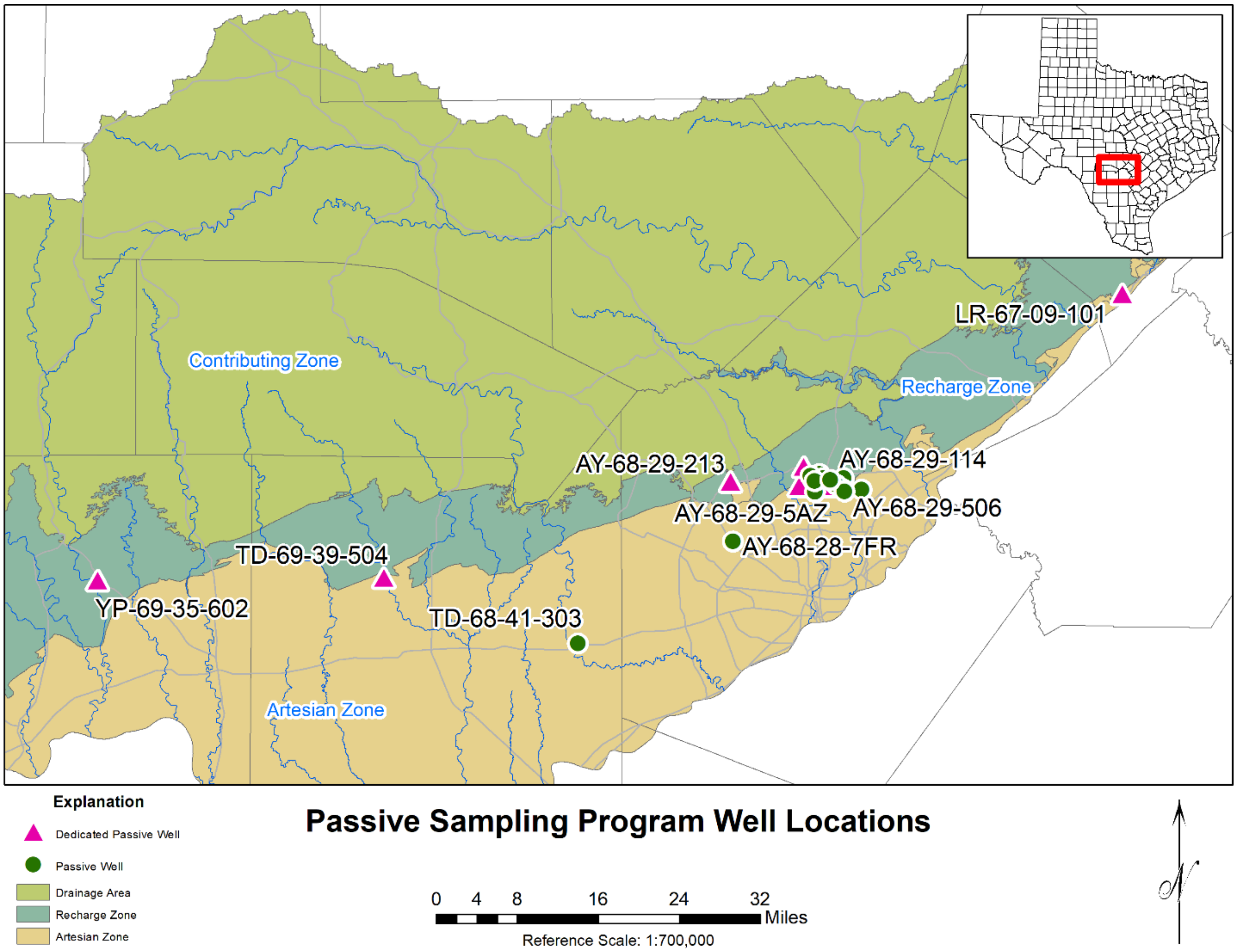


Figure 8. Passive Sampling Program Well Locations

Quality Assurance

Basic sampling instructions for EAA field staff are included in Appendix B of this document. Grab samples and UPSs were collected in accordance with the criteria set forth in the EAA's *Groundwater Quality Monitoring Plan*. An excerpt of the *Groundwater Quality Monitoring Plan* is included in Appendix C of this document.

Trip Blanks

The purpose of a trip blank is to capture any potential contamination that may have been introduced during storing, handling, and shipment of UPSs. EAA field staff designated at least one UPS as the trip blank with each shipment of samples. A shipment consisted of multiple rounds of samples because samplers were sometimes held for a few weeks after collection. All trip blanks remained sealed while in EAA's possession and were shipped in the same containers as the other UPSs.

During this study, the EAA submitted 32 UPSs as trip blanks, and 17 of them contained detectable masses of total petroleum hydrocarbons (TPH) ranging from 0.0219 to 7.655 µg (Table 9). TPH results are thought most likely to be post-sampling contamination, and the other compounds in the trip blanks were probably false positives, although some trip blanks could have been contaminated by airborne compounds. Trip blanks collected prior to 2012 contained more compounds than did subsequent ones because sample handling practices improved later in the study (Figure 9, Table 9). TPH results will therefore not be evaluated quantitatively in this report.

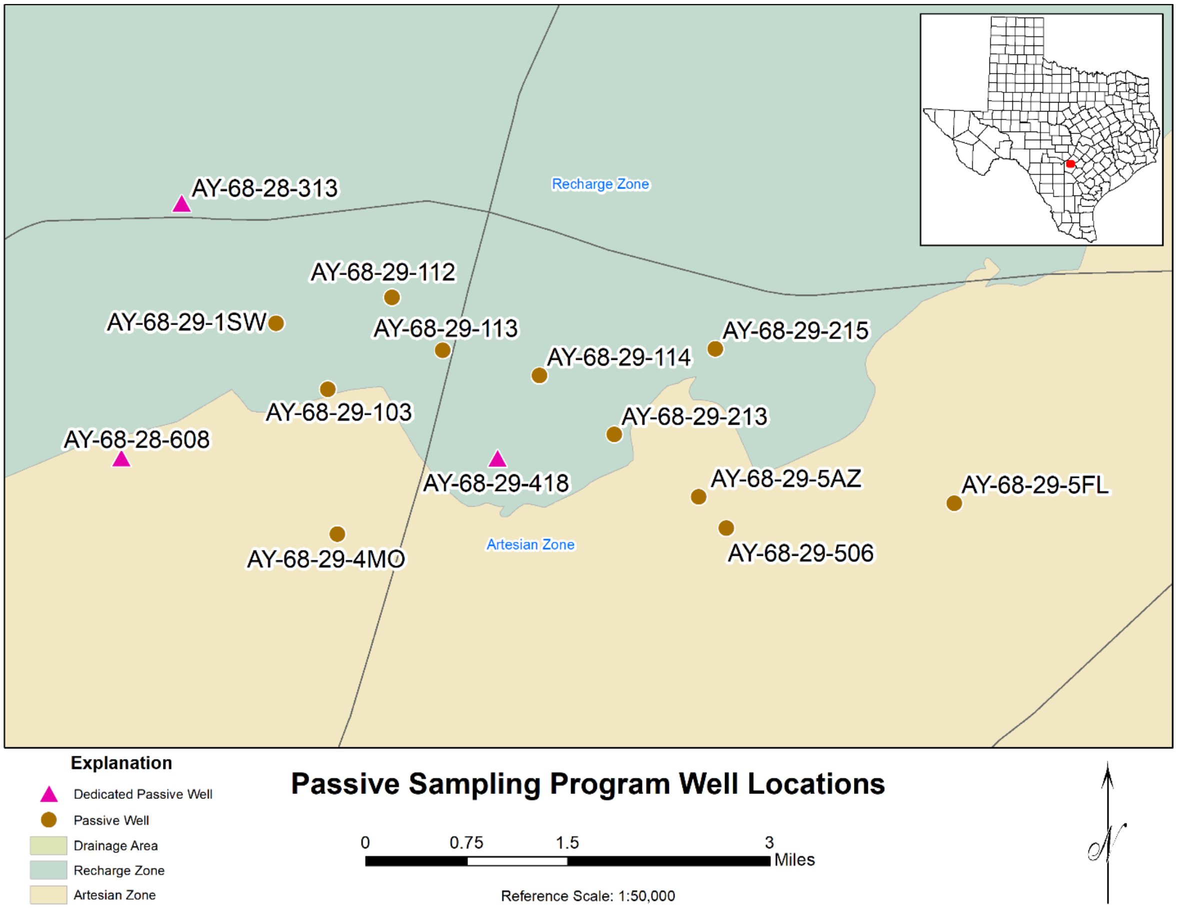


Figure 9. Detailed Map of Bexar County and Passive Sampling Well Locations

Table 9. Compounds Detected in Trip Blanks

Sample Date	Chemical Name	Mass (µg)	Sample Date	Chemical Name	Mass (µg)
4/24/2008	TPH	4.192	3/30/2009	TPH	0.0426
4/24/2008	PENTADEC	0.02	7/7/2009	TPH	0.052
4/24/2008	Tridecane	0.01	10/13/2009	TPH	0.2598
4/24/2008	C11, C13, & C15	0.03	6/4/2010	TPH	0.0597
4/24/2008	BTEX	0.03	7/14/2010	TPH	0.7151
4/24/2008	Toluene	0.03	10/11/2010	TPH	0.2346
5/29/2008	TPH	0.7715	1/25/2011	TPH	0.6902
8/12/2008	Naphthalene	0.023	3/22/2011	TPH	0.0219
8/12/2008	TPH	7.655	5/11/2011	TPH	0.1808
8/12/2008	BTEX	0.018	8/11/2011	TPH	0.0461
8/12/2008	Combined PAHs	0.023	10/11/2011	TPH	0.0929
8/12/2008	2-Methyl Naphthalene	0.023	1/22/2012	TPH	0.0275
8/12/2008	Toluene	0.018	2/12/2015	TPH	0.639
1/9/2009	TPH	0.0943			

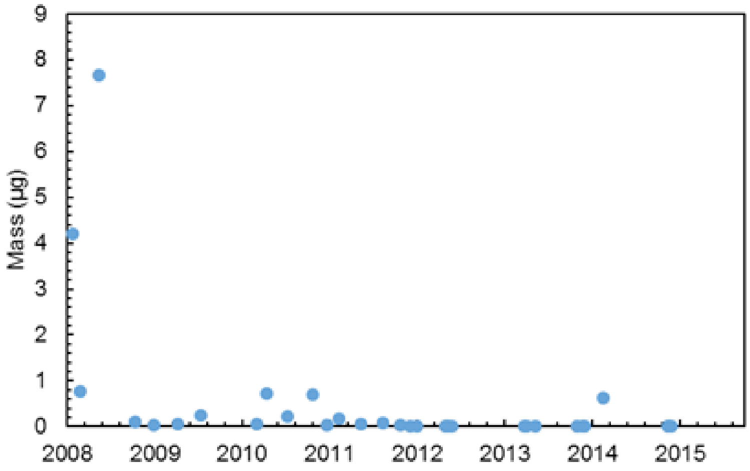


Figure 10. TPH Mass in Trip Blanks

Duplicate Samples

Quality control samples also included duplicate UPSs, which consisted of two UPSs that were handled and deployed identically and exposed to water for the same length of time at the sample site. Precision is calculated with relative percent difference (RPD), which is the absolute difference between the two masses of samples divided by the mean of the two masses multiplied by 100. An RPD of zero indicates that the two masses are equal. The RPD for all compounds ranged from 0% to 77.2%. For analytical chemistry, RPDs less than 20% are acceptable. There is no relevant standard for UPSs because of the variability introduced by sorption and desorption. However, 14 of the 27 RPDs were less than 20, which is satisfactory for the purposes of this study (Table 10).

RESULTS AND DISCUSSION

To determine the suitability of passive samplers in detecting transient contaminants, data from the passive samplers were compared with those of periodic grab water quality samples. This section presents results of the UPS and grab sample analyses. Of the 21 wells involved in the study, seven were sampled systematically up to 90 times. Tables list the results of detected compounds in the UPSs and grab samples, frequency of detections, and exposure times.

Background Wells

YP-69-35-602 (Frio Well)

YP-69-35-602 (Frio Well) is located within the recharge zone in Uvalde County. Surrounding land is used for agriculture. YP-69-35-602 was sampled 31 times from April 4, 2010, through February 20, 2013. During t his period, EAA field staff exchanged UPSs approximately once a month and obtained a grab sample quarterly.

Most UPSs collected between April 2010 and February 2013 contained detectable levels of VOCs. TPH was detected in 71% of the samples in the UPSs, which made it the most frequently detected contaminant found in YP-69-35-602. TPH was not detected in grab samples, which may be a result of UPSs concentrating TPH, which was below the detection limit for TPH in water or very low concentrations of naturally occurring crude oil in the Edwards Aquifer. Petroleum sheens are known from areas along the saline water/fresh water interface but generally not from the recharge zone. Only one grab sample contained a compound (naphthalene) that the UPSs did not detect. Benzene, BTEX, ethylbenzene, PCE, toluene, and TPH were detected by the UPSs that were not detected in grab samples. Table 11 lists the contaminants detected in YP-69-35-602.

Table 10. Relative Percent Difference for Duplicate Universal Passive Samplers

Sample Name	Sample Date	Chemical Name	Original Result (µg)	Duplicate Result (µg)	RPD
CCWS 1 Dup	5/11/2011	Benzene	0.01	0.01	0
CCWS 1 Dup	5/11/2011	BTEX	0.01	0.01	0
CCWS 1 Dup	5/11/2011	Trichloroethene	0.045	0.07	43.5
CCWS 1 Dup	5/11/2011	TPH	0.499	0.836	50.5
CCWS 1 Dup	7/5/2011	Trichloroethene	0.084	0.09	6.9
CCWS 1 Dup	7/5/2011	TPH	0.415	0.384	7.8
CCWS 4 Dup	5/11/2011	Trichloroethene	0.068	0.061	10.9
CCWS 4 Dup	5/11/2011	TPH	0.425	0.599	33.8
CCWS 4 Dup	7/5/2011	Trichloroethene	0.04	0.079	65.5
CCWS 4 Dup	7/5/2011	TPH	0.326	0.408	22.4
Rio Seco Dup	4/4/2011	Chloroform	0.042	0.044	4.7
Rio Seco Dup	4/4/2011	Trichloroethene	0.353	0.312	12.3
Rio Seco Dup	4/4/2011	TPH	0.268	0.299	11.1
Rio Seco FD	2/20/2015	Trichloroethene	0.28	0.37	27.7
Rio Seco FD	2/22/2015	BTEX	0.02	<0.02	NC
Rio Seco FD	2/22/2015	Trichloroethene	0.33	0.33	0
Rio Seco FD	2/22/2015	Toluene	0.02	<0.02	NC
Rio Seco FD	2/22/2015	TPH	0.83	<0.5	NC
Rio Seco FD	2/24/2015	Trichloroethene	0.48	0.46	4.3
Rio Seco FD	2/24/2015	TPH	0.69	0.66	4.4
Rio Seco FD	2/26/2015	Trichloroethene	0.3	0.38	23.5
Rio Seco FD	2/26/2015	TPH	0.82	1.85	77.2
Rio Seco FD	2/28/2015	Trichloroethene	0.53	0.57	7.3
Rio Seco FD	2/28/2015	TPH	0.77	0.88	13.3
Rio Seco FD	3/2/2015	Chloroform	0.04	0.03	28.6
Rio Seco FD	3/2/2015	Trichloroethene	2.26	2.05	9.7
Rio Seco FD	3/2/2015	TPH	0.5	0.53	5.8

NC = not calculated.

FD = field duplicate.

Although YP-69-35-602 was selected as a well located in a rural setting and most likely would reflect background conditions for the aquifer, samples contained detectable concentrations of several compounds that were not detected in grab samples. Some of the TPH results may be related to field or laboratory artifacts, although detections of BTEX, benzene, ethylbenzene, naphthalene, and toluene indicated low-concentration, fuel-related compounds in the groundwater.

TD-69-39-504 (Tarpley Well)

Well TD-69-39-504 (Tarpley Well), in the artesian zone in Medina County, was selected to represent a rural

Table 11. Contaminants Detected in YP-69-35-602 (Frio Well)

Sample Location	Sample Date	Chemical Name	UPS Results Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
YP-69-35-602	04/14/2010	TPH Total	0.706	NA	364
YP-69-35-602	04/29/2010	TPH Total	0.625	NA	356
YP-69-35-602	05/26/2010	TPH Total	1.143	NA	386
YP-69-35-602	06/07/2010	TPH Total	0.133	NA	310
YP-69-35-602	06/24/2010	TPH Total	0.322	NA	407
YP-69-35-602	06/24/2010	BTEX	0.03	NA	407
YP-69-35-602	06/24/2010	Benzene	0.03	NA	407
YP-69-35-602	07/14/2010	C11, C13, & C15	0.103	NA	383
YP-69-35-602	07/14/2010	TPH Total	7.439	NA	383
YP-69-35-602	07/14/2010	BTEX	0.398	NA	383
YP-69-35-602	07/14/2010	Toluene	0.123	NA	383
YP-69-35-602	07/14/2010	Ethylbenzene	0.039	NA	383
YP-69-35-602	07/14/2010	o-Xylene	0.105	NA	383
YP-69-35-602	07/14/2010	m,p-Xylenes	0.131	NA	383
YP-69-35-602	09/03/2010	TPH Total	2.014	NA	1,223
YP-69-35-602	09/09/2010	TPH Total	3.584	NA	143
YP-69-35-602	10/14/2010	TPH Total	2.366	NA	840
YP-69-35-602	01/05/2011	TPH Total	1.513	NA	386
YP-69-35-602	01/05/2011	BTEX	0.056	NA	386
YP-69-35-602	01/05/2011	Toluene	0.056	NA	386
YP-69-35-602	02/07/2011	TPH Total	0.952	NA	794
YP-69-35-602	03/14/2011	Naphthalene	ND	0.0358	838
YP-69-35-602	03/14/2011	TPH Total	2.405	NA	838
YP-69-35-602	04/12/2011	TPH Total	2.953	NA	699
YP-69-35-602	05/25/2011	Toluene	0.011	NA	1,027
YP-69-35-602	05/25/2011	TPH Total	0.752	NA	1,027
YP-69-35-602	05/25/2011	BTEX	0.011	NA	1,027
YP-69-35-602	06/28/2011	TPH Total	0.636	NA	817
YP-69-35-602	09/09/2011	TPH Total	0.038	NA	576
YP-69-35-602	10/12/2011	TPH Total	0.417	NA	791
YP-69-35-602	11/11/2011	TPH Total	0.617	NA	724
YP-69-35-602	12/12/2011	TPH Total	1.184	NA	762
YP-69-35-602	01/05/2012	TPH Total	1.361	NA	572
YP-69-35-602	06/11/2012	TPH Total	1.622	NA	263
YP-69-35-602	08/29/2012	TPH Total	0.516	NA	504
YP-69-35-602	02/20/2013	Tetrachloroethene	0.022	NA	529

NA = not analyzed.

ND = not detected.

Table 12. Contaminants Detected in TD-69-39-504 (Tarpley Well).

Sample Location	Sample Date	Chemical Name	UPS Mass (mg)	Laboratory Results (µg/L)	Exposure Hours
TD-69-39-504	03/27/2013	1,4-Dichlorobenzene	0.041	NA	835
TD-69-39-504	08/28/2013	TPH Total	1.811	NA	840
TD-69-39-504	09/18/2013	TPH Total	0.58	NA	503
TD-69-39-504	10/21/2013	TPH Total	0.641	NA	790
TD-69-39-504	12/12/2013	Toluene	0.06	NA	576
TD-69-39-504	12/12/2013	Ethylbenzene	0.03	NA	576
TD-69-39-504	12/12/2013	m,p-Xylenes	0.06	NA	576
TD-69-39-504	02/24/2014	Toluene	0.02	NA	982
TD-69-39-504	03/18/2014	TPH Total	0.885	NA	523
TD-69-39-504	06/18/2014	TPH Total	0.544	NA	698
TD-69-39-504	07/17/2014	m,p-Xylenes	0.03	NA	696
TD-69-39-504	07/17/2014	BTEX	0.03	NA	696
TD-69-39-504	07/17/2014	TPH Total	0.922	NA	696
TD-69-39-504	08/13/2014	1,2,4-Trimethylbenzene	0.17	NA	646
TD-69-39-504	08/13/2014	1,3,5-Trimethylbenzene	0.06	NA	646
TD-69-39-504	08/13/2014	1,4-Dichlorobenzene	0.02	NA	646
TD-69-39-504	08/13/2014	BTEX	2.35	NA	646
TD-69-39-504	08/13/2014	Ethylbenzene	1.02	NA	646
TD-69-39-504	08/13/2014	m,p-Xylenes	0.76	NA	646
TD-69-39-504	08/13/2014	o-Xylene	0.31	NA	646
TD-69-39-504	08/13/2014	Toluene	0.27	NA	646
TD-69-39-504	08/13/2014	TPH Total	22.46	NA	646
TD-69-39-504	12/11/2014	TPH Total	0.67	NA	749

NA = not analyzed.

setting and background conditions. Local land use around the well was agricultural. TD-69-39-504 was sampled 23 times from March 27, 2013, through January 12, 2015. During this period, EAA field staff exchanged the UPSs approximately once a month and obtained a grab sample quarterly.

Most samples from the UPSs contained detectable VOCs. TPH was detected in 35% of the samples and was the contaminant most frequently found in TD 69 39 504; 1, 4 Dichlorobenzene, ethylbenzene, m,p-xylenes, and toluene were also detected by the UPSs. Table 12 lists the contaminants detected in TD-69-39-504.

Universal passive samplers collected several compounds in TD-69-39-504 samples that were not detected in grab samples. Like YP-69-35-602, which is also in a rural setting, trace levels of fuel-related compounds were present in groundwater. Low concentrations of TPH may also indicate trace amounts of naturally occurring petroleum, or it may be residue from lubricants from nearby water well pumps.

Bexar County Wells

AY-68-27-303 (Chase Hill)

AY-68-27-303 is located within the recharge zone in northern San Antonio. The land surrounding the well is characterized by urban development. AY-68-27-303 was sampled 94 times at two different flow zones that were identified using a variety of geophysical and hydrophysical techniques and video logging. One zone, with UPSs labeled AY-68-27-303-1, was set at approximately 235 ft below ground surface. The second zone, with UPSs labeled AY-68-27-303-2, was set at approximately 253 ft below ground surface. Passive sampling for AY-68-27-303 occurred from July 15, 2010, through January 12, 2015. During this period, EAA field staff exchanged the UPSs approximately once a month and obtained a grab sample quarterly.

Most of the samples from the UPSs contained detectable concentrations of VOCs. Chloroform was detected in 68% of the samples; TPH was detected in 59% of the samples; PCE was detected in 53% of the samples; BTEX was detected in 16% of the samples; m,p-xylenes were detected in 11% of the samples; toluene was detected in 10% of the samples; and benzene was detected in 5% of the samples. The UPSs accumulate and effectively concentrate low levels of contaminants, thereby increasing their detectability relative to grab samples. In one sample, a UPS did not detect chloroform, although it was detected in the grab sample. Benzene, BTEX, PCE, and TPH were detected by the UPSs but were not detected by the grab samples. Chloroform was the only contaminant detected by both UPSs and grab samples. Table 13 lists the contaminants detected at the two levels in AY-68-27-303.

Table 13. Contaminants Detected in AY-68-27-303 (Chase Hill)

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-1	07/15/2010	1,3-Dichlorobenzene	0.019	NA	358
AY-68-27-303-1	07/15/2010	1,2-Dichlorobenzene	0.016	NA	358
AY-68-27-303-1	07/15/2010	1,4-Dichlorobenzene	0.02	NA	358
AY-68-27-303-1	07/15/2010	1,3,5-Trimethylbenzene	0.03	NA	358
AY-68-27-303-1	07/15/2010	1,2,4-Trimethylbenzene	0.027	NA	358
AY-68-27-303-1	07/15/2010	Trimethylbenzenes	0.057	NA	358
AY-68-27-303-1	07/15/2010	o-Xylene	0.025	NA	358
AY-68-27-303-1	07/15/2010	m,p-Xylenes	0.017	NA	358
AY-68-27-303-1	07/15/2010	Benzene	0.046	NA	358
AY-68-27-303-1	07/15/2010	BTEX	0.088	NA	358
AY-68-27-303-1	07/15/2010	TPH Total	1.419	NA	358
AY-68-27-303-1	09/09/2010	Chloroform	0.027	NA	1,343
AY-68-27-303-1	09/09/2010	Tetrachloroethene	0.019	NA	1,343
AY-68-27-303-1	09/09/2010	TPH Total	2.695	NA	1,343
AY-68-27-303-1	10/14/2010	TPH Total	0.429	NA	840
AY-68-27-303-1	01/05/2011	TPH Total	0.196	NA	1,994
AY-68-27-303-1	01/31/2011	TPH Total	0.963	NA	624
AY-68-27-303-1	01/31/2011	Chloroform	0.042	NA	624

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-1	03/16/2011	TPH Total	1.462	NA	1,056
AY-68-27-303-1	03/16/2011	Chloroform	0.068	0.339	1,056
AY-68-27-303-1	04/11/2011	TPH Total	1.585	NA	507
AY-68-27-303-1	04/11/2011	Chloroform	0.057	NA	507
AY-68-27-303-1	06/07/2011	C11, C13, & C15	0.067	NA	1,364
AY-68-27-303-1	06/07/2011	Tetrachloroethene	0.029	NA	1,364
AY-68-27-303-1	06/07/2011	BTEX	0.052	NA	1,364
AY-68-27-303-1	06/07/2011	TPH Total	1.876	NA	1,364
AY-68-27-303-1	06/07/2011	Toluene	0.052	NA	1,364
AY-68-27-303-1	07/06/2011	TPH Total	0.396	NA	695
AY-68-27-303-1	07/06/2011	BTEX	0.011	NA	695
AY-68-27-303-1	07/06/2011	Benzene	0.011	NA	695
AY-68-27-303-1	07/06/2011	Chloroform	0.051	0.403	695
AY-68-27-303-1	07/06/2011	1,1,2-Trichloroethane	0.075	NA	695
AY-68-27-303-1	07/06/2011	Tetrachloroethene	0.036	NA	695
AY-68-27-303-1	07/06/2011	Trichloroethene	0.028	NA	695
AY-68-27-303-1	07/06/2011	1,2-Dichloroethane	0.019	NA	695
AY-68-27-303-1	08/11/2011	Tetrachloroethene	0.037	NA	867
AY-68-27-303-1	08/11/2011	Chloroform	0.106	NA	867
AY-68-27-303-1	08/11/2011	TPH Total	0.044	NA	867
AY-68-27-303-1	09/08/2011	TPH Total	2.595	NA	671
AY-68-27-303-1	09/08/2011	Chloroform	0.07	NA	671
AY-68-27-303-1	09/08/2011	Tetrachloroethene	0.02	NA	671
AY-68-27-303-1	10/10/2011	Tetrachloroethene	0.037	NA	771
AY-68-27-303-1	10/10/2011	TPH Total	0.883	NA	771
AY-68-27-303-1	10/10/2011	Chloroform	0.082	NA	771
AY-68-27-303-1	11/10/2011	TPH Total	0.101	NA	744
AY-68-27-303-1	11/10/2011	Chloroform	0.091	NA	744
AY-68-27-303-1	11/10/2011	Tetrachloroethene	0.038	NA	744
AY-68-27-303-1	12/12/2011	TPH Total	0.172	NA	762
AY-68-27-303-1	12/12/2011	Tetrachloroethene	0.02	NA	762
AY-68-27-303-1	12/12/2011	Chloroform	0.108	NA	762
AY-68-27-303-1	12/20/2011	BTEX	0.133	NA	192
AY-68-27-303-1	12/20/2011	Toluene	0.063	NA	192
AY-68-27-303-1	12/20/2011	m,p-Xylenes	0.043	NA	192
AY-68-27-303-1	12/20/2011	o-Xylene	0.017	NA	192
AY-68-27-303-1	12/20/2011	C11, C13, & C15	0.028	NA	192
AY-68-27-303-1	12/20/2011	Benzene	0.01	NA	192
AY-68-27-303-1	12/20/2011	TPH Total	1.327	NA	192
AY-68-27-303-1	02/21/2012	Tetrachloroethene	0.03	NA	818
AY-68-27-303-1	02/21/2012	Chloroform	0.115	0.436	818
AY-68-27-303-1	03/07/2012	Chloroform	0.132	NA	358

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-1	04/10/2012	Chloroform	0.13	NA	811
AY-68-27-303-1	04/10/2012	Tetrachloroethene	0.028	NA	811
AY-68-27-303-1	05/23/2012	Chloroform	0.076	NA	1,035
AY-68-27-303-1	05/23/2012	Tetrachloroethene	0.027	NA	1,035
AY-68-27-303-1	06/13/2012	Tetrachloroethene	0.029	NA	501
AY-68-27-303-1	06/13/2012	Chloroform	0.093	NA	501
AY-68-27-303-1	07/31/2012	TPH Total	1.004	NA	1,153
AY-68-27-303-1	07/31/2012	Chloroform	0.073	NA	1,153
AY-68-27-303-1	08/21/2012	Tetrachloroethene	0.023	NA	502
AY-68-27-303-1	08/21/2012	Chloroform	0.137	NA	502
AY-68-27-303-1	08/21/2012	TPH Total	0.816	NA	502
AY-68-27-303-1	12/03/2012	Tetrachloroethene	0.027	NA	788
AY-68-27-303-1	12/03/2012	TPH Total	1.788	NA	788
AY-68-27-303-1	12/03/2012	Chloroform	0.147	NA	788
AY-68-27-303-1	01/31/2013	Tetrachloroethene	0.069	NA	1,417
AY-68-27-303-1	01/31/2013	TPH Total	0.817	NA	1,417
AY-68-27-303-1	01/31/2013	Chloroform	0.154	NA	1,417
AY-68-27-303-1	02/27/2013	Chloroform	0.15	0.519	643
AY-68-27-303-1	02/27/2013	Tetrachloroethene	0.059	NA	643
AY-68-27-303-1	02/27/2013	TPH Total	1.379	NA	643
AY-68-27-303-1	04/24/2013	Tetrachloroethene	0.03	NA	678
AY-68-27-303-1	04/24/2013	Chloroform	0.14	NA	678
AY-68-27-303-1	05/21/2013	Tetrachloroethene	0.025	NA	642
AY-68-27-303-1	05/21/2013	Chloroform	0.083	0.544	642
AY-68-27-303-1	05/21/2013	TPH Total	1.142	NA	642
AY-68-27-303-1	06/13/2013	Tetrachloroethene	0.044	NA	555
AY-68-27-303-1	06/13/2013	Chloroform	0.033	NA	555
AY-68-27-303-1	06/13/2013	TPH Total	0.801	NA	555
AY-68-27-303-1	07/24/2013	Chloroform	0.158	NA	981
AY-68-27-303-1	07/24/2013	Tetrachloroethene	0.043	NA	981
AY-68-27-303-1	08/29/2013	Tetrachloroethene	0.078	NA	864
AY-68-27-303-1	08/29/2013	Chloroform	0.139	NA	864
AY-68-27-303-1	10/01/2013	Chloroform	0.128	NA	795
AY-68-27-303-1	10/01/2013	Tetrachloroethene	0.065	NA	795
AY-68-27-303-1	10/25/2013	Chloroform	0.138	NA	573
AY-68-27-303-1	10/25/2013	Tetrachloroethene	0.079	NA	573
AY-68-27-303-1	11/18/2013	Tetrachloroethene	0.04	NA	577
AY-68-27-303-1	11/18/2013	Chloroform	0.14	NA	577
AY-68-27-303-1	12/19/2013	TPH Total	0.52	NA	743
AY-68-27-303-1	12/19/2013	m,p-Xylenes	0.03	NA	743
AY-68-27-303-1	12/19/2013	Tetrachloroethene	0.10	NA	743
AY-68-27-303-1	12/19/2013	Chloroform	0.03	NA	743

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-1	12/19/2013	Toluene	0.06	NA	743
AY-68-27-303-1	01/14/2014	Tetrachloroethene	0.03	NA	628
AY-68-27-303-1	01/14/2014	Chloroform	0.15	NA	628
AY-68-27-303-1	02/24/2014	Tetrachloroethene	0.04	NA	980
AY-68-27-303-1	02/24/2014	Chloroform	0.14	NA	980
AY-68-27-303-1	03/18/2014	m,p-Xylenes	0.05	NA	528
AY-68-27-303-1	03/18/2014	TPH Total	4.245	NA	528
AY-68-27-303-1	03/18/2014	Toluene	0.1	NA	528
AY-68-27-303-1	03/18/2014	BTEX	0.17	NA	528
AY-68-27-303-1	03/18/2014	Ethylbenzene	0.02	NA	528
AY-68-27-303-1	03/18/2014	C11, C13, & C15	0.06	NA	528
AY-68-27-303-1	03/18/2014	Tetrachloroethene	0.07	NA	528
AY-68-27-303-1	04/23/2014	Tetrachloroethene	0.11	NA	865
AY-68-27-303-1	04/23/2014	Carbon Tetrachloride	0.18	NA	865
AY-68-27-303-1	04/23/2014	Chloroform	0.18	0.56	865
AY-68-27-303-1	04/23/2014	TPH Total	1.471	NA	865
AY-68-27-303-1	05/21/2014	BTEX	0.11	NA	671
AY-68-27-303-1	05/21/2014	Toluene	0.08	NA	671
AY-68-27-303-1	05/21/2014	TPH Total	2.60	NA	671
AY-68-27-303-1	05/21/2014	Tetrachloroethene	0.05	NA	671
AY-68-27-303-1	05/21/2014	m,p-Xylenes	0.03	NA	671
AY-68-27-303-1	06/18/2014	TPH Total	2.008	NA	677
AY-68-27-303-1	06/18/2014	BTEX	0.11	NA	677
AY-68-27-303-1	06/18/2014	Toluene	0.02	NA	677
AY-68-27-303-1	06/18/2014	Ethylbenzene	0.02	NA	677
AY-68-27-303-1	06/18/2014	m,p-Xylenes	0.07	NA	677
AY-68-27-303-1	07/17/2014	TPH Total	2.519	NA	693
AY-68-27-303-1	08/13/2014	Chloroform	0.08	NA	648
AY-68-27-303-1	08/13/2014	Tetrachloroethene	0.12	NA	648
AY-68-27-303-1	12/11/2014	TPH Total	0.63	NA	747
AY-68-27-303-1	01/21/2015	TPH Total	0.76	NA	983
AY-68-27-303-1	01/21/2015	BTEX	0.02	NA	983
AY-68-27-303-1	01/21/2015	m,p-Xylenes	0.02	NA	983
AY-68-27-303-2	07/15/2010	TPH Total	0.11	NA	358
AY-68-27-303-2	07/15/2010	Chloroform	0.018	NA	358
AY-68-27-303-2	07/15/2010	BTEX	0.06	NA	358
AY-68-27-303-2	07/15/2010	Benzene	0.06	NA	358
AY-68-27-303-2	09/09/2010	Chloroform	0.027	NA	1,343
AY-68-27-303-2	09/09/2010	TPH Total	2.653	NA	1,343
AY-68-27-303-2	09/09/2010	Tetrachloroethene	0.084	NA	1,343
AY-68-27-303-2	10/14/2010	TPH Total	0.711	NA	840
AY-68-27-303-2	10/14/2010	NAPH&2-MN	0.024	NA	840

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-2	10/14/2010	Tetrachloroethene	0.024	NA	840
AY-68-27-303-2	10/14/2010	Fluorene	0.022	NA	840
AY-68-27-303-2	10/14/2010	Phenanthrene	0.021	NA	840
AY-68-27-303-2	10/14/2010	Combined PAHs	0.067	NA	840
AY-68-27-303-2	10/14/2010	2-Methyl Naphthalene	0.024	NA	840
AY-68-27-303-2	01/05/2011	TPH Total	0.401	NA	1,994
AY-68-27-303-2	01/31/2011	TPH Total	1.18	NA	624
AY-68-27-303-2	01/31/2011	Chloroform	0.018	NA	624
AY-68-27-303-2	03/16/2011	TPH Total	0.778	NA	1,056
AY-68-27-303-2	03/16/2011	Tetrachloroethene	0.026	NA	1,056
AY-68-27-303-2	03/16/2011	Chloroform	0.055	0.293	1,056
AY-68-27-303-2	04/11/2011	TPH Total	1.778	NA	507
AY-68-27-303-2	04/11/2011	BTEX	0.01	NA	507
AY-68-27-303-2	04/11/2011	Benzene	0.01	NA	507
AY-68-27-303-2	04/11/2011	Chloroform	0.052	NA	507
AY-68-27-303-2	04/11/2011	Tetrachloroethene	0.022	NA	507
AY-68-27-303-2	04/11/2011	C11, C13, & C15	0.015	NA	507
AY-68-27-303-2	06/07/2011	TPH Total	0.767	NA	1,364
AY-68-27-303-2	06/07/2011	Chloroform	0.044	NA	1,364
AY-68-27-303-2	06/07/2011	Tetrachloroethene	0.029	NA	1,364
AY-68-27-303-2	07/06/2011	Tetrachloroethene	0.105	NA	695
AY-68-27-303-2	07/06/2011	Chloroform	<0.02	0.399	695
AY-68-27-303-2	07/06/2011	Combined PAHs	0.013	NA	695
AY-68-27-303-2	07/06/2011	TPH Total	0.801	NA	695
AY-68-27-303-2	07/06/2011	Trimethylbenzenes	0.016	NA	695
AY-68-27-303-2	07/06/2011	Fluorene	0.013	NA	695
AY-68-27-303-2	07/06/2011	1,2,4-Trimethylbenzene	0.016	NA	695
AY-68-27-303-2	08/11/2011	TPH Total	0.028	NA	867
AY-68-27-303-2	08/11/2011	Chloroform	0.041	NA	867
AY-68-27-303-2	08/11/2011	Tetrachloroethene	0.025	NA	867
AY-68-27-303-2	08/11/2011	BTEX	0.029	NA	867
AY-68-27-303-2	08/11/2011	Toluene	0.029	NA	867
AY-68-27-303-2	09/08/2011	Combined PAHs	0.012	NA	671
AY-68-27-303-2	09/08/2011	Chloroform	0.054	NA	671
AY-68-27-303-2	09/08/2011	TPH Total	2.404	NA	671
AY-68-27-303-2	09/08/2011	Fluorene	0.012	NA	671
AY-68-27-303-2	10/10/2011	TPH Total	0.433	NA	771
AY-68-27-303-2	10/10/2011	C11, C13, & C15	0.05	NA	771
AY-68-27-303-2	10/10/2011	Chloroform	0.032	NA	771
AY-68-27-303-2	11/10/2011	TPH Total	0.085	NA	744
AY-68-27-303-2	11/10/2011	Chloroform	0.045	NA	744
AY-68-27-303-2	11/10/2011	Tetrachloroethene	0.041	NA	744

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-2	12/12/2011	TPH Total	1.037	NA	762
AY-68-27-303-2	12/12/2011	Chloroform	0.07	NA	762
AY-68-27-303-2	12/20/2011	Chloroform	0.054	0.51	192
AY-68-27-303-2	12/20/2011	TPH Total	0.444	NA	192
AY-68-27-303-2	02/21/2012	Chloroform	0.061	0.385	818
AY-68-27-303-2	03/07/2012	Chloroform	0.05	NA	358
AY-68-27-303-2	04/10/2012	Chloroform	0.081	NA	811
AY-68-27-303-2	04/10/2012	TPH Total	0.563	NA	811
AY-68-27-303-2	05/23/2012	Chloroform	0.079	NA	1,035
AY-68-27-303-2	05/23/2012	Tetrachloroethene	0.02	NA	1,035
AY-68-27-303-2	06/13/2012	Tetrachloroethene	0.029	NA	501
AY-68-27-303-2	07/31/2012	TPH Total	0.741	NA	1,153
AY-68-27-303-2	08/21/2012	BTEX	0.037	NA	502
AY-68-27-303-2	08/21/2012	TPH Total	1.081	NA	502
AY-68-27-303-2	08/21/2012	m,p-Xylenes	0.037	NA	502
AY-68-27-303-2	08/21/2012	Chloroform	0.038	NA	502
AY-68-27-303-2	12/03/2012	Chloroform	0.069	NA	788
AY-68-27-303-2	01/31/2013	TPH Total	2.072	NA	1,417
AY-68-27-303-2	01/31/2013	Tetrachloroethene	0.055	NA	1,417
AY-68-27-303-2	02/27/2013	Tetrachloroethene	0.032	NA	643
AY-68-27-303-2	02/27/2013	Chloroform	0.058	0.699	643
AY-68-27-303-2	04/24/2013	Chloroform	0.07	NA	678
AY-68-27-303-2	05/21/2013	Chloroform	0.072	0.628	642
AY-68-27-303-2	06/13/2013	Chloroform	0.086	NA	555
AY-68-27-303-2	07/24/2013	Chloroform	0.058	NA	981
AY-68-27-303-2	08/29/2013	Tetrachloroethene	0.047	NA	864
AY-68-27-303-2	10/01/2013	TPH Total	0.63	NA	795
AY-68-27-303-2	10/01/2013	Chloroform	0.103	NA	795
AY-68-27-303-2	10/01/2013	Tetrachloroethene	0.049	NA	795
AY-68-27-303-2	10/25/2013	Tetrachloroethene	0.055	NA	573
AY-68-27-303-2	10/25/2013	Chloroform	0.101	NA	573
AY-68-27-303-2	11/18/2013	Chloroform	0.04	NA	577
AY-68-27-303-2	12/19/2013	Chloroform	0.06	NA	743
AY-68-27-303-2	01/14/2014	Chloroform	0.03	NA	628
AY-68-27-303-2	01/14/2014	Tetrachloroethene	0.03	NA	628
AY-68-27-303-2	02/24/2014	Chloroform	0.02	NA	980
AY-68-27-303-2	03/18/2014	Chloroform	0.08	NA	528
AY-68-27-303-2	03/18/2014	Tetrachloroethene	0.09	NA	528
AY-68-27-303-2	03/18/2014	TPH Total	0.648	NA	528
AY-68-27-303-2	03/18/2014	Carbon Tetrachloride	0.08	NA	528
AY-68-27-303-2	04/23/2014	TPH Total	0.707	NA	865
AY-68-27-303-2	04/23/2014	Carbon Tetrachloride	0.11	NA	865

Table 13. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-27-303-2	04/23/2014	Tetrachloroethene	0.09	NA	865
AY-68-27-303-2	04/23/2014	Chloroform	0.11	NA	865
AY-68-27-303-2	05/21/2014	TPH Total	0.616	NA	671
AY-68-27-303-2	07/17/2014	Toluene	0.06	NA	693
AY-68-27-303-2	07/17/2014	m,p-Xylenes	0.03	NA	693
AY-68-27-303-2	07/17/2014	BTEX	0.09	NA	693
AY-68-27-303-2	07/17/2014	TPH Total	4.028	NA	693
AY-68-27-303-2	07/17/2014	C11, C13, & C15	0.06	NA	693
AY-68-27-303-2	08/13/2014	Tetrachloroethene	0.08	NA	648
AY-68-27-303-2	11/10/2014	TPH Total	1.40	NA	670
AY-68-27-303-2	11/10/2014	Toluene	0.06	NA	670
AY-68-27-303-2	11/10/2014	m,p-Xylenes	0.03	NA	670
AY-68-27-303-2	11/10/2014	Ethylbenzene	0.03	NA	670
AY-68-27-303-2	11/10/2014	BTEX	0.12	NA	670

NA = not analyzed.

ND = not detected.

µg = micrograms.

µg/L = micrograms per liter.

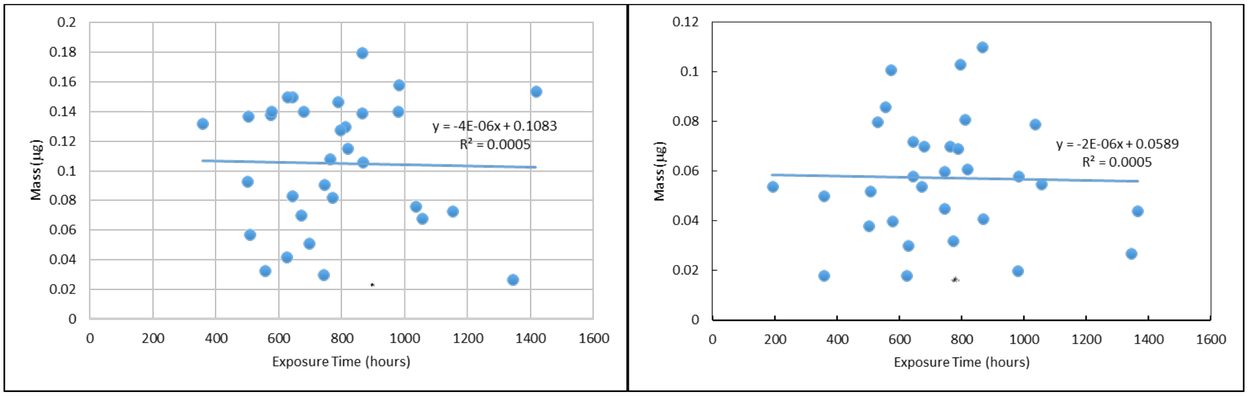


Figure 11. Universal Passive Sampler Data for Chloroform and Exposure Time for (left) AY-68-27-303-1 and (right) AY-68-27-303-2

Figure 11 illustrates data reported for chloroform from the UPSs and exposure time for AY-68-27-303-1 and AY-68-27-303-2. The data showed no direct correlation between mass and exposure time. That is, the mass of chloroform sorbed by the UPSs was independent of the exposure time. For AY-68-27-303-2, the data showed no correlation between mass and exposure time, although the mass was approximately half of the AY-68-27-303-1 average.

Figure 12 shows PCE results for AY-68-27-303-1 and AY-68-27-303-2, respectively, and no relationship exists between mass and exposure time.

Figure 13 compares results from UPSs in mass and concentrations in grab samples in AY-68-27-303-1 for chloroform. The data show no correlation between UPSs and grab samples because mass tended to fluctuate between 0.02 and about 0.18 µg throughout

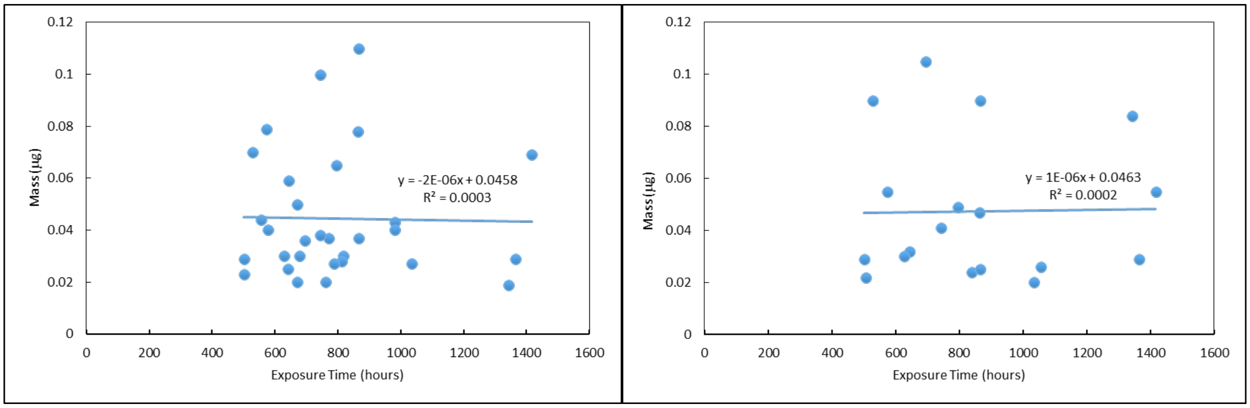


Figure 12. Universal Passive Sampler Data for PCE and Exposure Time for (left) AY-68-27-303-1 and (right) AY-68-27-303-2

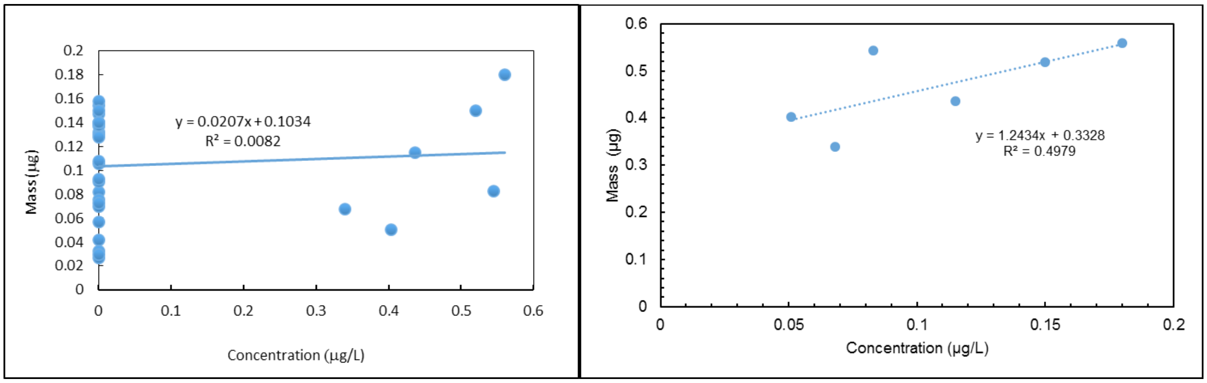


Figure 13. Universal Passive Sampler Data for Chloroform Mass and Concentration for (left) AY-68-27-303-1 and (right) Regression

the duration, whereas concentration fluctuated between non-detectable to about 0.6 µg/L. Results for AY-68-27-303-2 (not shown) were similar. However, the right side of Figure 13 shows a slight positive correlation between concentrations detected in grab samples and the accompanying mass in UPSs. Unfortunately, too few corresponding mass and concentration values define a predictive regression.

Figure 14 compares chloroform mass and concentrations for AY-68-27-303-1 and AY-68-27-303-2. Exposure periods correspond to the horizontal segments of the line graphs, and periods at the zero level represent no detections in the UPSs. Each marker is a grab sample. Both mass and concentration of chloroform generally increased during the sampling period.

AY-68-28-313 (BexarMet)

AY-68-28-313 is located in the recharge zone in northern San Antonio. Land use surrounding the well is urban development. AY-68-28-313 was sampled 45 times from January 3, 2011, through December 12, 2014. During this period, EAA field staff exchanged UPSs approximately once a month and obtained a grab sample quarterly.

The principal compounds detected in UPSs at AY-68-28-313 were chloroform, PCE, TPH, BTEX, m,p-xylene, and carbon tetrachloride. Only chloroform was detected in grab samples.

The amount of mass of PCE and chloroform sorbed by UPSs during the long exposures varied considerably (Figure 15). There was a slight proportional relationship for PCE, but not chloroform.

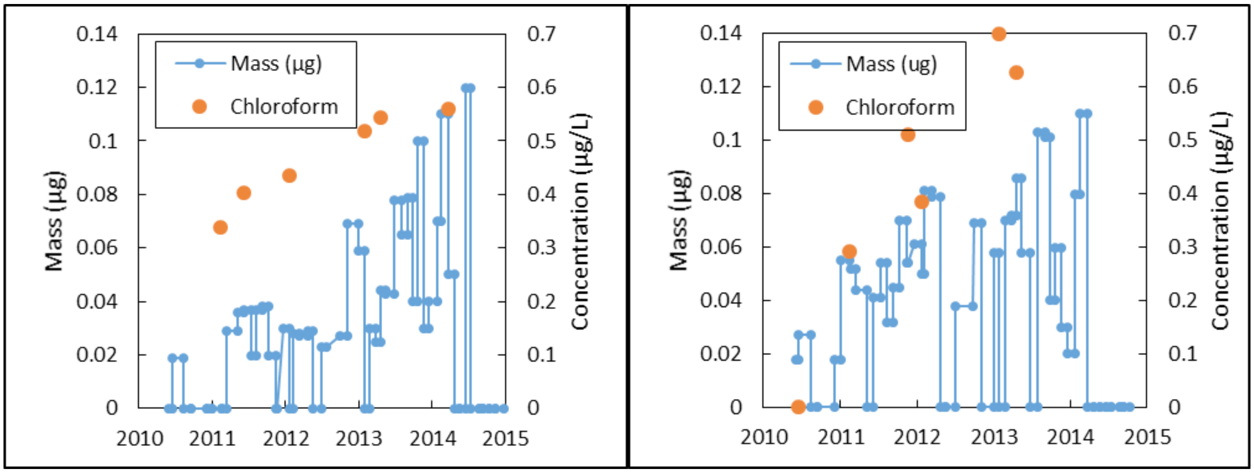


Figure 14. Time Series Data for Chloroform from (left) AY-68-27-303-1 and (right) AY-68-27-303-2

Table 14. Contaminants Detected in AY-68-28-313 (Bexar Met)

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-313	01/03/2011	Tetrachloroethene	1.161	NA	2,043
AY-68-28-313	01/03/2011	Chloroform	0.299	NA	2,043
AY-68-28-313	01/03/2011	TPH Total	1.742	NA	2,043
AY-68-28-313	01/03/2011	BTEX	0.163	NA	2,043
AY-68-28-313	01/03/2011	Ethylbenzene	0.034	NA	2,043
AY-68-28-313	01/03/2011	m,p-Xylenes	0.083	NA	2,043
AY-68-28-313	01/03/2011	o-Xylene	0.046	NA	2,043
AY-68-28-313	02/17/2011	TPH Total	0.484	NA	820
AY-68-28-313	02/17/2011	Chloroform	0.052	NA	820
AY-68-28-313	03/16/2011	TPH Total	0.004	NA	643
AY-68-28-313	03/16/2011	Tetrachloroethene	0.292	NA	643
AY-68-28-313	03/16/2011	Chloroform	0.313	1.86	643
AY-68-28-313	04/11/2011	TPH Total	3.259	NA	579
AY-68-28-313	04/11/2011	1,1,2-Trichloroethane	0.055	NA	579
AY-68-28-313	04/11/2011	Tetrachloroethene	0.374	NA	579
AY-68-28-313	04/11/2011	Trichloroethene	0.082	NA	579
AY-68-28-313	04/11/2011	1,2-Dichloroethane	0.031	NA	579
AY-68-28-313	04/11/2011	Chloroform	0.714	NA	579
AY-68-28-313	06/30/2011	Chloroform	0.389	1.8	1,918
AY-68-28-313	06/30/2011	TPH Total	0.679	NA	1,918
AY-68-28-313	06/30/2011	Tetrachloroethene	0.603	NA	1,918
AY-68-28-313	08/11/2011	Tetrachloroethene	0.58	NA	1,010
AY-68-28-313	08/11/2011	TPH Total	0.201	NA	1,010
AY-68-28-313	08/11/2011	C11, C13, & C15	0.015	NA	1,010
AY-68-28-313	08/11/2011	Chloroform	0.444	NA	1,010
AY-68-28-313	09/08/2011	Tetrachloroethene	0.38	NA	669

Table 14. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-313	09/08/2011	TPH Total	1.042	NA	669
AY-68-28-313	09/08/2011	Chloroform	0.333	NA	669
AY-68-28-313	09/08/2011	C11, C13, & C15	0.012	NA	669
AY-68-28-313	10/12/2011	Chloroform	0.259	NA	819
AY-68-28-313	10/12/2011	Tetrachloroethene	0.149	NA	819
AY-68-28-313	10/12/2011	TPH Total	0.30	NA	819
AY-68-28-313	11/10/2011	TPH Total	0.446	NA	698
AY-68-28-313	11/10/2011	Chloroform	0.319	NA	698
AY-68-28-313	11/10/2011	Tetrachloroethene	0.414	NA	698
AY-68-28-313	12/07/2011	Tetrachloroethene	0.17	NA	647
AY-68-28-313	12/07/2011	Chloroform	0.332	1.57	647
AY-68-28-313	12/07/2011	TPH Total	0.078	NA	647
AY-68-28-313	01/18/2012	TPH Total	0.154	NA	1,006
AY-68-28-313	01/18/2012	Chloroform	0.36	NA	1,006
AY-68-28-313	01/18/2012	Tetrachloroethene	0.476	NA	1,006
AY-68-28-313	02/10/2012	Tetrachloroethene	0.366	NA	553
AY-68-28-313	02/10/2012	Chloroform	0.416	1.39	553
AY-68-28-313	03/07/2012	Tetrachloroethene	0.491	NA	623
AY-68-28-313	03/07/2012	Chloroform	0.42	NA	623
AY-68-28-313	04/10/2012	Tetrachloroethene	0.498	NA	812
AY-68-28-313	04/10/2012	Chloroform	0.328	NA	812
AY-68-28-313	05/24/2012	Tetrachloroethene	0.303	NA	1,056
AY-68-28-313	05/24/2012	Chloroform	0.101	0.99	1,056
AY-68-28-313	06/12/2012	Chloroform	0.20	NA	458
AY-68-28-313	06/12/2012	Tetrachloroethene	0.184	NA	458
AY-68-28-313	07/31/2012	TPH Total	0.674	NA	1,175
AY-68-28-313	07/31/2012	Chloroform	0.135	NA	1,175
AY-68-28-313	07/31/2012	Tetrachloroethene	0.343	NA	1,175
AY-68-28-313	08/29/2012	Chloroform	0.338	NA	697
AY-68-28-313	08/29/2012	Tetrachloroethene	0.406	NA	697
AY-68-28-313	08/29/2012	TPH Total	0.94	NA	697
AY-68-28-313	11/26/2012	TPH Total	6.205	NA	620
AY-68-28-313	11/26/2012	Tetrachloroethene	0.387	NA	620
AY-68-28-313	11/26/2012	1,3,5-Trimethylbenzene	0.027	NA	620
AY-68-28-313	11/26/2012	1,2,4-Trimethylbenzene	0.068	NA	620
AY-68-28-313	11/26/2012	Trimethylbenzenes	0.095	NA	620
AY-68-28-313	11/26/2012	o-Xylene	0.065	NA	620
AY-68-28-313	11/26/2012	m,p-Xylenes	0.168	NA	620
AY-68-28-313	11/26/2012	Ethylbenzene	0.045	NA	620
AY-68-28-313	11/26/2012	Toluene	0.103	NA	620
AY-68-28-313	11/26/2012	BTEX	0.381	NA	620
AY-68-28-313	12/18/2012	TPH Total	1.242	NA	526

Table 14. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-313	12/18/2012	Chloroform	0.433	NA	526
AY-68-28-313	12/18/2012	Tetrachloroethene	0.707	NA	526
AY-68-28-313	01/31/2013	TPH Total	0.65	NA	1,060
AY-68-28-313	01/31/2013	Tetrachloroethene	0.25	NA	1,060
AY-68-28-313	01/31/2013	Chloroform	0.40	NA	1,060
AY-68-28-313	02/28/2013	Tetrachloroethene	0.31	NA	668
AY-68-28-313	02/28/2013	Chloroform	0.09	1.19	668
AY-68-28-313	03/27/2013	Chloroform	0.29	NA	653
AY-68-28-313	03/27/2013	Tetrachloroethene	0.30	NA	653
AY-68-28-313	04/24/2013	Chloroform	0.36	NA	673
AY-68-28-313	04/24/2013	Tetrachloroethene	0.34	NA	673
AY-68-28-313	05/21/2013	TPH Total	0.90	NA	642
AY-68-28-313	05/21/2013	Toluene	0.04	NA	642
AY-68-28-313	05/21/2013	Chloroform	0.06	1.28	642
AY-68-28-313	05/21/2013	BTEX	0.04	NA	642
AY-68-28-313	05/21/2013	Tetrachloroethene	0.35	NA	642
AY-68-28-313	06/14/2013	Chloroform	0.113	NA	577
AY-68-28-313	06/14/2013	Tetrachloroethene	0.093	NA	577
AY-68-28-313	07/24/2013	Tetrachloroethene	0.123	NA	958
AY-68-28-313	07/24/2013	Chloroform	0.13	NA	958
AY-68-28-313	10/01/2013	Tetrachloroethene	0.307	NA	794
AY-68-28-313	10/01/2013	Chloroform	0.109	NA	794
AY-68-28-313	10/25/2013	Chloroform	0.342	NA	574
AY-68-28-313	10/25/2013	Tetrachloroethene	0.337	NA	574
AY-68-28-313	10/25/2013	TPH Total	0.514	NA	574
AY-68-28-313	11/18/2013	Chloroform	0.17	NA	581
AY-68-28-313	11/18/2013	Tetrachloroethene	0.05	NA	581
AY-68-28-313	12/19/2013	Chloroform	0.10	NA	741
AY-68-28-313	12/19/2013	Tetrachloroethene	0.03	NA	741
AY-68-28-313	01/14/2014	Tetrachloroethene	0.06	NA	623
AY-68-28-313	01/14/2014	Chloroform	0.13	NA	623
AY-68-28-313	02/24/2014	Tetrachloroethene	0.10	NA	984
AY-68-28-313	02/24/2014	Chloroform	0.17	NA	984
AY-68-28-313	03/19/2014	Chloroform	0.28	NA	530
AY-68-28-313	03/19/2014	Tetrachloroethene	0.24	NA	530
AY-68-28-313	03/19/2014	Carbon Tetrachloride	0.28	NA	530
AY-68-28-313	03/19/2014	TPH Total	0.827	NA	530
AY-68-28-313	04/28/2014	TPH Total	0.53	NA	986
AY-68-28-313	04/28/2014	Chloroform	0.10	2.33	986
AY-68-28-313	04/28/2014	Tetrachloroethene	0.19	NA	986
AY-68-28-313	04/28/2014	Carbon Tetrachloride	0.10	NA	986
AY-68-28-313	05/20/2014	Carbon Tetrachloride	0.14	NA	526

Table 14. Continued

Sample Name	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-313	05/20/2014	TPH Total	1.105	NA	526
AY-68-28-313	05/20/2014	BTEX	0.05	NA	526
AY-68-28-313	05/20/2014	m,p-Xylenes	0.05	NA	526
AY-68-28-313	05/20/2014	Chloroform	0.14	NA	526
AY-68-28-313	06/18/2014	BTEX	0.04	NA	700
AY-68-28-313	06/18/2014	m,p-Xylenes	0.04	NA	700
AY-68-28-313	06/18/2014	Chloroform	0.15	NA	700
AY-68-28-313	06/18/2014	Tetrachloroethene	0.03	NA	700
AY-68-28-313	06/18/2014	Carbon Tetrachloride	0.15	NA	700
AY-68-28-313	06/18/2014	TPH Total	1.492	NA	700
AY-68-28-313	07/17/2014	Tetrachloroethene	0.02	NA	692
AY-68-28-313	07/17/2014	Chloroform	0.13	NA	692
AY-68-28-313	07/17/2014	BTEX	0.04	NA	692
AY-68-28-313	07/17/2014	Carbon Tetrachloride	0.13	NA	692
AY-68-28-313	07/17/2014	TPH Total	1.396	NA	692
AY-68-28-313	07/17/2014	m,p-Xylenes	0.04	NA	692
AY-68-28-313	08/13/2014	Tetrachloroethene	1.62	NA	648
AY-68-28-313	08/13/2014	Carbon Tetrachloride	0.02	NA	648
AY-68-28-313	08/13/2014	Chloroform	0.50	NA	648
AY-68-28-313	09/23/2014	Toluene	0.03	NA	980
AY-68-28-313	09/23/2014	m,p-Xylenes	0.02	NA	980
AY-68-28-313	09/23/2014	BTEX	0.05	NA	980
AY-68-28-313	10/14/2014	m,p-Xylenes	0.05	NA	506
AY-68-28-313	10/14/2014	TPH Total	1.07	NA	506
AY-68-28-313	10/14/2014	Toluene	0.06	NA	506
AY-68-28-313	10/14/2014	BTEX	0.12	NA	506
AY-68-28-313	12/12/2014	Toluene	0.08	NA	762
AY-68-28-313	12/12/2014	BTEX	0.19	NA	762
AY-68-28-313	12/12/2014	Ethylbenzene	0.03	NA	762
AY-68-28-313	12/12/2014	m,p-Xylenes	0.07	NA	762
AY-68-28-313	12/12/2014	o-Xylene	0.02	NA	762
AY-68-28-313	12/12/2014	TPH Total	0.74	NA	762

NA = not analyzed.

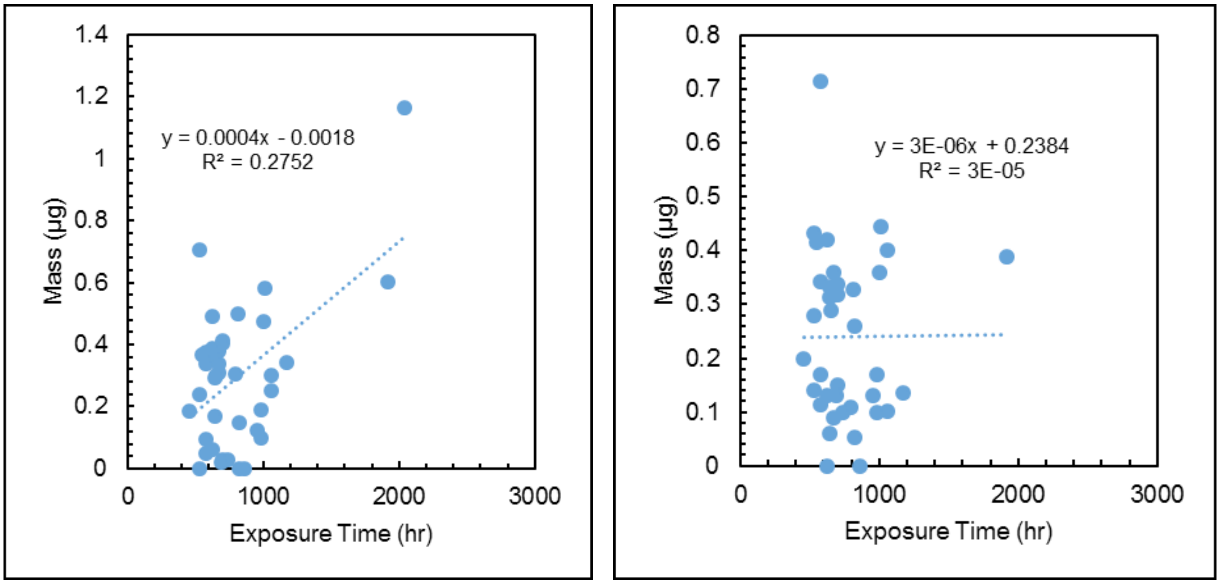


Figure 15. Mass and Exposure Time for (left) PCE and (right) Chloroform from AY-68-28-313

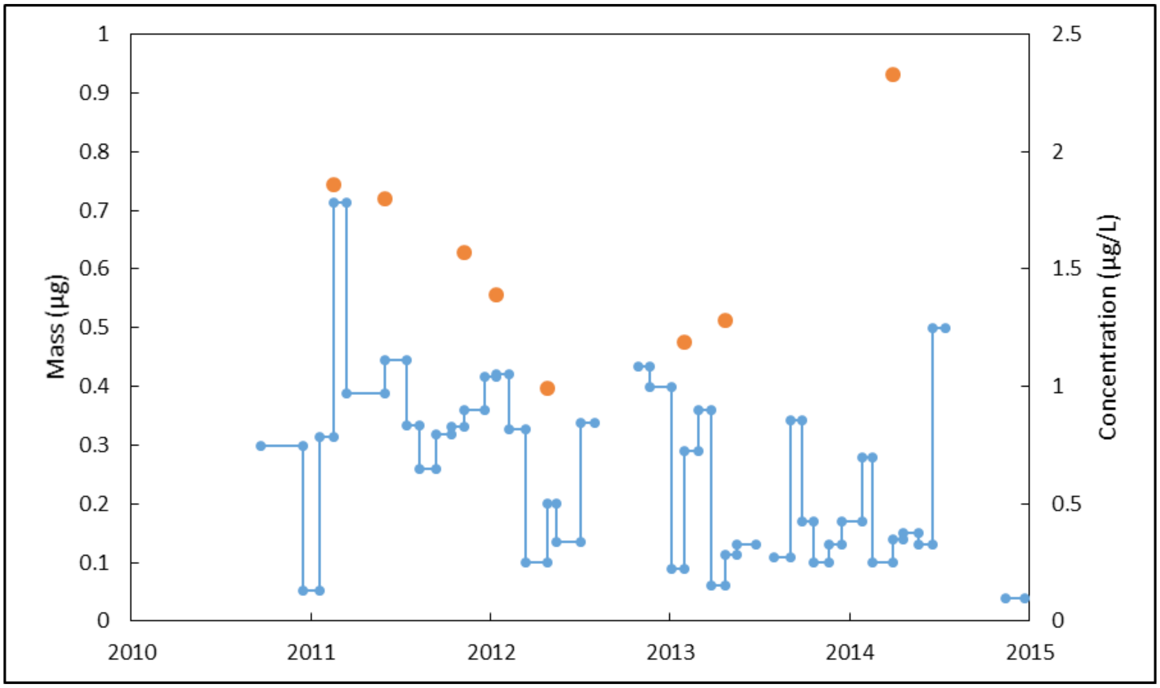


Figure 16. Time Series Data for Chloroform from AY-68-28-313

The time series data for chloroform (Figure 16) indicated that fluctuations in chloroform concentrations measured by grab samples were not reflected in mass sorbed by UPSs.

AY-68-28-608 (608)

AY-68-28-608, located in northern San Antonio in the transition zone, is surrounded by urban development. The top of the Edwards Aquifer is approximately 75 ft below land surface, and the well is 500 ft deep. AY-68-28-608 was sampled 162 times at three different flow zones that were identified using a variety of geophysical and hydrophysical techniques, including video logging. The upper part of the well has a different hydraulic head than the lower part, and the two heads fluctuated independently of each other during the study. The upper

Table 15. Chemicals Detected in AY-68-28-608 (608) UPSs

Chemical Name	Number of Detections	Percent Detections
TPH Total	107	83
BTEX	68	44
Toluene	55	34
C11, C13, & C15 Hydrocarbons	49	32
Tetrachloroethene	44	27
Combined PAHs	43	29
m,p-Xylenes	40	25
Naphthalene & 2-Methyl Naphthalene	38	25
2-Methyl Naphthalene	36	22
Trimethylbenzenes	36	23
1,2,4-Trimethylbenzene	35	21
Tridec (13 carbons)	30	18
Undecane (11 carbons)	27	17
Ethylbenzene	24	15
Pentadec (five carbons)	24	15
o-Xylene	23	15
Naphthalene	22	13
Oct (eight carbons)	19	12
1,3,5-Trimethylbenzene	17	10
Acenaphthene	13	8
Fluorene	12	7
Chloroform	11	7
Trichloroethene	10	6
Benzene	8	5
Phenanthrene	3	2
Chlorobenzene	3	5
Phenanthrene	2	1
1,4-Dichlorobenzene	2	1
Fluoranthene	2	1
1,2-Dichlorobenzene	2	2
Pyrene	2	1
Methyl tert-butyl ether	1	1
o-Xylene	1	20

and lower zones in AY-68-28-608 were isolated by two inflatable packers that were placed in the borehole at different intervals. One UPS was set between 120 and 237 ft below ground surface because of fluctuating water levels and was labeled AY-68-28-608-SH. The second UPS was set at 425 or 427 ft below ground surface and was labeled AY-68-28-608-D. The inflatable packers were removed from AY-68-28-608 in 2011, and subsequent UPSs were set between 195 and 250 ft below ground surface and labeled AY-68-28-608. Between August 16, 2007, and July 17, 2014, EAA field staff exchanged the UPSs approximately once a month and obtained a grab sample quarterly.

Most of the UPSs contained detectable concentrations of VOCs and other chemicals from August 2007 through July 2014 (Table 15). TPH was detected in 83% of the samples, BTEX in 44% of the samples, toluene in 34% of the samples, PCE in 27% of the samples, combined PAHs in 29% of the samples, and m,p–xylenes in 25% of the samples. One grab sample detected chloroform that was not detected by a UPS. Ten analytes, including PCE, TPH, and toluene, were detected by the UPSs and were not detected by the grab samples. Chloroform, although detected in only 7% of the UPSs, was the only contaminant detected by both the UPSs and grab samples. Table 16 lists the top ten contaminants detected in AY-68-28-608 on the basis of their detection frequencies.

Table 16. Top Ten Contaminants Detected in AY-68-28-608 (608)

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608	03/07/2012	Tetrachloroethene	0.188	NA	625
AY-68-28-608	03/20/2012	Tetrachloroethene	0.088	NA	74
AY-68-28-608	03/20/2012	BTEX	0.064	NA	74
AY-68-28-608	03/20/2012	Trimethylbenzenes	0.085	NA	74
AY-68-28-608	03/20/2012	TPH Total	6.159	NA	74
AY-68-28-608	03/20/2012	m,p-Xylenes	0.036	NA	74
AY-68-28-608	04/02/2012	TPH Total	0.623	NA	306
AY-68-28-608	04/02/2012	Tetrachloroethene	0.026	NA	306
AY-68-28-608	05/22/2012	TPH Total	1.964	NA	1172
AY-68-28-608	05/22/2012	Tetrachloroethene	0.184	NA	1172
AY-68-28-608	06/12/2012	TPH Total	4.551	NA	504
AY-68-28-608	06/12/2012	Tetrachloroethene	0.121	NA	504
AY-68-28-608	07/31/2012	Tetrachloroethene	0.042	NA	1176
AY-68-28-608	08/29/2012	Tetrachloroethene	0.064	NA	697
AY-68-28-608	08/29/2012	TPH Total	0.614	NA	697
AY-68-28-608	12/03/2012	Tetrachloroethene	0.132	NA	790
AY-68-28-608	12/09/2012	Tetrachloroethene	0.114	NA	380
AY-68-28-608	01/31/2013	Tetrachloroethene	0.088	NA	1033
AY-68-28-608	02/21/2013	Tetrachloroethene	0.079	NA	503
AY-68-28-608	03/27/2013	Tetrachloroethene	0.04	NA	820
AY-68-28-608	04/24/2013	Tetrachloroethene	0.03	NA	674
AY-68-28-608	05/22/2013	Tetrachloroethene	0.04	NA	670
AY-68-28-608	06/13/2013	TPH Total	2.377	NA	527
AY-68-28-608	07/24/2013	TPH Total	1.279	NA	979
AY-68-28-608	07/24/2013	Tetrachloroethene	0.034	NA	979
AY-68-28-608	10/01/2013	Tetrachloroethene	0.02	NA	797
AY-68-28-608	02/24/2014	TPH Total	0.67	NA	979
AY-68-28-608	02/24/2014	Tetrachloroethene	0.02	NA	979
AY-68-28-608	03/19/2014	Tetrachloroethene	0.03	NA	556

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608	04/02/2014	TPH Total	36.63	NA	960
AY-68-28-608	04/02/2014	BTEX	0.53	NA	960
AY-68-28-608	04/02/2014	Toluene	0.14	NA	960
AY-68-28-608	04/02/2014	m,p-Xylenes	0.17	NA	960
AY-68-28-608	04/02/2014	C11, C13, & C15	1.12	NA	960
AY-68-28-608	04/02/2014	Trimethylbenzenes	0.14	NA	960
AY-68-28-608	08/13/2014	Tetrachloroethene	0.08	NA	648
AY-68-28-608 Standpipe	08/16/2007	Toluene	0.06	NA	1
AY-68-28-608 Standpipe	08/16/2007	BTEX	0.06	NA	1
AY-68-28-608 Standpipe	08/19/2007	BTEX	0.036	NA	1
AY-68-28-608 Standpipe	08/19/2007	Toluene	0.036	NA	1
AY-68-28-608 Standpipe	08/19/2007	Trimethylbenzenes	0.011	NA	1
AY-68-28-608 Standpipe	08/23/2007	Toluene	0.073	NA	164
AY-68-28-608 Standpipe	08/23/2007	BTEX	0.027	NA	1
AY-68-28-608 Standpipe	08/23/2007	Toluene	0.027	NA	1
AY-68-28-608 Standpipe	08/23/2007	BTEX	0.073	NA	164
AY-68-28-608 Standpipe	08/29/2007	Toluene	0.051	NA	1
AY-68-28-608 Standpipe	08/29/2007	BTEX	0.051	NA	1
AY-68-28-608 Standpipe	09/06/2007	BTEX	0.05	NA	332
AY-68-28-608 Standpipe	09/06/2007	Toluene	0.05	NA	332
AY-68-28-608 Standpipe	09/26/2007	C11, C13, & C15	0.025	NA	338
AY-68-28-608 Standpipe	09/26/2007	m,p-Xylenes	0.01	NA	338
AY-68-28-608 Standpipe	09/26/2007	BTEX	0.072	NA	338
AY-68-28-608 Standpipe	09/26/2007	Tetrachloroethene	0.046	NA	338
AY-68-28-608 Standpipe	09/26/2007	Toluene	0.028	NA	338
AY-68-28-608 Standpipe	10/10/2007	BTEX	0.084	NA	334
AY-68-28-608 Standpipe	10/10/2007	C11, C13, & C15	0.033	NA	334
AY-68-28-608 Standpipe	10/10/2007	m,p-Xylenes	0.012	NA	334
AY-68-28-608 Standpipe	10/10/2007	Toluene	0.035	NA	334
AY-68-28-608 Standpipe	11/06/2007	2-Methyl Naphthalene	0.011	NA	309
AY-68-28-608 Standpipe	11/06/2007	Naphthalene & 2-Methyl Naphthalene	0.011	NA	309
AY-68-28-608 Standpipe	11/06/2007	Combined PAHs	0.011	NA	309
AY-68-28-608 Standpipe	11/06/2007	C11, C13, & C15	0.037	NA	309
AY-68-28-608 Standpipe	11/06/2007	m,p-Xylenes	0.02	NA	309
AY-68-28-608 Standpipe	11/06/2007	BTEX	0.111	NA	309
AY-68-28-608 Standpipe	11/06/2007	Toluene	0.041	NA	309
AY-68-28-608 Standpipe	11/19/2007	BTEX	0.068	NA	291
AY-68-28-608 Standpipe	11/19/2007	Toluene	0.03	NA	291
AY-68-28-608 Standpipe	12/03/2007	m,p-Xylenes	0.01	NA	333
AY-68-28-608 Standpipe	12/03/2007	BTEX	0.024	NA	333
AY-68-28-608 Standpipe	12/18/2007	BTEX	0.07	NA	364

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Standpipe	12/18/2007	Toluene	0.022	NA	364
AY-68-28-608 Standpipe	02/22/2008	C11, C13, & C15	0.035	NA	528
AY-68-28-608 Standpipe	02/22/2008	Combined PAHs	0.011	NA	528
AY-68-28-608 Standpipe	02/22/2008	Naphthalene & 2-Methyl Naphthalene	0.011	NA	528
AY-68-28-608 Standpipe	02/22/2008	2-Methyl Naphthalene	0.011	NA	528
AY-68-28-608 Standpipe	03/24/2008	Toluene	0.022	NA	313
AY-68-28-608 Standpipe	03/24/2008	BTEX	0.022	NA	313
AY-68-28-608 Standpipe	04/07/2008	C11, C13, & C15	0.01	NA	334
AY-68-28-608 Standpipe	04/07/2008	Toluene	0.05	NA	334
AY-68-28-608 Standpipe	04/07/2008	TPH Total	4.164	NA	334
AY-68-28-608 Standpipe	04/07/2008	BTEX	0.05	NA	334
AY-68-28-608 Standpipe	04/23/2008	Combined PAHs	0.01	NA	142
AY-68-28-608 Standpipe	04/23/2008	C11, C13, & C15	0.06	NA	142
AY-68-28-608 Standpipe	04/23/2008	2-Methyl Naphthalene	0.01	NA	142
AY-68-28-608 Standpipe	04/23/2008	TPH Total	2.796	NA	380
AY-68-28-608 Standpipe	04/23/2008	BTEX	0.05	NA	142
AY-68-28-608 Standpipe	04/23/2008	C11, C13, & C15	0.01	NA	380
AY-68-28-608 Standpipe	04/23/2008	TPH Total	4.742	NA	142
AY-68-28-608 Standpipe	04/23/2008	Toluene	0.05	NA	142
AY-68-28-608 Standpipe	04/23/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	142
AY-68-28-608 Standpipe	05/14/2008	Combined PAHs	0.01	NA	503
AY-68-28-608 Standpipe	05/14/2008	TPH Total	4.79	NA	503
AY-68-28-608 Standpipe	05/14/2008	BTEX	0.02	NA	503
AY-68-28-608 Standpipe	05/14/2008	Toluene	0.02	NA	503
AY-68-28-608 Standpipe	05/14/2008	C11, C13, & C15	0.03	NA	503
AY-68-28-608 Standpipe	05/29/2008	Combined PAHs	0.01	NA	362
AY-68-28-608 Standpipe	05/29/2008	TPH Total	1.982	NA	362
AY-68-28-608 Standpipe	05/29/2008	C11, C13, & C15	0.01	NA	362
AY-68-28-608 Standpipe	06/11/2008	TPH Total	6.227	NA	308
AY-68-28-608 Standpipe	06/11/2008	C11, C13, & C15	0.012	NA	308
AY-68-28-608 Standpipe	06/11/2008	Combined PAHs	0.015	NA	308
AY-68-28-608 Standpipe	06/11/2008	Tetrachloroethene	0.011	NA	308
AY-68-28-608 Standpipe	07/16/2008	Toluene	0.01	NA	196
AY-68-28-608 Standpipe	07/16/2008	C11, C13, & C15	0.02	NA	196
AY-68-28-608 Standpipe	07/16/2008	TPH Total	9.542	NA	196
AY-68-28-608 Standpipe	07/16/2008	TPH Total	1.731	NA	842
AY-68-28-608 Standpipe	07/16/2008	Tetrachloroethene	0.023	NA	842
AY-68-28-608 Standpipe	07/16/2008	BTEX	0.01	NA	196
AY-68-28-608 Standpipe	07/25/2008	Toluene	0.017	NA	1
AY-68-28-608 Standpipe	07/25/2008	BTEX	0.017	NA	1
AY-68-28-608 Standpipe	07/25/2008	TPH Total	6.803	NA	1

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Standpipe	07/29/2008	TPH Total	7.792	NA	120
AY-68-28-608 Standpipe	07/29/2008	BTEX	1.756	NA	120
AY-68-28-608 Standpipe	07/29/2008	Toluene	1.569	NA	120
AY-68-28-608 Standpipe	07/29/2008	m,p-Xylenes	0.095	NA	120
AY-68-28-608 Standpipe	07/29/2008	Tetrachloroethene	0.021	NA	305
AY-68-28-608 Standpipe	07/29/2008	Trimethylbenzenes	0.054	NA	120
AY-68-28-608 Standpipe	07/29/2008	Toluene	0.028	NA	305
AY-68-28-608 Standpipe	07/29/2008	Combined PAHs	0.01	NA	120
AY-68-28-608 Standpipe	07/29/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	120
AY-68-28-608 Standpipe	07/29/2008	Tetrachloroethene	0.055	NA	120
AY-68-28-608 Standpipe	07/29/2008	C11, C13, & C15	0.072	NA	120
AY-68-28-608 Standpipe	07/29/2008	Trimethylbenzenes	0.018	NA	305
AY-68-28-608 Standpipe	07/29/2008	m,p-Xylenes	0.025	NA	305
AY-68-28-608 Standpipe	07/29/2008	BTEX	0.053	NA	305
AY-68-28-608 Standpipe	07/29/2008	TPH Total	5.959	NA	305
AY-68-28-608 Standpipe	07/29/2008	Tetrachloroethene	0.013	NA	305
AY-68-28-608 Standpipe	07/29/2008	Combined PAHs	0.01	NA	305
AY-68-28-608 Standpipe	07/29/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	305
AY-68-28-608 Standpipe	07/29/2008	C11, C13, & C15	0.024	NA	305
AY-68-28-608 Standpipe	07/29/2008	m,p-Xylenes	0.02	NA	305
AY-68-28-608 Standpipe	07/29/2008	Toluene	0.032	NA	305
AY-68-28-608 Standpipe	07/29/2008	BTEX	0.052	NA	305
AY-68-28-608 Standpipe	07/29/2008	TPH Total	6.698	NA	305
AY-68-28-608 Standpipe	07/29/2008	C11, C13, & C15	0.015	NA	305
AY-68-28-608 Standpipe	07/29/2008	Trimethylbenzenes	0.013	NA	305
AY-68-28-608 Standpipe	09/11/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	676
AY-68-28-608 Standpipe	09/11/2008	C11, C13, & C15	0.39	NA	676
AY-68-28-608 Standpipe	09/11/2008	Trimethylbenzenes	0.04	NA	676
AY-68-28-608 Standpipe	09/11/2008	Combined PAHs	0.02	NA	676
AY-68-28-608 Standpipe	09/11/2008	m,p-Xylenes	0.02	NA	676
AY-68-28-608 Standpipe	09/11/2008	TPH Total	4.719	NA	676
AY-68-28-608 Standpipe	09/11/2008	2-Methyl Naphthalene	0.01	NA	676
AY-68-28-608 Standpipe	09/11/2008	BTEX	0.02	NA	676
AY-68-28-608 Standpipe	10/15/2008	Combined PAHs	0.03	NA	810
AY-68-28-608 Standpipe	10/15/2008	TPH Total	0.221	NA	810
AY-68-28-608 Standpipe	10/15/2008	Combined PAHs	0.02	NA	810
AY-68-28-608 Standpipe	10/15/2008	TPH Total	1.164	NA	810
AY-68-28-608 Standpipe	11/20/2008	TPH Total	0.295	NA	862
AY-68-28-608 Standpipe	12/18/2008	TPH Total	0.076	NA	674

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Standpipe	02/25/2009	Toluene	0.013	NA	836
AY-68-28-608 Standpipe	02/25/2009	BTEX	0.013	NA	836
AY-68-28-608 Standpipe	02/25/2009	TPH Total	0.027	NA	836
AY-68-28-608 Standpipe	03/13/2009	TPH Total	0.091	NA	385
AY-68-28-608 Standpipe	03/17/2009	TPH Total	0.036	NA	90
AY-68-28-608 Standpipe	03/19/2009	TPH Total	0.025	NA	46
AY-68-28-608 Standpipe	04/21/2009	Trimethylbenzenes	0.01	NA	790
AY-68-28-608 Standpipe	04/21/2009	BTEX	0.03	NA	790
AY-68-28-608 Standpipe	04/21/2009	Toluene	0.03	NA	790
AY-68-28-608 Standpipe	04/21/2009	C11, C13, & C15	0.01	NA	790
AY-68-28-608 Standpipe	04/21/2009	Combined PAHs	0.01	NA	790
AY-68-28-608 Standpipe	04/21/2009	Naphthalene & 2-Methyl Naphthalene	0.01	NA	790
AY-68-28-608 Standpipe	04/21/2009	2-Methyl Naphthalene	0.01	NA	790
AY-68-28-608 Standpipe	04/21/2009	TPH Total	2.434	NA	790
AY-68-28-608 Standpipe	05/26/2009	TPH Total	2.823	NA	692
AY-68-28-608 Standpipe	07/02/2009	TPH Total	1.191	NA	885
AY-68-28-608 Standpipe	07/02/2009	Tetrachloroethene	0.03	NA	885
AY-68-28-608 Standpipe	07/02/2009	2-Methyl Naphthalene	0.01	NA	885
AY-68-28-608 Standpipe	07/02/2009	Combined PAHs	0.01	NA	885
AY-68-28-608 Standpipe	07/02/2009	Naphthalene & 2-Methyl Naphthalene	0.01	NA	885
AY-68-28-608 Standpipe	08/13/2009	TPH Total	0.612	NA	1011
AY-68-28-608 Standpipe	09/16/2009	TPH Total	0.451	NA	810
AY-68-28-608 Standpipe	10/02/2009	C11, C13, & C15	0.012	NA	387
AY-68-28-608 Standpipe	10/02/2009	TPH Total	0.347	NA	387
AY-68-28-608 Standpipe	10/06/2009	C11, C13, & C15	0.023	NA	91
AY-68-28-608 Standpipe	10/06/2009	TPH Total	0.606	NA	91
AY-68-28-608 Standpipe	10/06/2009	TPH Total	0.26	NA	336
AY-68-28-608 Standpipe	10/28/2009	TPH Total	0.121	NA	530
AY-68-28-608 Standpipe	11/10/2009	TPH Total	0.148	NA	840
AY-68-28-608 Standpipe	11/23/2009	Tetrachloroethene	0.026	NA	315
AY-68-28-608 Standpipe	11/23/2009	C11, C13, & C15	0.028	NA	315
AY-68-28-608 Standpipe	11/23/2009	TPH Total	0.141	NA	315
AY-68-28-608 Standpipe	12/15/2009	TPH Total	0.14	NA	528
AY-68-28-608 Standpipe	12/15/2009	Tetrachloroethene	0.026	NA	528
AY-68-28-608 Standpipe	01/20/2010	C11, C13, & C15	0.029	NA	861
AY-68-28-608 Standpipe	01/20/2010	TPH Total	2.09	NA	118
AY-68-28-608 Standpipe	01/20/2010	C11, C13, & C15	0.045	NA	118
AY-68-28-608 Standpipe	01/20/2010	Tetrachloroethene	0.037	NA	861
AY-68-28-608 Standpipe	01/20/2010	Tetrachloroethene	0.014	NA	118
AY-68-28-608 Standpipe	01/20/2010	TPH Total	0.213	NA	861

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Standpipe	01/20/2010	Trimethylbenzenes	0.012	NA	118
AY-68-28-608 Standpipe	02/09/2010	TPH Total	2.868	NA	289
AY-68-28-608 Standpipe	02/09/2010	TPH Total	3.028	NA	478
AY-68-28-608 Standpipe	02/26/2010	TPH Total	1.901	NA	406
AY-68-28-608 Standpipe	03/10/2010	TPH Total	0.708	NA	285
AY-68-28-608 Standpipe	07/07/2010	TPH Total	0.067	NA	381
AY-68-28-608 Standpipe	07/07/2010	BTEX	0.036	NA	381
AY-68-28-608 Standpipe	09/22/2010	TPH Total	2.402	NA	310
AY-68-28-608 Standpipe	10/11/2010	TPH Total	11.249	NA	456
AY-68-28-608 Standpipe	10/25/2010	TPH Total	0.12	NA	339
AY-68-28-608 Standpipe	10/25/2010	TPH Total	0.099	NA	339
AY-68-28-608 Standpipe	12/01/2010	TPH Total	2.442	NA	900
AY-68-28-608 Standpipe	12/15/2010	TPH Total	6.231	NA	332
AY-68-28-608 Standpipe	01/07/2011	TPH Total	1.447	NA	553
AY-68-28-608 Standpipe	02/17/2011	TPH Total	3.388	NA	984
AY-68-28-608 Standpipe	03/15/2011	Toluene	0.036	NA	626
AY-68-28-608 Standpipe	03/15/2011	BTEX	0.036	NA	626
AY-68-28-608 Standpipe	03/15/2011	TPH Total	1.898	NA	626
AY-68-28-608 Annular	08/16/2007	C11, C13, & C15	0.131	NA	1
AY-68-28-608 Annular	08/16/2007	BTEX	66.657	NA	1
AY-68-28-608 Annular	08/16/2007	Toluene	66.507	NA	1
AY-68-28-608 Annular	08/16/2007	m,p-Xylenes	0.068	NA	1
AY-68-28-608 Annular	08/17/2007	Toluene	0.046	NA	1
AY-68-28-608 Annular	08/17/2007	BTEX	0.046	NA	1
AY-68-28-608 Annular	08/19/2007	Toluene	5.247	NA	66
AY-68-28-608 Annular	08/19/2007	BTEX	5.247	NA	66
AY-68-28-608 Annular	08/23/2007	BTEX	2.759	NA	97
AY-68-28-608 Annular	08/23/2007	Toluene	2.759	NA	97
AY-68-28-608 Annular	09/06/2007	BTEX	0.052	NA	331
AY-68-28-608 Annular	09/06/2007	Toluene	0.038	NA	331
AY-68-28-608 Annular	09/06/2007	BTEX	0.038	NA	331
AY-68-28-608 Annular	09/06/2007	Toluene	0.052	NA	331
AY-68-28-608 Annular	09/26/2007	Toluene	0.209	NA	338
AY-68-28-608 Annular	09/26/2007	BTEX	0.263	NA	338
AY-68-28-608 Annular	09/26/2007	2-Methyl Naphthalene	0.02	NA	338
AY-68-28-608 Annular	09/26/2007	m,p-Xylenes	0.015	NA	338
AY-68-28-608 Annular	09/26/2007	C11, C13, & C15	0.018	NA	338
AY-68-28-608 Annular	09/26/2007	Trimethylbenzenes	0.013	NA	338
AY-68-28-608 Annular	09/26/2007	Combined PAHs	0.072	NA	338
AY-68-28-608 Annular	09/26/2007	Naphthalene & 2-Methyl Naphthalene	0.02	NA	338
AY-68-28-608 Annular	10/10/2007	BTEX	0.177	NA	333

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	10/10/2007	Naphthalene & 2-Methyl Naphthalene	0.014	NA	333
AY-68-28-608 Annular	10/10/2007	Combined PAHs	0.014	NA	333
AY-68-28-608 Annular	10/10/2007	C11, C13, & C15	0.035	NA	333
AY-68-28-608 Annular	10/10/2007	Toluene	0.119	NA	333
AY-68-28-608 Annular	10/10/2007	m,p-Xylenes	0.014	NA	333
AY-68-28-608 Annular	10/10/2007	2-Methyl Naphthalene	0.014	NA	333
AY-68-28-608 Annular	10/24/2007	Combined PAHs	0.028	NA	312
AY-68-28-608 Annular	10/24/2007	Toluene	0.076	NA	312
AY-68-28-608 Annular	10/24/2007	m,p-Xylenes	0.019	NA	312
AY-68-28-608 Annular	10/24/2007	Trimethylbenzenes	0.015	NA	312
AY-68-28-608 Annular	10/24/2007	BTEX	0.117	NA	312
AY-68-28-608 Annular	10/24/2007	Naphthalene & 2-Methyl Naphthalene	0.028	NA	312
AY-68-28-608 Annular	10/24/2007	2-Methyl Naphthalene	0.028	NA	312
AY-68-28-608 Annular	10/24/2007	C11, C13, & C15	0.012	NA	312
AY-68-28-608 Annular	11/06/2007	Trimethylbenzenes	0.023	NA	308
AY-68-28-608 Annular	11/06/2007	Toluene	0.067	NA	308
AY-68-28-608 Annular	11/06/2007	BTEX	0.096	NA	308
AY-68-28-608 Annular	11/06/2007	m,p-Xylenes	0.017	NA	308
AY-68-28-608 Annular	11/06/2007	C11, C13, & C15	0.011	NA	308
AY-68-28-608 Annular	11/06/2007	Combined PAHs	0.127	NA	308
AY-68-28-608 Annular	11/06/2007	2-Methyl Naphthalene	0.071	NA	308
AY-68-28-608 Annular	11/06/2007	Naphthalene & 2-Methyl Naphthalene	0.104	NA	308
AY-68-28-608 Annular	11/19/2007	m,p-Xylenes	0.023	NA	290
AY-68-28-608 Annular	11/19/2007	Toluene	0.046	NA	290
AY-68-28-608 Annular	11/19/2007	Combined PAHs	0.024	NA	290
AY-68-28-608 Annular	11/19/2007	Naphthalene & 2-Methyl Naphthalene	0.024	NA	290
AY-68-28-608 Annular	11/19/2007	2-Methyl Naphthalene	0.024	NA	290
AY-68-28-608 Annular	11/19/2007	BTEX	0.108	NA	290
AY-68-28-608 Annular	12/03/2007	Trimethylbenzenes	0.036	NA	334
AY-68-28-608 Annular	12/03/2007	Tetrachloroethene	0.139	NA	334
AY-68-28-608 Annular	12/03/2007	2-Methyl Naphthalene	0.046	NA	334
AY-68-28-608 Annular	12/03/2007	Naphthalene & 2-Methyl Naphthalene	0.07	NA	334
AY-68-28-608 Annular	12/03/2007	m,p-Xylenes	0.036	NA	334
AY-68-28-608 Annular	12/03/2007	C11, C13, & C15	0.03	NA	334
AY-68-28-608 Annular	12/03/2007	Toluene	0.33	NA	334
AY-68-28-608 Annular	12/03/2007	BTEX	0.42	NA	334
AY-68-28-608 Annular	12/03/2007	Combined PAHs	0.07	NA	334
AY-68-28-608 Annular	12/18/2007	m,p-Xylenes	0.018	NA	364

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	12/18/2007	BTEX	0.03	NA	364
AY-68-28-608 Annular	12/18/2007	Combined PAHs	0.026	NA	364
AY-68-28-608 Annular	12/18/2007	Naphthalene & 2-Methyl Naphthalene	0.026	NA	364
AY-68-28-608 Annular	12/18/2007	2-Methyl Naphthalene	0.026	NA	364
AY-68-28-608 Annular	12/18/2007	Trimethylbenzenes	0.014	NA	364
AY-68-28-608 Annular	01/31/2008	Naphthalene & 2-Methyl Naphthalene	0.162	NA	1032
AY-68-28-608 Annular	01/31/2008	2-Methyl Naphthalene	0.1	NA	1032
AY-68-28-608 Annular	01/31/2008	Combined PAHs	0.162	NA	1032
AY-68-28-608 Annular	01/31/2008	Trimethylbenzenes	0.07	NA	1032
AY-68-28-608 Annular	01/31/2008	m,p-Xylenes	0.052	NA	1032
AY-68-28-608 Annular	01/31/2008	Toluene	0.099	NA	1032
AY-68-28-608 Annular	01/31/2008	BTEX	0.203	NA	1032
AY-68-28-608 Annular	02/22/2008	Toluene	0.104	NA	528
AY-68-28-608 Annular	02/22/2008	Naphthalene & 2-Methyl Naphthalene	0.074	NA	528
AY-68-28-608 Annular	02/22/2008	Combined PAHs	0.074	NA	528
AY-68-28-608 Annular	02/22/2008	Trimethylbenzenes	0.03	NA	528
AY-68-28-608 Annular	02/22/2008	m,p-Xylenes	0.025	NA	528
AY-68-28-608 Annular	02/22/2008	BTEX	0.14	NA	528
AY-68-28-608 Annular	02/22/2008	2-Methyl Naphthalene	0.045	NA	528
AY-68-28-608 Annular	03/11/2008	BTEX	0.128	NA	435
AY-68-28-608 Annular	03/11/2008	Combined PAHs	0.027	NA	435
AY-68-28-608 Annular	03/11/2008	Trimethylbenzenes	0.016	NA	435
AY-68-28-608 Annular	03/11/2008	2-Methyl Naphthalene	0.027	NA	435
AY-68-28-608 Annular	03/11/2008	Toluene	0.128	NA	435
AY-68-28-608 Annular	03/11/2008	Naphthalene & 2-Methyl Naphthalene	0.027	NA	435
AY-68-28-608 Annular	03/24/2008	Toluene	0.087	NA	313
AY-68-28-608 Annular	03/24/2008	m,p-Xylenes	0.018	NA	313
AY-68-28-608 Annular	03/24/2008	Trimethylbenzenes	0.021	NA	313
AY-68-28-608 Annular	03/24/2008	Combined PAHs	0.076	NA	313
AY-68-28-608 Annular	03/24/2008	Naphthalene & 2-Methyl Naphthalene	0.076	NA	313
AY-68-28-608 Annular	03/24/2008	2-Methyl Naphthalene	0.049	NA	313
AY-68-28-608 Annular	03/24/2008	BTEX	0.105	NA	313
AY-68-28-608 Annular	04/07/2008	2-Methyl Naphthalene	0.04	NA	334
AY-68-28-608 Annular	04/07/2008	Combined PAHs	0.06	NA	334
AY-68-28-608 Annular	04/07/2008	Trimethylbenzenes	0.03	NA	334
AY-68-28-608 Annular	04/07/2008	C11, C13, & C15	0.01	NA	334
AY-68-28-608 Annular	04/07/2008	TPH Total	2.288	NA	334
AY-68-28-608 Annular	04/07/2008	BTEX	0.11	NA	334

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	04/07/2008	Naphthalene & 2-Methyl Naphthalene	0.06	NA	334
AY-68-28-608 Annular	04/07/2008	Toluene	0.09	NA	334
AY-68-28-608 Annular	04/07/2008	Tetrachloroethene	0.03	NA	334
AY-68-28-608 Annular	04/07/2008	m,p-Xylenes	0.02	NA	334
AY-68-28-608 Annular	04/23/2008	Trimethylbenzenes	0.04	NA	380
AY-68-28-608 Annular	04/23/2008	Combined PAHs	0.01	NA	142
AY-68-28-608 Annular	04/23/2008	C11, C13, & C15	0.01	NA	142
AY-68-28-608 Annular	04/23/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	142
AY-68-28-608 Annular	04/23/2008	2-Methyl Naphthalene	0.06	NA	380
AY-68-28-608 Annular	04/23/2008	Combined PAHs	0.45	NA	380
AY-68-28-608 Annular	04/23/2008	C11, C13, & C15	0.04	NA	380
AY-68-28-608 Annular	04/23/2008	m,p-Xylenes	0.03	NA	380
AY-68-28-608 Annular	04/23/2008	Toluene	0.1	NA	380
AY-68-28-608 Annular	04/23/2008	BTEX	0.14	NA	380
AY-68-28-608 Annular	04/23/2008	TPH Total	6.524	NA	380
AY-68-28-608 Annular	04/23/2008	Naphthalene & 2-Methyl Naphthalene	0.1	NA	380
AY-68-28-608 Annular	04/23/2008	TPH Total	1.333	NA	142
AY-68-28-608 Annular	04/23/2008	2-Methyl Naphthalene	0.01	NA	142
AY-68-28-608 Annular	05/14/2008	TPH Total	7.02	NA	501
AY-68-28-608 Annular	05/14/2008	2-Methyl Naphthalene	0.01	NA	501
AY-68-28-608 Annular	05/14/2008	BTEX	0.05	NA	501
AY-68-28-608 Annular	05/14/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	501
AY-68-28-608 Annular	05/14/2008	Toluene	0.05	NA	501
AY-68-28-608 Annular	05/14/2008	C11, C13, & C15	0.02	NA	501
AY-68-28-608 Annular	05/14/2008	Combined PAHs	0.02	NA	501
AY-68-28-608 Annular	05/29/2008	Combined PAHs	0.02	NA	363
AY-68-28-608 Annular	05/29/2008	2-Methyl Naphthalene	0.01	NA	363
AY-68-28-608 Annular	05/29/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	363
AY-68-28-608 Annular	05/29/2008	C11, C13, & C15	0.02	NA	363
AY-68-28-608 Annular	05/29/2008	TPH Total	3.209	NA	363
AY-68-28-608 Annular	06/11/2008	Naphthalene & 2-Methyl Naphthalene	0.084	NA	308
AY-68-28-608 Annular	06/11/2008	Combined PAHs	0.123	NA	308
AY-68-28-608 Annular	06/11/2008	Trimethylbenzenes	0.027	NA	308
AY-68-28-608 Annular	06/11/2008	C11, C13, & C15	0.01	NA	308
AY-68-28-608 Annular	06/11/2008	2-Methyl Naphthalene	0.052	NA	308
AY-68-28-608 Annular	06/11/2008	m,p-Xylenes	0.025	NA	308

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	06/11/2008	Toluene	0.036	NA	308
AY-68-28-608 Annular	06/11/2008	BTEX	0.061	NA	308
AY-68-28-608 Annular	06/11/2008	TPH Total	5.763	NA	308
AY-68-28-608 Annular	07/16/2008	Trimethylbenzenes	0.096	NA	843
AY-68-28-608 Annular	07/16/2008	BTEX	0.212	NA	843
AY-68-28-608 Annular	07/16/2008	Toluene	0.092	NA	843
AY-68-28-608 Annular	07/16/2008	TPH Total	6.743	NA	196
AY-68-28-608 Annular	07/16/2008	C11, C13, & C15	0.017	NA	843
AY-68-28-608 Annular	07/16/2008	BTEX	0.031	NA	196
AY-68-28-608 Annular	07/16/2008	Combined PAHs	0.188	NA	843
AY-68-28-608 Annular	07/16/2008	Naphthalene & 2-Methyl Naphthalene	0.147	NA	843
AY-68-28-608 Annular	07/16/2008	2-Methyl Naphthalene	0.016	NA	196
AY-68-28-608 Annular	07/16/2008	2-Methyl Naphthalene	0.086	NA	843
AY-68-28-608 Annular	07/16/2008	Combined PAHs	0.03	NA	196
AY-68-28-608 Annular	07/16/2008	Naphthalene & 2-Methyl Naphthalene	0.03	NA	196
AY-68-28-608 Annular	07/16/2008	Trimethylbenzenes	0.015	NA	196
AY-68-28-608 Annular	07/16/2008	m,p-Xylenes	0.013	NA	196
AY-68-28-608 Annular	07/16/2008	Toluene	0.018	NA	196
AY-68-28-608 Annular	07/16/2008	m,p-Xylenes	0.067	NA	843
AY-68-28-608 Annular	07/16/2008	TPH Total	9.326	NA	843
AY-68-28-608 Annular	07/16/2008	Tetrachloroethene	0.021	NA	196
AY-68-28-608 Annular	07/25/2008	TPH Total	6.758	NA	1
AY-68-28-608 Annular	07/29/2008	Trimethylbenzenes	0.019	NA	309
AY-68-28-608 Annular	07/29/2008	BTEX	0.751	NA	309
AY-68-28-608 Annular	07/29/2008	Toluene	0.492	NA	309
AY-68-28-608 Annular	07/29/2008	m,p-Xylenes	0.127	NA	309
AY-68-28-608 Annular	07/29/2008	C11, C13, & C15	0.048	NA	309
AY-68-28-608 Annular	07/29/2008	Trimethylbenzenes	0.111	NA	309
AY-68-28-608 Annular	07/29/2008	Combined PAHs	0.112	NA	309
AY-68-28-608 Annular	07/29/2008	Naphthalene & 2-Methyl Naphthalene	0.112	NA	309
AY-68-28-608 Annular	07/29/2008	2-Methyl Naphthalene	0.033	NA	309
AY-68-28-608 Annular	07/29/2008	TPH Total	25.881	NA	309
AY-68-28-608 Annular	07/29/2008	Toluene	0.041	NA	309
AY-68-28-608 Annular	07/29/2008	TPH Total	18.911	NA	309
AY-68-28-608 Annular	07/29/2008	C11, C13, & C15	0.062	NA	309
AY-68-28-608 Annular	07/29/2008	Tetrachloroethene	0.015	NA	309
AY-68-28-608 Annular	07/29/2008	Combined PAHs	0.037	NA	309
AY-68-28-608 Annular	07/29/2008	Naphthalene & 2-Methyl Naphthalene	0.037	NA	309

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	07/29/2008	2-Methyl Naphthalene	0.011	NA	309
AY-68-28-608 Annular	07/29/2008	TPH Total	19.671	NA	125
AY-68-28-608 Annular	07/29/2008	BTEX	0.245	NA	125
AY-68-28-608 Annular	07/29/2008	Toluene	0.045	NA	125
AY-68-28-608 Annular	07/29/2008	m,p-Xylenes	0.096	NA	125
AY-68-28-608 Annular	07/29/2008	C11, C13, & C15	0.028	NA	125
AY-68-28-608 Annular	07/29/2008	Trimethylbenzenes	0.114	NA	125
AY-68-28-608 Annular	07/29/2008	Combined PAHs	0.081	NA	125
AY-68-28-608 Annular	07/29/2008	Naphthalene & 2-Methyl Naphthalene	0.081	NA	125
AY-68-28-608 Annular	07/29/2008	2-Methyl Naphthalene	0.025	NA	125
AY-68-28-608 Annular	07/29/2008	m,p-Xylenes	0.033	NA	309
AY-68-28-608 Annular	07/29/2008	BTEX	0.09	NA	309
AY-68-28-608 Annular	09/12/2008	TPH Total	6.628	NA	605
AY-68-28-608 Annular	09/12/2008	2-Methyl Naphthalene	0.16	NA	605
AY-68-28-608 Annular	09/12/2008	Naphthalene & 2-Methyl Naphthalene	0.41	NA	605
AY-68-28-608 Annular	09/12/2008	Trimethylbenzenes	0.11	NA	605
AY-68-28-608 Annular	09/12/2008	BTEX	0.08	NA	605
AY-68-28-608 Annular	09/12/2008	m,p-Xylenes	0.03	NA	605
AY-68-28-608 Annular	09/12/2008	Combined PAHs	0.42	NA	605
AY-68-28-608 Annular	10/15/2008	BTEX	0.15	NA	787
AY-68-28-608 Annular	10/15/2008	2-Methyl Naphthalene	0.04	NA	787
AY-68-28-608 Annular	10/15/2008	Combined PAHs	0.16	NA	787
AY-68-28-608 Annular	10/15/2008	TPH Total	4.577	NA	787
AY-68-28-608 Annular	10/15/2008	BTEX	0.15	NA	787
AY-68-28-608 Annular	10/15/2008	Naphthalene & 2-Methyl Naphthalene	0.12	NA	787
AY-68-28-608 Annular	10/15/2008	Combined PAHs	0.13	NA	787
AY-68-28-608 Annular	10/15/2008	Trimethylbenzenes	0.09	NA	787
AY-68-28-608 Annular	10/15/2008	m,p-Xylenes	0.06	NA	787
AY-68-28-608 Annular	10/15/2008	Naphthalene & 2-Methyl Naphthalene	0.14	NA	787
AY-68-28-608 Annular	10/15/2008	2-Methyl Naphthalene	0.05	NA	787
AY-68-28-608 Annular	10/15/2008	m,p-Xylenes	0.05	NA	787
AY-68-28-608 Annular	10/15/2008	Trimethylbenzenes	0.09	NA	787
AY-68-28-608 Annular	10/15/2008	TPH Total	1.638	NA	787
AY-68-28-608 Annular	11/20/2008	2-Methyl Naphthalene	0.01	NA	862
AY-68-28-608 Annular	11/20/2008	Trimethylbenzenes	0.02	NA	862
AY-68-28-608 Annular	11/20/2008	Combined PAHs	0.01	NA	862
AY-68-28-608 Annular	11/20/2008	Naphthalene & 2-Methyl Naphthalene	0.01	NA	862

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	11/20/2008	TPH Total	1.467	NA	862
AY-68-28-608 Annular	12/18/2008	TPH Total	0.558	NA	673
AY-68-28-608 Annular	01/21/2009	Tetrachloroethene	0.01	NA	814
AY-68-28-608 Annular	01/21/2009	Naphthalene & 2-Methyl Naphthalene	0.06	NA	814
AY-68-28-608 Annular	01/21/2009	C11, C13, & C15	0.02	NA	814
AY-68-28-608 Annular	01/21/2009	Trimethylbenzenes	0.04	NA	814
AY-68-28-608 Annular	01/21/2009	Toluene	0.04	NA	814
AY-68-28-608 Annular	01/21/2009	BTEX	0.11	NA	814
AY-68-28-608 Annular	01/21/2009	2-Methyl Naphthalene	0.02	NA	814
AY-68-28-608 Annular	01/21/2009	m,p-Xylenes	0.04	NA	814
AY-68-28-608 Annular	01/21/2009	Combined PAHs	0.1	NA	814
AY-68-28-608 Annular	01/21/2009	TPH Total	2.098	NA	814
AY-68-28-608 Annular	02/25/2009	BTEX	0.211	NA	834
AY-68-28-608 Annular	02/25/2009	Tetrachloroethene	0.084	NA	834
AY-68-28-608 Annular	02/25/2009	Toluene	0.087	NA	834
AY-68-28-608 Annular	02/25/2009	m,p-Xylenes	0.049	NA	834
AY-68-28-608 Annular	02/25/2009	C11, C13, & C15	0.034	NA	834
AY-68-28-608 Annular	02/25/2009	Trimethylbenzenes	0.054	NA	834
AY-68-28-608 Annular	02/25/2009	Combined PAHs	0.099	NA	834
AY-68-28-608 Annular	02/25/2009	TPH Total	4.379	NA	834
AY-68-28-608 Annular	02/25/2009	Naphthalene & 2-Methyl Naphthalene	0.075	NA	834
AY-68-28-608 Annular	02/25/2009	2-Methyl Naphthalene	0.036	NA	834
AY-68-28-608 Annular	03/13/2009	C11, C13, & C15	0.028	NA	383
AY-68-28-608 Annular	03/13/2009	m,p-Xylenes	0.033	NA	383
AY-68-28-608 Annular	03/13/2009	Toluene	0.083	NA	383
AY-68-28-608 Annular	03/13/2009	TPH Total	1.104	NA	383
AY-68-28-608 Annular	03/13/2009	Trimethylbenzenes	0.014	NA	383
AY-68-28-608 Annular	03/13/2009	BTEX	0.176	NA	383
AY-68-28-608 Annular	03/17/2009	TPH Total	0.273	NA	94
AY-68-28-608 Annular	03/19/2009	C11, C13, & C15	0.034	NA	46
AY-68-28-608 Annular	03/19/2009	Toluene	0.065	NA	46
AY-68-28-608 Annular	03/19/2009	TPH Total	0.92	NA	46
AY-68-28-608 Annular	03/19/2009	BTEX	0.076	NA	46
AY-68-28-608 Annular	03/19/2009	m,p-Xylenes	0.011	NA	46
AY-68-28-608 Annular	04/21/2009	TPH Total	0.058	NA	790
AY-68-28-608 Annular	05/26/2009	Tetrachloroethene	0.28	NA	693
AY-68-28-608 Annular	05/26/2009	Trimethylbenzenes	0.01	NA	693
AY-68-28-608 Annular	05/26/2009	C11, C13, & C15	0.02	NA	693
AY-68-28-608 Annular	05/26/2009	m,p-Xylenes	0.02	NA	693
AY-68-28-608 Annular	05/26/2009	BTEX	0.02	NA	693

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	05/26/2009	TPH Total	3.763	NA	693
AY-68-28-608 Annular	07/02/2009	C11, C13, & C15	0.03	NA	886
AY-68-28-608 Annular	07/02/2009	Tetrachloroethene	0.61	NA	886
AY-68-28-608 Annular	07/02/2009	TPH Total	8.938	NA	886
AY-68-28-608 Annular	08/13/2009	TPH Total	1.478	NA	1011
AY-68-28-608 Annular	08/13/2009	BTEX	0.013	NA	1011
AY-68-28-608 Annular	08/13/2009	C11, C13, & C15	0.011	NA	1011
AY-68-28-608 Annular	08/13/2009	Tetrachloroethene	0.022	NA	1011
AY-68-28-608 Annular	09/16/2009	TPH Total	0.221	NA	810
AY-68-28-608 Annular	10/02/2009	TPH Total	1.343	NA	386
AY-68-28-608 Annular	10/06/2009	BTEX	0.02	NA	336
AY-68-28-608 Annular	10/06/2009	TPH Total	0.189	NA	91
AY-68-28-608 Annular	10/06/2009	Trimethylbenzenes	0.013	NA	336
AY-68-28-608 Annular	10/06/2009	C11, C13, & C15	0.057	NA	336
AY-68-28-608 Annular	10/06/2009	m,p-Xylenes	0.02	NA	336
AY-68-28-608 Annular	10/06/2009	TPH Total	3.904	NA	336
AY-68-28-608 Annular	10/28/2009	TPH Total	0.287	NA	529
AY-68-28-608 Annular	11/10/2009	TPH Total	0.604	NA	841
AY-68-28-608 Annular	11/10/2009	Combined PAHs	0.055	NA	841
AY-68-28-608 Annular	11/10/2009	2-Methyl Naphthalene	0.013	NA	841
AY-68-28-608 Annular	11/10/2009	Naphthalene & 2-Methyl Naphthalene	0.045	NA	841
AY-68-28-608 Annular	11/10/2009	BTEX	0.016	NA	841
AY-68-28-608 Annular	11/10/2009	m,p-Xylenes	0.016	NA	841
AY-68-28-608 Annular	11/23/2009	TPH Total	0.263	NA	316
AY-68-28-608 Annular	11/23/2009	C11, C13, & C15	0.02	NA	316
AY-68-28-608 Annular	11/23/2009	Tetrachloroethene	0.042	NA	316
AY-68-28-608 Annular	12/15/2009	C11, C13, & C15	0.01	NA	528
AY-68-28-608 Annular	12/15/2009	TPH Total	1.270	NA	528
AY-68-28-608 Annular	01/20/2010	BTEX	0.038	NA	863
AY-68-28-608 Annular	01/20/2010	Naphthalene & 2-Methyl Naphthalene	0.046	NA	121
AY-68-28-608 Annular	01/20/2010	TPH Total	12.712	NA	121
AY-68-28-608 Annular	01/20/2010	BTEX	0.120	NA	121
AY-68-28-608 Annular	01/20/2010	TPH Total	0.933	NA	863
AY-68-28-608 Annular	01/20/2010	Toluene	0.050	NA	121
AY-68-28-608 Annular	01/20/2010	m,p-Xylenes	0.036	NA	121
AY-68-28-608 Annular	01/20/2010	C11, C13, & C15	0.109	NA	121
AY-68-28-608 Annular	01/20/2010	Trimethylbenzenes	0.020	NA	121
AY-68-28-608 Annular	01/20/2010	Combined PAHs	0.046	NA	121
AY-68-28-608 Annular	01/20/2010	Tetrachloroethene	0.066	NA	121

Table 16. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-28-608 Annular	01/20/2010	2-Methyl Naphthalene	0.014	NA	121
AY-68-28-608 Annular	02/09/2010	TPH Total	1.341	NA	291
AY-68-28-608 Annular	02/09/2010	TPH Total	1.194	NA	480
AY-68-28-608 Annular	02/26/2010	TPH Total	1.173	NA	408
AY-68-28-608 Annular	03/10/2010	TPH Total	0.457	NA	286
AY-68-28-608 Annular	07/07/2010	TPH Total	0.103	NA	381
AY-68-28-608 Annular	08/18/2010	Tetrachloroethene	0.085	NA	1004
AY-68-28-608 Annular	08/18/2010	TPH Total	2.712	NA	1004
AY-68-28-608 Annular	09/22/2010	TPH Total	0.303	NA	309
AY-68-28-608 Annular	10/11/2010	TPH Total	9.155	NA	457
AY-68-28-608 Annular	12/01/2010	TPH Total	1.207	NA	888
AY-68-28-608 Annular	12/15/2010	TPH Total	1.351	NA	332
AY-68-28-608 Annular	01/07/2011	TPH Total	1.814	NA	553
AY-68-28-608 Annular	02/17/2011	TPH Total	1.442	NA	985
AY-68-28-608 Annular	02/17/2011	BTEX	0.014	NA	985
AY-68-28-608 Annular	02/17/2011	Toluene	0.014	NA	985
AY-68-28-608 Annular	02/17/2011	Tetrachloroethene	0.043	NA	985
AY-68-28-608 Annular	03/15/2011	TPH Total	0.639	NA	626
AY-68-28-608 Annular	03/15/2011	Tetrachloroethene	0.036	NA	626

NA = not analyzed.
µg = micrograms.
µg/L = micrograms per liter.

In general, the UPSs at AY-68-28-608 detected PCE and fuel-related compounds at low levels in the groundwater. There was little difference between the samples collected from shallow, deep, or mixed parts of the well. Between 2008 and 2010, TPH and other fuel-related compounds (Figure 17) were detected at higher frequencies and concentrations. The frequencies and concentrations diminished after 2010, probably because handling practices for the passive sample devices improved. No relationship was observed between mass and exposure time for the UPSs in AY-68-28-608 (Figure 17). Other compounds similarly showed no relationship between mass and exposure time. The UPS results indicated that the detected compounds were present in the groundwater, but the actual concentrations were not determined.

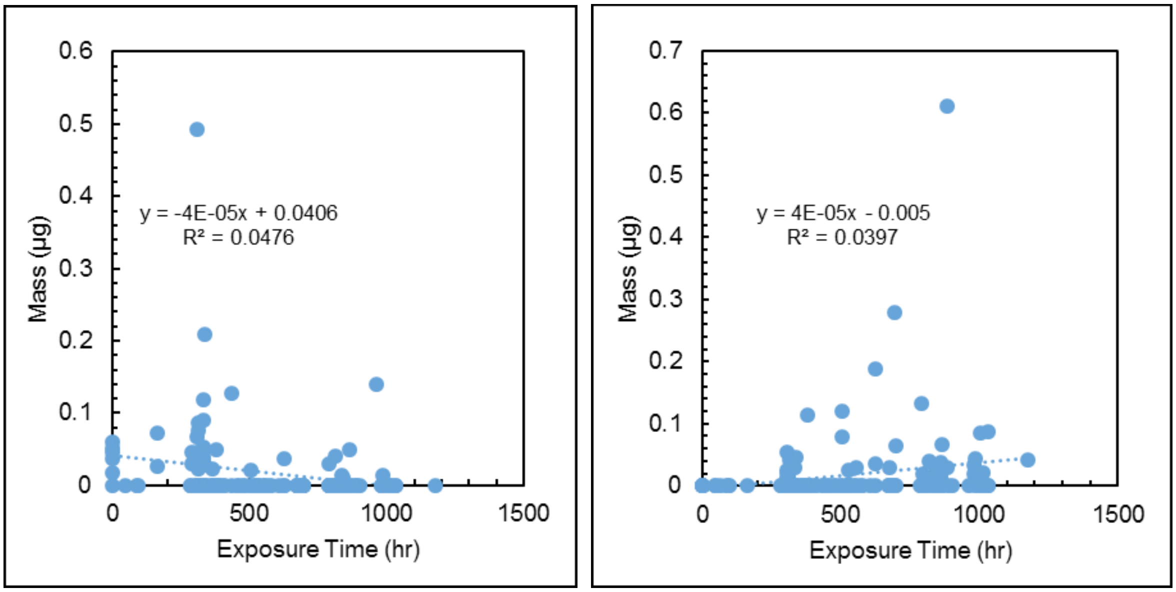


Figure 17. Mass and Exposure Time for (left) Toluene and (right) PCE from AY-68-28-608

AY-68-29-418 (Rio Seco)

AY-68-29-418, located in the recharge zone in north central San Antonio, is surrounded by urban development. AY-68-29-418 was sampled 46 times from March 28, 2013, through April 10, 2015. During this period, EAA field staff exchanged the UPSs approximately once a month and obtained a grab sample quarterly. AY-68-29-418 was included in this study because PCE has been detected historically in groundwater samples at concentrations of between 3 and 4 µg/L. The source is not known, although a former dry-cleaning facility is nearby that is in TCEQ's Dry Cleaner Remediation Program (TCEQ, 2016).

Most of the UPSs contained detectable concentrations of one or more compounds. PCE was detected in 98% of the samples, TPH was detected in 65% of the samples, chloroform was detected in 51% of the samples, BTEX was detected in 27% of the samples, and toluene was detected in 20% of the samples. Only one UPS (5/01/2014) did not detect PCE, but it was detected in the accompanying grab sample. Chloroform was also detected in several grab samples and the accompanying UPS samples. Table 17 lists the top five most frequently detected contaminants in AY-68-28-418.

Table 17. Top Five Contaminants Detected in AY-68-28-418 (Rio Seco)

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-29-418	03/28/2011	TPH Total	0.288	NA	244
AY-68-29-418	03/28/2011	Chloroform	0.029	NA	244
AY-68-29-418	03/28/2011	Tetrachloroethene	0.24	NA	244
AY-68-29-418	04/04/2011	TPH Total	0.299	NA	165
AY-68-29-418	04/04/2011	Chloroform	0.044	0.411	165
AY-68-29-418	04/04/2011	Tetrachloroethene	0.312	2.02	165
AY-68-29-418	03/07/2012	Chloroform	0.075	NA	623
AY-68-29-418	03/07/2012	Tetrachloroethene	5.503	NA	623
AY-68-29-418	04/10/2012	Chloroform	0.071	NA	816
AY-68-29-418	04/10/2012	Tetrachloroethene	4.561	NA	816
AY-68-29-418	05/31/2012	Chloroform	0.142	0.511	1,220
AY-68-29-418	05/31/2012	Tetrachloroethene	9.442	3.43	1,220
AY-68-29-418	06/12/2012	Tetrachloroethene	2.983	NA	720
AY-68-29-418	06/12/2012	Chloroform	0.11	NA	720
AY-68-29-418	06/12/2012	TPH Total	1.763	NA	720
AY-68-29-418	07/31/2012	Tetrachloroethene	5.997	NA	1,179
AY-68-29-418	08/10/2012	Chloroform	0.039	NA	166
AY-68-29-418	08/10/2012	Tetrachloroethene	1.186	NA	166
AY-68-29-418	08/28/2012	Chloroform	0.064	NA	669
AY-68-29-418	08/28/2012	Tetrachloroethene	4.092	NA	669
AY-68-29-418	11/26/2012	TPH Total	1.473	NA	620
AY-68-29-418	11/26/2012	Chloroform	0.107	NA	620
AY-68-29-418	11/26/2012	Tetrachloroethene	11.716	NA	620
AY-68-29-418	12/18/2012	Tetrachloroethene	0.049	NA	355
AY-68-29-418	12/19/2012	TPH Total	0.82	NA	552
AY-68-29-418	12/19/2012	Chloroform	0.098	0.242	552
AY-68-29-418	12/19/2012	Tetrachloroethene	27.699	4.34	552
AY-68-29-418	01/31/2013	TPH Total	0.639	NA	1,030
AY-68-29-418	01/31/2013	Chloroform	0.046	NA	1,030
AY-68-29-418	01/31/2013	Tetrachloroethene	16.379	NA	1,030
AY-68-29-418	03/27/2013	TPH Total	0.553	NA	806
AY-68-29-418	03/27/2013	Tetrachloroethene	24.759	NA	806
AY-68-29-418	04/24/2013	Chloroform	0.09	NA	674
AY-68-29-418	04/24/2013	TPH Total	1.09	NA	674
AY-68-29-418	04/24/2013	Tetrachloroethene	18.01	NA	674
AY-68-29-418	05/22/2013	Tetrachloroethene	17.0	4.33	666
AY-68-29-418	05/22/2013	Chloroform	0.09	NA	666
AY-68-29-418	05/22/2013	TPH Total	0.96	NA	666
AY-68-29-418	06/14/2013	Tetrachloroethene	9.747	NA	553
AY-68-29-418	06/14/2013	Chloroform	0.028	NA	553

Table 17. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-29-418	07/24/2013	Tetrachloroethene	1.339	NA	957
AY-68-29-418	08/12/2013	Tetrachloroethene	10.4	NA	458
AY-68-29-418	08/12/2013	Chloroform	0.075	NA	458
AY-68-29-418	08/12/2013	TPH Total	1.474	NA	458
AY-68-29-418	10/01/2013	Tetrachloroethene	25.879	4.59	813
AY-68-29-418	10/01/2013	Chloroform	0.064	0.292	813
AY-68-29-418	10/01/2013	TPH Total	0.516	NA	813
AY-68-29-418	10/25/2013	Tetrachloroethene	25.775	NA	576
AY-68-29-418	10/25/2013	Chloroform	0.064	NA	576
AY-68-29-418	11/18/2013	Chloroform	0.07	NA	578
AY-68-29-418	11/18/2013	Tetrachloroethene	10.9	NA	578
AY-68-29-418	12/19/2013	Tetrachloroethene	11.3	NA	743
AY-68-29-418	12/19/2013	Chloroform	0.07	NA	743
AY-68-29-418	01/14/2014	Tetrachloroethene	9.8	NA	630
AY-68-29-418	01/14/2014	Chloroform	0.07	NA	630
AY-68-29-418	02/24/2014	Tetrachloroethene	8.99	NA	976
AY-68-29-418	02/24/2014	Chloroform	0.06	NA	976
AY-68-29-418	02/24/2014	Toluene	0.05	NA	976
AY-68-29-418	03/19/2014	Chloroform	0.03	NA	557
AY-68-29-418	03/19/2014	Tetrachloroethene	18.36	NA	557
AY-68-29-418	03/19/2014	TPH Total	1.30	NA	557
AY-68-29-418	03/19/2014	Carbon Tetrachloride	0.03	NA	557
AY-68-29-418	05/01/2014	Tetrachloroethene	<0.02	4.21	1,028
AY-68-29-418	05/20/2014	Carbon Tetrachloride	0.05	NA	457
AY-68-29-418	05/20/2014	Tetrachloroethene	22.21	NA	457
AY-68-29-418	05/20/2014	Chloroform	0.05	NA	457
AY-68-29-418	05/20/2014	TPH Total	0.688	NA	457
AY-68-29-418	06/18/2014		0.03	NA	698
AY-68-29-418	06/18/2014	m,p-Xylenes	0.08	NA	698
AY-68-29-418	06/18/2014	Ethylbenzene	0.02	NA	698
AY-68-29-418	06/18/2014	Toluene	0.02	NA	698
AY-68-29-418	06/18/2014	Tetrachloroethene	0.05	NA	698
AY-68-29-418	06/18/2014	BTEX	0.12	NA	698
AY-68-29-418	06/18/2014	TPH Total	2.274	NA	698
AY-68-29-418	07/17/2014	BTEX	1.25	NA	696
AY-68-29-418	07/17/2014	C11, C13, & C15	0.61	NA	696
AY-68-29-418	07/17/2014	Toluene	0.59	NA	696
AY-68-29-418	07/17/2014	Tetrachloroethene	0.21	NA	696
AY-68-29-418	07/17/2014	TMBs	0.09	NA	696
AY-68-29-418	07/17/2014	Ethylbenzene	0.16	NA	696
AY-68-29-418	07/17/2014	1,2,4-Trimethylbenzene	0.07	NA	696

Table 17. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-29-418	07/17/2014	Benzene	0.02	NA	696
AY-68-29-418	07/17/2014	1,3,5-Trimethylbenzene	0.02	NA	696
AY-68-29-418	07/17/2014	m,p-Xylenes	0.36	NA	696
AY-68-29-418	07/17/2014	TPH Total	7.214	NA	696
AY-68-29-418	07/17/2014	1,1,1,2-Tetrachloroethane	0.03	NA	696
AY-68-29-418	08/13/2014	Tetrachloroethene	14.16	NA	648
AY-68-29-418	08/13/2014	TPH Total	2.35	NA	648
AY-68-29-418	08/13/2014	Chloroform	0.05	NA	648
AY-68-29-418	09/22/2014	TPH Total	1.57	NA	958
AY-68-29-418	09/22/2014	Tetrachloroethene	14.25	4.96	958
AY-68-29-418	09/22/2014	Chloroform	<0.02	0.251	958
AY-68-29-418	09/22/2014	BTEX	0.04	NA	958
AY-68-29-418	09/22/2014	Toluene	0.04	NA	958
AY-68-29-418	10/14/2014	1,2,4-Trimethylbenzene	0.07	NA	530
AY-68-29-418	10/14/2014	BTEX	0.28	NA	530
AY-68-29-418	10/14/2014	Ethylbenzene	0.03	NA	530
AY-68-29-418	10/14/2014	m,p-Xylenes	0.09	NA	530
AY-68-29-418	10/14/2014	Naphthalene	0.13	NA	530
AY-68-29-418	10/14/2014	o-Xylene	0.04	NA	530
AY-68-29-418	10/14/2014	Tetrachloroethene	4.31	NA	530
AY-68-29-418	10/14/2014	Toluene	0.12	NA	530
AY-68-29-418	10/14/2014	TPH Total	24.06	NA	530
AY-68-29-418	11/14/2014	m,p-Xylenes	0.09	NA	692
AY-68-29-418	11/14/2014	TPH Total	24.36	NA	692
AY-68-29-418	11/14/2014	1,2,4-Trimethylbenzene	0.06	NA	692
AY-68-29-418	11/14/2014	Naphthalene	0.13	NA	692
AY-68-29-418	11/14/2014	Ethylbenzene	0.03	NA	692
AY-68-29-418	11/14/2014	BTEX	0.27	NA	692
AY-68-29-418	11/14/2014	Tetrachloroethene	4.21	NA	692
AY-68-29-418	11/14/2014	o-Xylene	0.03	NA	692
AY-68-29-418	11/14/2014	Toluene	0.12	NA	692
AY-68-29-418	12/17/2014	BTEX	0.05	NA	845
AY-68-29-418	12/17/2014	Benzene	0.05	NA	845
AY-68-29-418	12/17/2014	Tetrachloroethene	0.04	4.34	845
AY-68-29-418	12/17/2014	Chloroform	<0.02	0.24	845
AY-68-29-418	01/22/2015	Benzene	0.22	NA	863
AY-68-29-418	01/22/2015	TPH Total	0.57	NA	863
AY-68-29-418	01/22/2015	BTEX	0.22	NA	863
AY-68-29-418	01/22/2015	Tetrachloroethene	0.04	NA	863
AY-68-29-418	02/12/2015	Benzene	0.11	NA	505
AY-68-29-418	02/12/2015	TPH Total	0.51	NA	505

Table 17. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
AY-68-29-418	02/12/2015	BTEX	0.11	NA	505
AY-68-29-418	02/12/2015	Tetrachloroethene	0.04	NA	505
AY-68-29-418	02/18/2015	Tetrachloroethene	0.03	0.958	1
AY-68-29-418	02/18/2015	TPH Total	1.06	NA	1
AY-68-29-418	02/20/2015	TPH Total	0.65	NA	45
AY-68-29-418	02/20/2015	Tetrachloroethene	0.37	0.718	45
AY-68-29-418	02/22/2015	Tetrachloroethene	0.33	0.618	51
AY-68-29-418	02/24/2015	Tetrachloroethene	0.46	1.27	45
AY-68-29-418	02/24/2015	TPH Total	0.66	NA	45
AY-68-29-418	02/26/2015	Toluene	0.06	NA	48
AY-68-29-418	02/26/2015	TPH Total	1.85	NA	48
AY-68-29-418	02/26/2015	BTEX	0.06	NA	48
AY-68-29-418	02/26/2015	Tetrachloroethene	0.38	0.593	48
AY-68-29-418	02/28/2015	Chloroform	0.05	NA	48
AY-68-29-418	02/28/2015	TPH Total	0.88	NA	48
AY-68-29-418	02/28/2015	Benzene	0.02	NA	48
AY-68-29-418	02/28/2015	Tetrachloroethene	0.57	0.87	48
AY-68-29-418	02/28/2015	BTEX	0.05	NA	48
AY-68-29-418	02/28/2015	Toluene	0.03	NA	48
AY-68-29-418	03/02/2015	Tetrachloroethene	0.39	0.807	48
AY-68-29-418	03/02/2015	BTEX	0.08	NA	48
AY-68-29-418	03/02/2015	Toluene	0.08	NA	48
AY-68-29-418	03/02/2015	TPH Total	3.36	NA	48
AY-68-29-418	03/02/2015	Chloroform	0.03	NA	239
AY-68-29-418	03/02/2015	Tetrachloroethene	2.05	0.807	239
AY-68-29-418	03/02/2015	TPH Total	0.53	NA	239
AY-68-29-418	03/02/2015	Tetrachloroethene	0.39	0.807	48
AY-68-29-418	03/31/2015	Benzene	0.13	NA	0.25
AY-68-29-418	03/31/2015	TPH Total	1.13	NA	0.25
AY-68-29-418	03/31/2015	Toluene	0.04	NA	0.25
AY-68-29-418	03/31/2015	Tetrachloroethene	0.07	2.53	0.25
AY-68-29-418	03/31/2015	BTEX	0.16	NA	0.25
AY-68-29-418	03/31/2015	Chloroform	<0.02	0.202	0.25
AY-68-29-418	04/10/2015	Benzene	0.03	NA	236
AY-68-29-418	04/10/2015	BTEX	0.03	NA	236
AY-68-29-418	04/10/2015	Tetrachloroethene	1.85	NA	236
AY-68-29-418	04/10/2015	TPH Total	1.24	NA	236

NA = not analyzed.

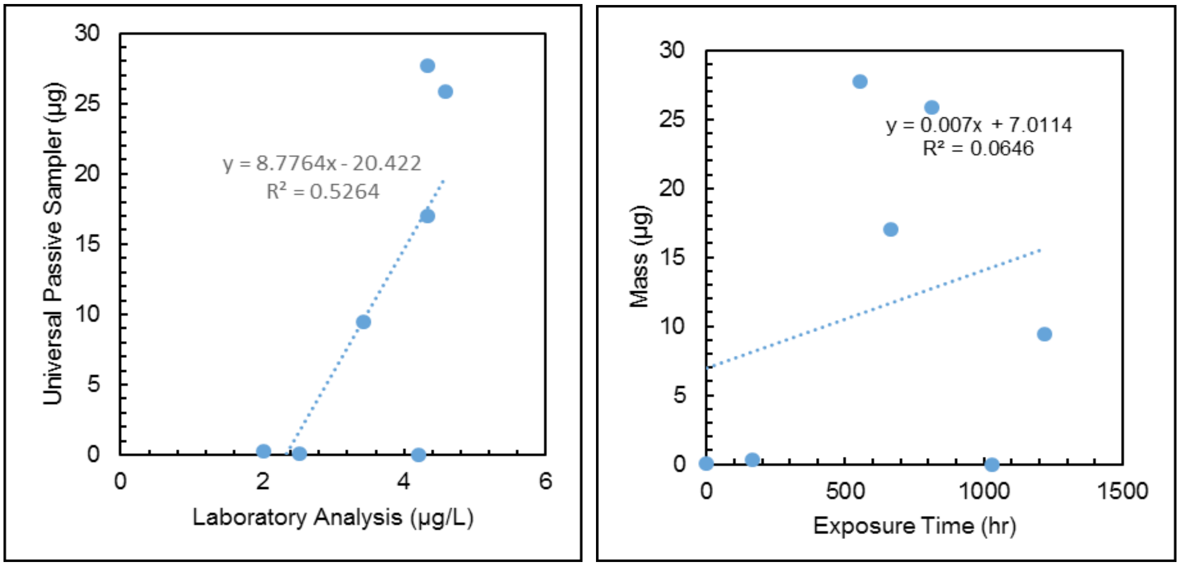


Figure 18. Mass Compared with (left) Laboratory Analyses and (right) Exposure Time for PCE from AY-68-29-418

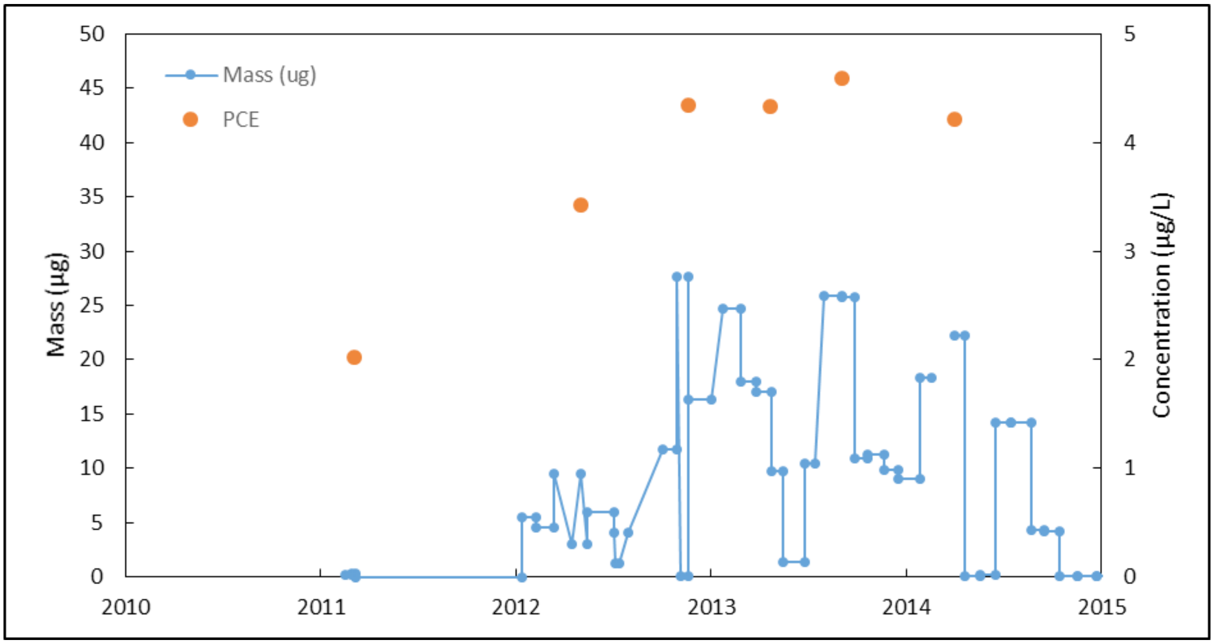


Figure 19. Time Series Chart for PCE from AY-68-29-418

PCE was detected in all grab samples and all but one UPS. Figure 18 shows that the mass of PCE in the UPSs was related slightly to the concentration of PCE in the well, although no relationship existed to the exposure time.

Both mass and concentration results are shown as a function of time in Figure 19. The measured values are significantly higher than those of other wells. Despite the relatively consistent concentrations of PCE, mass values from the UPSs were variable.

Hays County Well

LR-67-09-101 (Crystal Clear)

LR-67-09-101 is located in the recharge zone in western San Marcos. The land around the well is a developed urban area. LR-67-09-101 was sampled 88 times at two different flow zones that were identified using a variety of geophysical and hydrophysical techniques, including video logging. One UPS was set at 136 to 152 ft below ground surface (LR-67-09-101-1), and the second UPS was set at 180 to 190.5 ft below ground surface (LR-67-09-101-4). Sampling in LR-67-09-101 occurred from November 11, 2007, through April 4, 2015. During this period, EAA field staff exchanged the UPSs approximately once a month and obtained a grab sample quarterly.

Table 18. Most Frequently Detected Contaminants in LR-67-09-101 (Crystal Clear)

Sample Location	Chemical Name	Percent Detections
LR-67-09-101-1	PCE	67
LR-67-09-101-1	TPH	65
LR-67-09-101-4	TPH	56
LR-67-09-101-4	PCE	49
LR-67-09-101-1	BTEX	13
LR-67-09-101-4	C11, C13, & C15	14
LR-67-09-101-1	C11, C13, & C15	12
LR-67-09-101-1	Undecane (11 carbons)	10
LR-67-09-101-4	BTEX	9
LR-67-09-101-4	Tridecane (three carbons)	8
LR-67-09-101-1	Benzene	7

Table 19. Top Three Contaminants Detected in LR-67-09-101 (Crystal Clear)

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101-1	11/13/2007	Tetrachloroethene	0.024	NA	362
LR-67-09-101-1	11/13/2007	Tetrachloroethene	0.026	NA	362
LR-67-09-101-1	12/04/2007	Tetrachloroethene	0.032	NA	503
LR-67-09-101-1	12/18/2007	Tetrachloroethene	0.151	NA	332
LR-67-09-101-1	01/25/2008	Tetrachloroethene	0.051	NA	909
LR-67-09-101-1	04/07/2008	TPH Total	0.555	NA	333
LR-67-09-101-1	04/07/2008	Tetrachloroethene	0.08	NA	333
LR-67-09-101-1	04/23/2008	TPH Total	4.847	NA	388
LR-67-09-101-1	05/14/2008	Tetrachloroethene	0.03	NA	502
LR-67-09-101-1	05/14/2008	TPH Total	8.952	NA	502
LR-67-09-101-1	05/28/2008	BTEX	0.02	NA	334
LR-67-09-101-1	05/28/2008	TPH Total	5.612	NA	334
LR-67-09-101-1	06/11/2008	TPH Total	2.431	NA	335
LR-67-09-101-1	06/11/2008	Tetrachloroethene	0.019	NA	335
LR-67-09-101-1	07/16/2008	TPH Total	6.4	NA	814
LR-67-09-101-1	07/16/2008	Tetrachloroethene	0.066	NA	814
LR-67-09-101-1	08/27/2008	Tetrachloroethene	0.04	NA	959
LR-67-09-101-1	08/27/2008	BTEX	0.01	NA	959
LR-67-09-101-1	08/27/2008	TPH Total	3.374	NA	959

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101-1	09/12/2008	TPH Total	0.058	NA	357
LR-67-09-101-1	10/15/2008	TPH Total	2.16	NA	797
LR-67-09-101-1	10/15/2008	Tetrachloroethene	0.03	NA	797
LR-67-09-101-1	11/20/2008	TPH Total	0.164	NA	862
LR-67-09-101-1	11/20/2008	Tetrachloroethene	0.04	NA	862
LR-67-09-101-1	12/18/2008	TPH Total	0.078	NA	670
LR-67-09-101-1	12/18/2008	Tetrachloroethene	0.03	NA	670
LR-67-09-101-1	02/25/2009	Tetrachloroethene	0.039	NA	671
LR-67-09-101-1	04/21/2009	Tetrachloroethene	0.13	NA	626
LR-67-09-101-1	04/21/2009	TPH Total	0.316	NA	626
LR-67-09-101-1	05/26/2009	TPH Total	0.004	NA	700
LR-67-09-101-1	07/02/2009	Tetrachloroethene	0.04	NA	885
LR-67-09-101-1	07/02/2009	TPH Total	0.002	NA	885
LR-67-09-101-1	07/08/2009	TPH Total	1.722	NA	141
LR-67-09-101-1	09/16/2009	TPH Total	0.08	NA	819
LR-67-09-101-1	09/16/2009	Tetrachloroethene	0.069	NA	819
LR-67-09-101-1	10/08/2009	TPH Total	0.068	NA	503
LR-67-09-101-1	10/08/2009	Tetrachloroethene	0.037	NA	503
LR-67-09-101-1	11/10/2009	Tetrachloroethene	0.032	NA	792
LR-67-09-101-1	11/10/2009	TPH Total	0.088	NA	792
LR-67-09-101-1	11/23/2009	TPH Total	0.607	NA	315
LR-67-09-101-1	11/23/2009	BTEX	0.345	NA	315
LR-67-09-101-1	11/23/2009	Tetrachloroethene	0.036	NA	315
LR-67-09-101-1	12/10/2009	TPH Total	0.464	NA	405
LR-67-09-101-1	12/30/2009	TPH Total	0.093	NA	885
LR-67-09-101-1	12/30/2009	BTEX	0.013	NA	885
LR-67-09-101-1	12/30/2009	Tetrachloroethene	0.24	NA	885
LR-67-09-101-1	01/21/2010	Tetrachloroethene	0.049	NA	523
LR-67-09-101-1	01/21/2010	TPH Total	0.171	NA	523
LR-67-09-101-1	02/08/2010	TPH Total	1.334	NA	434
LR-67-09-101-1	02/25/2010	TPH Total	0.58	NA	408
LR-67-09-101-1	03/16/2010	TPH Total	0.749	NA	449
LR-67-09-101-1	04/21/2010	TPH Total	0.262	NA	864
LR-67-09-101-1	05/27/2010	TPH Total	0.796	NA	864
LR-67-09-101-1	06/16/2010	BTEX	0.063	NA	499
LR-67-09-101-1	06/16/2010	TPH Total	0.893	NA	499
LR-67-09-101-1	06/16/2010	Tetrachloroethene	0.023	NA	499
LR-67-09-101-1	06/30/2010	BTEX	0.032	NA	333

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101-1	06/30/2010	TPH Total	0.685	NA	333
LR-67-09-101-1	07/22/2010	TPH Total	0.966	NA	526
LR-67-09-101-1	07/22/2010	BTEX	0.094	NA	526
LR-67-09-101-1	09/13/2010	Tetrachloroethene	0.034	NA	1,275
LR-67-09-101-1	09/13/2010	TPH Total	3.156	NA	1,275
LR-67-09-101-1	09/13/2010	BTEX	0.011	NA	1,275
LR-67-09-101-1	10/14/2010	TPH Total	1.893	NA	745
LR-67-09-101-1	10/14/2010	Tetrachloroethene	0.043	NA	745
LR-67-09-101-1	01/06/2011	TPH Total	1.111	NA	2,013
LR-67-09-101-1	01/06/2011	Tetrachloroethene	0.113	NA	2,013
LR-67-09-101-1	02/08/2011	Tetrachloroethene	0.076	NA	794
LR-67-09-101-1	02/08/2011	TPH Total	1.33	NA	794
LR-67-09-101-1	03/15/2011	Tetrachloroethene	0.032	NA	598
LR-67-09-101-1	03/15/2011	TPH Total	1.43	NA	598
LR-67-09-101-1	04/01/2011	TPH Total	0.24	NA	409
LR-67-09-101-1	04/01/2011	Tetrachloroethene	0.022	NA	409
LR-67-09-101-1	05/11/2011	TPH Total	0.836	NA	956
LR-67-09-101-1	05/11/2011	BTEX	0.01	NA	956
LR-67-09-101-1	05/11/2011	Tetrachloroethene	0.07	NA	956
LR-67-09-101-1	07/05/2011	Tetrachloroethene	0.09	NA	1,368
LR-67-09-101-1	07/05/2011	BTEX	0.012	NA	1,368
LR-67-09-101-1	07/05/2011	TPH Total	0.384	NA	1,368
LR-67-09-101-1	08/11/2011	Tetrachloroethene	0.08	NA	886
LR-67-09-101-1	09/08/2011	Tetrachloroethene	0.041	NA	675
LR-67-09-101-1	09/08/2011	TPH Total	0.542	NA	675
LR-67-09-101-1	10/10/2011	TPH Total	0.074	NA	768
LR-67-09-101-1	10/10/2011	Tetrachloroethene	0.063	NA	768
LR-67-09-101-1	11/10/2011	TPH Total	0.051	NA	740
LR-67-09-101-1	11/10/2011	Tetrachloroethene	0.058	NA	740
LR-67-09-101-1	11/18/2011	Tetrachloroethene	0.034	NA	190
LR-67-09-101-1	11/18/2011	TPH Total	9.414	NA	190
LR-67-09-101-1	04/10/2012	Tetrachloroethene	0.031	NA	817
LR-67-09-101-1	05/23/2012	Tetrachloroethene	0.054	NA	1,034
LR-67-09-101-1	06/12/2012	TPH Total	0.716	NA	474
LR-67-09-101-1	06/12/2012	Tetrachloroethene	0.022	NA	474
LR-67-09-101-1	07/31/2012	Tetrachloroethene	0.041	NA	1,176
LR-67-09-101-1	08/28/2012	TPH Total	0.506	NA	676
LR-67-09-101-1	12/03/2012	Tetrachloroethene	0.105	NA	793

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101-1	01/29/2013	Tetrachloroethene	0.093	NA	1,006
LR-67-09-101-1	05/28/2013	Tetrachloroethene	0.04	NA	816
LR-67-09-101-1	07/25/2013	Tetrachloroethene	0.038	NA	1,064
LR-67-09-101-1	08/29/2013	Tetrachloroethene	0.112	NA	833
LR-67-09-101-1	09/25/2013	Tetrachloroethene	0.065	NA	649
LR-67-09-101-1	09/25/2013	TPH Total	0.729	NA	649
LR-67-09-101-1	10/23/2013	Tetrachloroethene	0.05	NA	671
LR-67-09-101-1	10/23/2013	TPH Total	0.848	NA	671
LR-67-09-101-1	11/19/2013	TPH Total	0.745	NA	650
LR-67-09-101-1	11/19/2013	Tetrachloroethene	0.098	NA	650
LR-67-09-101-1	12/12/2013	Tetrachloroethene	0.03	NA	551
LR-67-09-101-1	01/14/2014	Tetrachloroethene	0.02	NA	789
LR-67-09-101-1	02/20/2014	Tetrachloroethene	0.03	NA	888
LR-67-09-101-1	03/19/2014	Tetrachloroethene	0.04	NA	651
LR-67-09-101-1	04/22/2014	TPH Total	1.73	NA	812
LR-67-09-101-1	05/22/2014	Tetrachloroethene	0.15	NA	718
LR-67-09-101-1	05/22/2014	BTEX	0.57	NA	718
LR-67-09-101-1	05/22/2014	TPH Total	8.586	NA	718
LR-67-09-101-1	06/18/2014	TPH Total	0.922	NA	653
LR-67-09-101-1	06/18/2014	Tetrachloroethene	0.02	NA	653
LR-67-09-101-1	07/18/2014	TPH Total	1.727	NA	715
LR-67-09-101-1	08/14/2014	Tetrachloroethene	0.08	NA	648
LR-67-09-101-1	08/14/2014	Tetrachloroethene	0.05	NA	648
LR-67-09-101-1	10/15/2014	Tetrachloroethene	0.15	NA	698
LR-67-09-101-1	11/12/2014	Tetrachloroethene	0.11	NA	675
LR-67-09-101-1	12/17/2014	Tetrachloroethene	0.18	NA	838
LR-67-09-101-1	01/26/2015	TPH Total	0.6	NA	961
LR-67-09-101 4	11/13/2007	Tetrachloroethene	0.032	NA	362
LR-67-09-101 4	12/04/2007	Tetrachloroethene	0.024	NA	504
LR-67-09-101 4	01/25/2008	Tetrachloroethene	0.051	NA	909
LR-67-09-101 4	04/07/2008	TPH Total	2.336	NA	333
LR-67-09-101 4	04/07/2008	Tetrachloroethene	0.23	NA	333
LR-67-09-101 4	04/23/2008	TPH Total	2.903	NA	388
LR-67-09-101 4	05/14/2008	BTEX	0.02	NA	502
LR-67-09-101 4	05/14/2008	TPH Total	5.756	NA	502
LR-67-09-101 4	05/28/2008	TPH Total	2.733	NA	334
LR-67-09-101 4	06/11/2008	TPH Total	7.784	NA	335
LR-67-09-101 4	06/11/2008	Tetrachloroethene	0.026	NA	335

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101 4	07/16/2008	Tetrachloroethene	0.04	NA	814
LR-67-09-101 4	07/16/2008	TPH Total	3.619	NA	814
LR-67-09-101 4	08/28/2008	Tetrachloroethene	0.03	NA	984
LR-67-09-101 4	08/28/2008	TPH Total	9.63	NA	984
LR-67-09-101 4	09/12/2008	TPH Total	1.398	NA	357
LR-67-09-101 4	10/15/2008	Tetrachloroethene	0.04	NA	797
LR-67-09-101 4	10/15/2008	TPH Total	0.183	NA	797
LR-67-09-101 4	11/20/2008	TPH Total	0.051	NA	862
LR-67-09-101 4	11/20/2008	Tetrachloroethene	0.04	NA	862
LR-67-09-101 4	12/18/2008	Tetrachloroethene	0.02	NA	670
LR-67-09-101 4	12/18/2008	TPH Total	0.12	NA	670
LR-67-09-101 4	01/27/2009	TPH Total	0.361	NA	961
LR-67-09-101 4	02/25/2009	Tetrachloroethene	0.035	NA	671
LR-67-09-101 4	02/25/2009	TPH Total	0.072	NA	671
LR-67-09-101 4	03/26/2009	Tetrachloroethene	0.029	NA	689
LR-67-09-101 4	04/21/2009	TPH Total	0.168	NA	626
LR-67-09-101 4	04/21/2009	Tetrachloroethene	0.08	NA	626
LR-67-09-101 4	07/02/2009	Tetrachloroethene	0.06	NA	885
LR-67-09-101 4	07/02/2009	TPH Total	0.002	NA	885
LR-67-09-101 4	07/08/2009	TPH Total	1.038	NA	141
LR-67-09-101 4	09/16/2009	Tetrachloroethene	0.045	NA	819
LR-67-09-101 4	09/16/2009	TPH Total	0.078	NA	819
LR-67-09-101 4	10/08/2009	Tetrachloroethene	0.026	NA	503
LR-67-09-101 4	10/08/2009	TPH Total	0.113	NA	503
LR-67-09-101 4	11/10/2009	TPH Total	0.121	NA	792
LR-67-09-101 4	11/23/2009	TPH Total	0.179	NA	315
LR-67-09-101 4	11/23/2009	Tetrachloroethene	0.015	NA	315
LR-67-09-101 4	12/10/2009	TPH Total	0.729	NA	405
LR-67-09-101 4	12/30/2009	TPH Total	0.159	NA	885
LR-67-09-101 4	12/30/2009	Tetrachloroethene	0.051	NA	885
LR-67-09-101 4	01/21/2010	Tetrachloroethene	0.032	NA	523
LR-67-09-101 4	01/21/2010	TPH Total	0.087	NA	523
LR-67-09-101 4	02/08/2010	TPH Total	0.867	NA	434
LR-67-09-101 4	02/25/2010	TPH Total	0.813	NA	408
LR-67-09-101 4	02/25/2010	BTEX	0.09	NA	408
LR-67-09-101 4	03/16/2010	TPH Total	1.283	NA	449
LR-67-09-101 4	04/21/2010	TPH Total	0.38	NA	864
LR-67-09-101 4	05/27/2010	TPH Total	0.547	NA	864

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101 4	06/16/2010	BTEX	0.074	NA	499
LR-67-09-101 4	06/16/2010	TPH Total	1.12	NA	499
LR-67-09-101 4	06/16/2010	Tetrachloroethene	0.024	NA	499
LR-67-09-101 4	06/30/2010	BTEX	0.035	NA	333
LR-67-09-101 4	06/30/2010	TPH Total	0.204	NA	333
LR-67-09-101 4	07/22/2010	TPH Total	1.17	NA	526
LR-67-09-101 4	07/22/2010	BTEX	0.031	NA	526
LR-67-09-101 4	09/13/2010	BTEX	0.014	NA	1,275
LR-67-09-101 4	09/13/2010	TPH Total	3.299	NA	1,275
LR-67-09-101 4	09/13/2010	Tetrachloroethene	0.057	NA	1,275
LR-67-09-101 4	10/14/2010	TPH Total	2.115	NA	745
LR-67-09-101 4	01/06/2011	TPH Total	0.335	NA	2,013
LR-67-09-101 4	01/06/2011	Tetrachloroethene	0.06	NA	2,013
LR-67-09-101 4	02/08/2011	TPH Total	1.523	NA	794
LR-67-09-101 4	03/15/2011	TPH Total	1.918	NA	598
LR-67-09-101 4	04/01/2011	TPH Total	0.108	NA	409
LR-67-09-101 4	05/11/2011	Tetrachloroethene	0.061	NA	956
LR-67-09-101 4	05/11/2011	TPH Total	0.599	NA	956
LR-67-09-101 4	05/11/2011	BTEX	0.011	NA	956
LR-67-09-101 4	07/05/2011	Tetrachloroethene	0.079	NA	1,368
LR-67-09-101 4	07/05/2011	TPH Total	0.408	NA	1,368
LR-67-09-101 4	08/11/2011	Tetrachloroethene	0.044	NA	886
LR-67-09-101 4	09/08/2011	TPH Total	0.147	NA	675
LR-67-09-101 4	09/08/2011	Tetrachloroethene	0.03	NA	675
LR-67-09-101 4	10/10/2011	Tetrachloroethene	0.044	NA	768
LR-67-09-101 4	11/10/2011	TPH Total	0.127	NA	740
LR-67-09-101 4	11/10/2011	Tetrachloroethene	0.045	NA	740
LR-67-09-101 4	11/18/2011	TPH Total	6.799	NA	190
LR-67-09-101 4	11/18/2011	BTEX	0.086	NA	190
LR-67-09-101 4	02/14/2012	Tetrachloroethene	0.026	NA	649
LR-67-09-101 4	05/23/2012	Tetrachloroethene	0.02	NA	1,034
LR-67-09-101 4	06/12/2012	TPH Total	0.662	NA	474
LR-67-09-101 4	12/03/2012	Tetrachloroethene	0.075	NA	793
LR-67-09-101 4	12/18/2012	Tetrachloroethene	0.03	NA	355
LR-67-09-101 4	01/29/2013	Tetrachloroethene	0.06	NA	1,006
LR-67-09-101 4	05/28/2013	Tetrachloroethene	0.02	NA	816
LR-67-09-101 4	07/25/2013	Tetrachloroethene	0.03	NA	1,064
LR-67-09-101 4	08/29/2013	Tetrachloroethene	0.082	NA	833

Table 19. Continued

Sample Location	Sample Date	Chemical Name	Mass (µg)	Laboratory Results (µg/L)	Exposure Hours
LR-67-09-101 4	08/29/2013	TPH Total	0.691	NA	833
LR-67-09-101 4	10/23/2013	TPH Total	0.693	NA	671
LR-67-09-101 4	11/19/2013	Tetrachloroethene	0.062	NA	650
LR-67-09-101 4	11/19/2013	Tetrachloroethene	0.034	NA	650
LR-67-09-101 4	02/20/2014	Tetrachloroethene	<0.02	NA	888
LR-67-09-101 4	06/18/2014	TPH Total	0.52	NA	653
LR-67-09-101 4	08/14/2014	Tetrachloroethene	0.06	NA	648
LR-67-09-101 4	09/16/2014	Tetrachloroethene	0.05	NA	791
LR-67-09-101 4	10/15/2014	Tetrachloroethene	0.1	NA	698
LR-67-09-101 4	11/12/2014	Tetrachloroethene	0.09	NA	675
LR-67-09-101 4	12/17/2014	Tetrachloroethene	0.09	NA	838

NA = not analyzed.

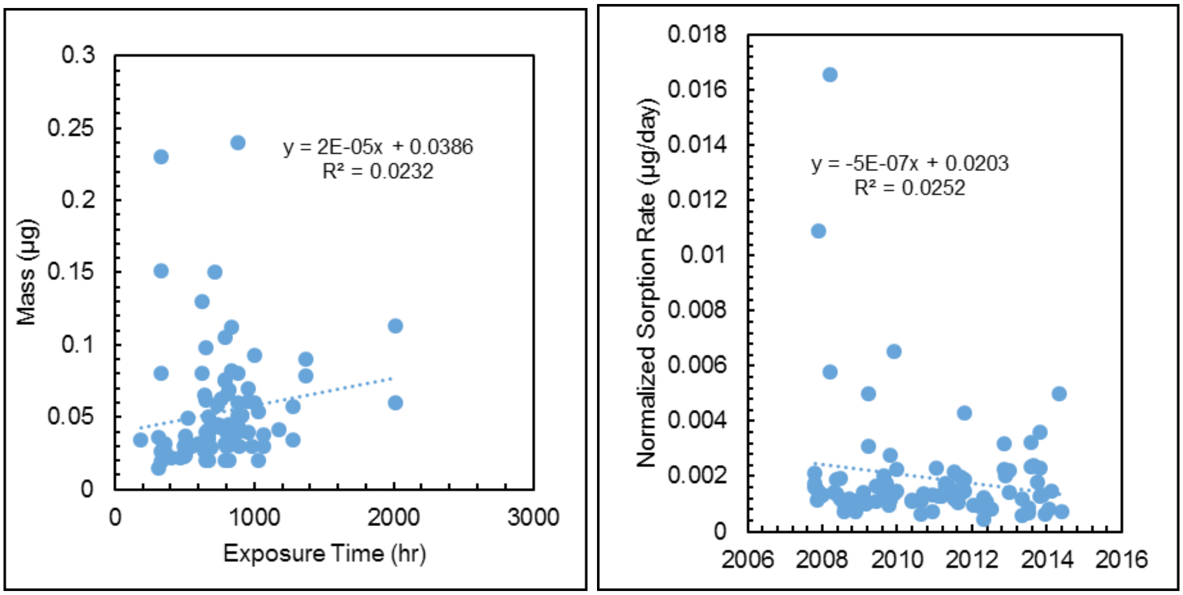


Figure 20. (left) Mass and Exposure Time for PCE and (right) Normalized Sorption Rate for PCE from LR-67-09-101

Most of the UPSs contained detectable concentrations of one or more compounds. The three most frequently detected compounds were PCE, TPH, and BTEX (Table 18). None of these compounds was detected in the grab samples. Unlike at other sites, chloroform was not detected in any UPSs or grab samples. Table 19 lists the top three contaminants detected in LR-67-09-101.

PCE was the most frequently detected compound in UPSs from LR-67-09-101. Figure 20 shows no relationship between PCE mass and exposure time. The normalized sorption rate, which is the sorbed mass divided by exposure time in days, is also shown in Figure 20. Except for a few outliers, it was relatively uniform throughout the study.

SUMMARY AND CONCLUSIONS

Between 2007 and 2015, the EAA evaluated passive sampling devices for improving collection of representative samples for its water quality monitoring program. Historically, EAA's water quality sampling program has consisted of grab samples from wells, stream, and springs. The purpose of this study was to examine the effectiveness of passive sampling techniques in wells. For passive sampling, groundwater samples are collected without purging. Instead, the sampling device is exposed to groundwater in the well, and soluble compounds diffuse through a membrane or sorb onto an appropriate media. The passive samplers evaluated for this study were the PDB, the RPPS, and the UPS. For several reasons, UPSs were selected over PDBs and RPPSs.

UPSs were tested extensively in the field at seven wells throughout the Edwards Aquifer. Four wells are located within the recharge zone surrounded by urban development in Bexar County. One well is located within the recharge zone surrounded by urban development in Hays County. The final two wells are considered to be background wells surrounded by agricultural land—one located in Medina County within the artesian zone and the other in Uvalde County within the recharge zone. The wells were sampled systematically using UPSs for exposure periods ranging from 0.25 to 2,043 hr. On a quarterly basis, EAA field staff exchanged the UPSs and collected a grab sample. Results were compared to determine whether direct relationships existed between mass sorbed on the UPSs and grab sample concentrations.

The UPSs consistently detected fuel-related compounds and solvents at low masses. TPH, PCE, chloroform, BTEX, and toluene were the principal contaminants detected, composing approximately 56% of all detections. A number of TPH analyses were determined to be false positives on the basis of TPH detections in the trip blanks, especially early in the study. Most trip blanks collected after 2011 were uncontaminated, indicating that many later TPH results were representative. The next five compounds, composing 17% of the detections, were C11, C13, & C15 (combined masses of undecane, tridecane, and pentadecane, which are diesel range alkanes); m,p–xylenes; undecane (11 carbons); combined PAHs; and tridecane (three carbons). UPSs consequently appeared to be very sensitive to fuel-related compounds and chlorinated VOCs. Other parameters detected in the UPS analyses are listed in Tables 4 through 7. In general, concentrations were too low or non-existent for grab samples to detect. Only PCE (seven samples), chloroform (27 samples), methyl tert-butyl ether (once), and naphthalene (once) were detected in 238 grab samples. Compounds accumulate on the sorbent in UPSs, facilitating an extremely low effective limit of detection.

Low-level concentrations of fuel-related compounds were also commonly detected by UPSs. Both gasoline range (i.e., BTEX) and diesel range compounds were present at virtually all wells. Although some of the TPH detections were false positives, other fuel-related compounds were representative of groundwater quality in the wells. Many potential sources of fuel-related contaminants are found on the recharge zone, including past and present leaking underground storage tanks and urban stormwater runoff.

Principal Contaminants

Table 20 lists the principal contaminants that were detected in the UPSs. The most frequently detected contaminant was TPH, although a number of the detections are false positives, given the presence of TPH in many trip blanks. In general, grab samples and UPSs commonly detected VOCs, especially PCE and chloroform, and fuel-related compounds, e.g., toluene and naphthalene. These compounds have been and continue to be used widely in relatively large volumes throughout the Edwards Aquifer recharge zone and are highly mobile in groundwater.

Table 20. Top Seven Contaminants Detected and Maximum Concentrations

Chemical Name	Number of Detections	Percentage of Detection	Maximum Concentration (mg)
TPH	383	63	36.63
PCE	307	46	27.699
Chloroform	217	22	0.714
BTEX	140	22	65.657
Toluene	100	15	65.507
C11, C13, & C15	84	15	1.12
m,p-Xylenes	73	11	0.76

Table 21. Top Ten Compounds by Total Detections in Passive Samplers and Locations

Chemical Name	Urban Wells					Rural Wells	
	AY-68-28-608	AY-68-28-313	LR-67-09-101	AY-68-27-303	AY-68-29-418	YP-69-35-602	TD-69-39-504
TPH	107	25	98	55	30	22	8
PCE	44	37	103	50	47	1	0
Chloroform	11	38	0	64	26	0	0
BTEX	68	9	19	14	13	4	2
Toluene	55	5	6	9	10	3	3
C11, C13, & C15	49	2	20	6	1	1	0
m,p - Xylenes	40	8	6	10	4	1	3
Combined PAHs	43	0	8	3	0	0	0
Undecane	27	0	15	6	3	1	1
1,2,4-Trimethyl Benzene	35	1	6	2	3	0	1

Urban and Rural Wells

One of the objectives of the study was to compare results between the five urban wells and two rural wells. Table 21 lists the top ten compounds with respect to total detections in the UPSs at each of the seven wells. In general, significantly fewer compounds were detected at the two rural wells, YP-69-35-602 and TD-69-39-504, than at the urban wells. Only one sample contained PCE, and all other detections were fuel related. In addition, chloroform was absent from the rural wells.

Chloroform, a disinfection byproduct of water chlorination, is commonly detected in urban groundwater. Musgrove et al. (2011) reported that chloroform was the third most commonly detected organic compound in their study of San Antonio area groundwater. They cited “drinking-water treatment processes, leaking water and wastewater lines, septic systems, and recharge from irrigation with treated water” as potential sources of chloroform in an urban setting (p. 47). The five urban wells are located on the recharge zone where many potential contamination sources can be found. The absence of chloroform at LR-67-09-101 is unexplained, although the population density near that well is less near the recharge zone wells in San Antonio.

Like chloroform, PCE was detected frequently in the urban wells in this study. Musgrove et al. (2011) reported that PCE was the fourth most common organic compound in their study of groundwater in the San Antonio area. Of the potential sources they cited, auto parts and repair businesses and dry cleaners are present on the recharge zone. PCE is persistent and highly mobile in groundwater and may travel long distances from its sources. A relatively small release of PCE can contaminate large volumes of groundwater.

Vulnerability of Edwards Aquifer

Vulnerability of the Edwards Aquifer to solvents, especially PCE, and fuel-related compounds was the principal finding from this study. Results indicated that low-level contamination by PCE and fuel-related compounds occurs throughout the aquifer. Many potential sources of PCE and fuel-related compounds can be found on the recharge zone. When a solvent or fuel is spilled or leaked onto the recharge zone, it may be carried readily to groundwater via infiltrating surface water or stormwater. Waste products, such as non-aqueous phase liquids, may accumulate above or below the water table and remain active sources long after the initial spill. Groundwater moves quickly in the recharge zone because of steep hydraulic gradients entraining the compounds and transporting them long distances. Large volumes of groundwater in the aquifer may dilute the compounds to concentrations that the UPSs could detect but are too low for detection in grab samples.

Results showed that UPSs, as used in this study, were most effective as indicators of the presence or absence of organic compounds. Because universal passive sampler results do not correlate with mass or concentration, they cannot be used to quantify water quality between grab sampling events.

Universal passive samplers were deployed for long exposure periods, ranging from 0.25 to 2,043 hr, with an average deployment of 611 hr. One of the objectives of this study was to determine whether UPSs would record the maximum concentration of compounds in the groundwater during the exposure period. Although UPSs detected several compounds at low concentrations, detections of the same compounds in accompanying grab samples were too few to verify that the mass was the maximum. Consequently, the mass sorbed by UPSs did not necessarily represent the maximum concentrations of compounds but did indicate that they were present during the exposure period. In addition, the data did not indicate a correlation between the mass sorbed by UPSs and water concentrations in grab samples. In many cases, mass tended to be independent of the exposure time, suggesting that the UPSs had reached saturation. If a reliable regression existed between mass and water concentration, then the maximums could be calculated. However, determining that the UPSs were capable of detecting contaminants between grab sampling events was an important result.

With respect to addressing the aliasing issue related to changes in water quality between grab sampling events, UPSs could reveal whether particular compounds were present in groundwater between sampling events—even though the mass was not necessarily directly related to the concentration in the water. Universal passive samplers appear to accumulate and concentrate organic compounds, making them more sensitive than grab samples and capable of detecting compounds at concentrations well below conventional laboratory analyses of groundwater samples. They could be used to determine whether a particular compound appeared at a sampling point during the exposure period, possibly reducing the need for high-frequency sampling. Under normal conditions, after the compound has moved past the sampling point, the UPS retains evidence of the detection. Verifying that a particular compound was absent or present may be useful information to regulators or researchers. It could also be a low-cost means of collecting presence/absence indications that would otherwise be unaffordable using multiple grab samples. Universal passive samplers may be deployed at remote locations in ways that are more cost effective than the use of grab samples.

ACKNOWLEDGMENTS

This research was funded by the Edwards Aquifer Authority. The draft manuscript was improved by comments by Geary Schindel and Paul Bertetti. Fieldwork was provided by Chanda Burgoon, Gizelle Luevano, Thomas Marsalia, Ramiro Mendoza, and Anastacio Moncada.

REFERENCES

EPA, 2002, Environmental Technology Verification Report, Gore-Sorber® Water Quality Monitoring: Las Vegas, Nevada, National Exposure Research Laboratory, Environmental Science Division, Report Number EPA/600/R-00/091. (Also available at http://www.epa.gov/ordntrnt/ORD/NRMRL/archive-etv/pubs/01_vr_gore.pdf).

ITRC (Interstate Technology & Regulatory Council), 2005, Technology Overview of Passive Sampler Technologies DSP-4: Washington, D.C, Interstate Technology & Regulatory Council, Authoring Team.

Musgrove, M., Fahlquist, L., Stanton, G.P., Houston, N.A., and Lindgren, R.J., 2011, Hydrogeology, Chemical Characteristics, and Water Sources and Pathways in the Zone of Contribution of a Public-Supply Well in San Antonio, Texas: U.S. Geological Survey Scientific Investigations Report 2011–5146, 194 p.

TCEQ, 2016, http://www.tceq.state.tx.us/assets/public/remediation/dry_cleaners/priorlist_current.pdf, visited August 30, 2016.

APPENDIX A—GLOSSARY OF TERMS

Aliasing	What occurs when a high frequency signal takes on the characteristics of a lower frequency signal because of the sampling interval.
Ambient blank	Sample known to contain no target analytes, which are used to assess airborne contaminants at the site. The ambient blank (AB) is opened at the site and exposed to site (ambient) conditions and treated as an environmental sample thereafter. AB samples apply to VOC analysis only.
Anion	Negatively charged ion.
Aquifer	Underground geological formation or group of formations containing water; source of groundwater for wells and springs.
Cation	Positively charged ion.
DOC	Abbreviation for *dissolved organic carbon*, a broad classification of organic molecules of varied origin and composition within aquatic systems. Organic carbon compounds result from decomposition processes of dead organic matter, such as plants.
DQO	Abbreviation for *data quality objectives*, a process used to develop performance and acceptance criteria or data quality objectives that clarify study objectives, define appropriate type of data, and specify tolerable levels of data needed to support decisions.
Equipment blank	Sample used to assess the effectiveness of the decontamination process on sampling equipment. The equipment blank is prepared by pouring reagent-grade water over/through sampling equipment and analyzing for parameters of concern (to match the sampling routine applicable to the site).
Field duplicate	Second sample collected simultaneously from the same source as that of the parent sample, but which is submitted and analyzed as a separate sample. This sample should generally be identified such that the laboratory is unaware that it is a field duplicate.
Field replicate	Sometimes referred to as a *split sample*, it is a single sample divided into two (or more) samples.
Groundwater	Water found beneath Earth's surface that fills pores between materials, such as sand, soil, or gravel.
Initial rise	Initial surface runoff of a rainstorm. During this phase, water pollution entering storm drains in areas with high proportions of impervious surfaces is typically more concentrated during first flush than it is during the remainder of the storm.
Matrix spike	Sample used to determine the effect of the matrix on a method's recovery efficiency. A known amount of the target analyte is added to a specified amount of matrix sample for which an independent estimate of the target analyte concentration is available. Duplicate samples must be available as well (matrix spike duplicate, or MSD).
MDL	Abbreviation for *method detection limit*, minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero, as determined from analysis of a sample containing the analyte in a given matrix.
Peak	Maximum instantaneous flow at a specific location resulting from a given storm condition.
PQL	Abbreviation for *practical quantitation limit*, which is the smallest concentration of the analyte that can be reported with a specific degree of confidence.
Precision	State or quality of being precise; exactness. The ability of a measurement to be consistently reproduced.

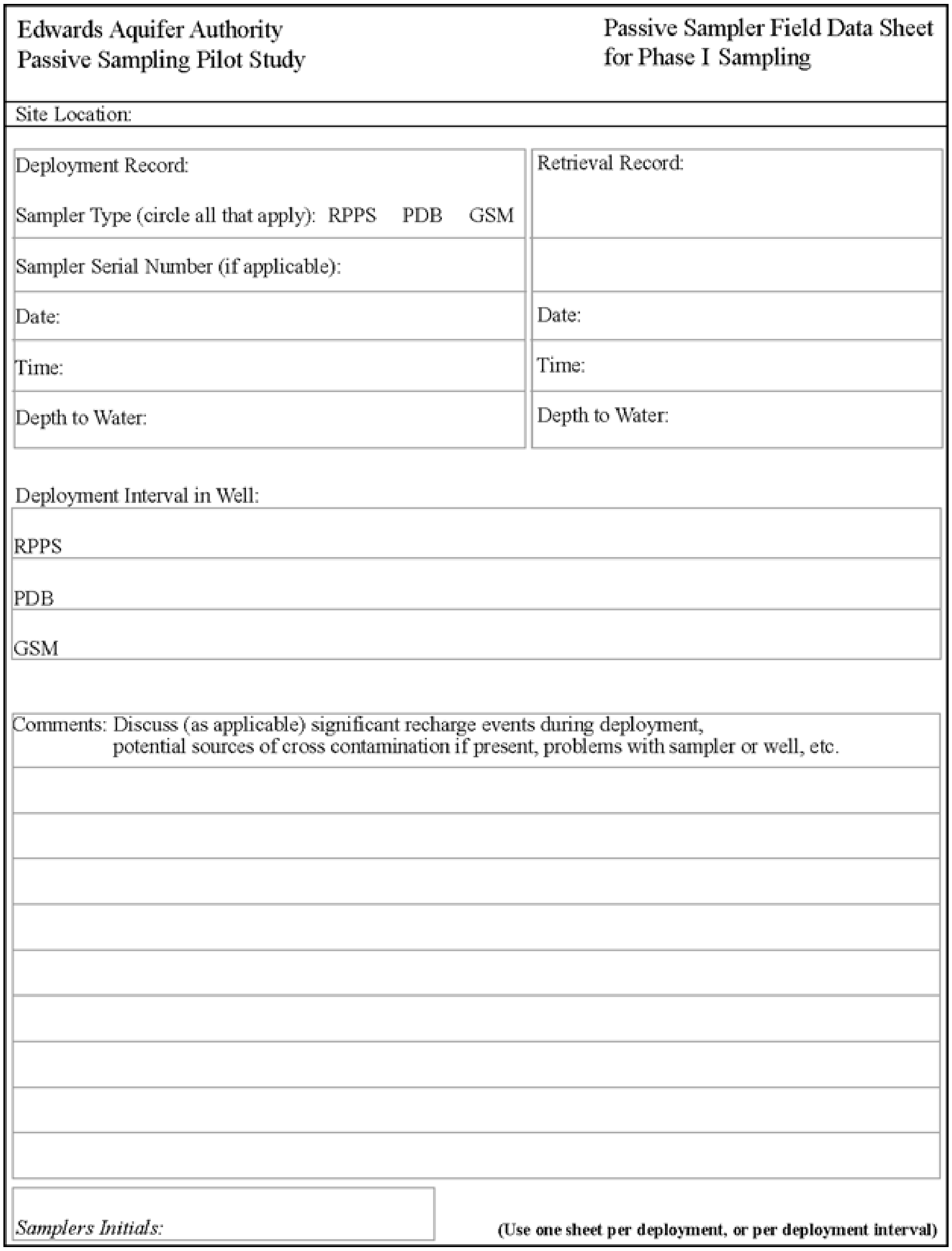
Purge	The act of removing standing water in a well.
Recession	End of runoff event, which is defined as the point in time when the recession limb of the hydrograph is <2% of the peak or is within 10% of the prestorm base flow, whichever is greater.
Recharge zone	Area in which an aquifer is replenished with water by the downward percolation of precipitation through soil and rock.
Representative	Said of samples collected that are similar to those of groundwater in its in situ condition.
RL	Abbreviation for *reporting limit*, the smallest concentration of an analyte reported by the laboratory to a customer. The RL is never less than the PQL and is generally twice the MDL.
Spike sample	One of any known concentrations of specific analytes that have been added to minimize change in the matrix of the original sample. Every spike sample analyzed should have an associated reference to the spike solution and the volume added.
Spring	Water coming naturally out of the ground.
Surface water	Water that forms and remains above ground, such as lakes, ponds, rivers, streams, bays, and oceans.
SVOC	Abbreviation for *semivolatile organic compounds*, which is a group of chemicals composed primarily of carbon and hydrogen that have a tendency to evaporate (volatilize) into the air from water or soil. Some of the compounds that make up asphalt are examples of SVOCs.
TDS	Abbreviation for *total dissolved solids*, or the total amount of all inorganic and organic substances, including minerals, salts, metal, cations, or anions that are dispersed within a volume of water.
Temporal	Over a period of time.
TKN	Abbreviation for *total Kjeldahl nitrogen*, which is the total concentration of organic and ammonia nitrogen in wastewater.
TOC	Abbreviation for *total organic carbon*, which is the gross amount of organic matter found in natural water. Suspended-particulate, colloidal, and dissolved organic matter are part of the TOC measurement. Settable solids consisting of inorganic sediments and some organic particulate are not transferred from the sample by the lab analyst and are not part of the TOC measurement.
Trip blank	Sample known to be free of contamination (for target analytes) that is prepared in the laboratory and treated as an environmental sample after receipt by the sampler. Trip blank (TB) samples are applicable to VOC analysis only.
TSS	Abbreviation for *total suspended solids*, which are the nonfilterable residue retained on a glass-fiber disk filter mesh measuring 1.2 micrometers after filtration of a sample of water or wastewater.
VOC	Abbreviation for *volatile organic compounds*, which are often used as solvents in industrial processes and are either known or suspected carcinogens or mutagens. The five most toxic are vinyl chloride, tetrachloroethylene, trichloroethylene, 1,2-dichloroethane, and carbon tetrachloride.
Well	Bored, drilled, or driven shaft whose purpose is to reach underground water supplies.

APPENDIX B—BASIC FIELD INSTRUCTIONS

Basic Instructions for Environmental Science Technicians

Environmental science technicians will need to maintain records (field logs) specific to the passive samplers, as well as records for any grab samples collected during the pilot study. Field data will be transferred to an electronic master log of all samples taken in relation to the pilot study program. Data from the master log will be transferred weekly to a duplicate (backup) file located on the EAA's network.

Field data will be recorded on the field data sheet (Figure B1, Phase I field data sheet). Field personnel must receive instruction on passive sampling procedures prior to participation in field activities. Instruction will be provided in-house in the form of a one day seminar.



Edwards Aquifer Authority
Passive Sampling Pilot Study

Passive Sampler Field Data Sheet
for Phase I Sampling

Site Location:

Deployment Record: Sampler Type (circle all that apply): RPPS PDB GSM	Retrieval Record:
Sampler Serial Number (if applicable):	
Date:	Date:
Time:	Time:
Depth to Water:	Depth to Water:

Deployment Interval in Well:

RPPS

PDB

GSM

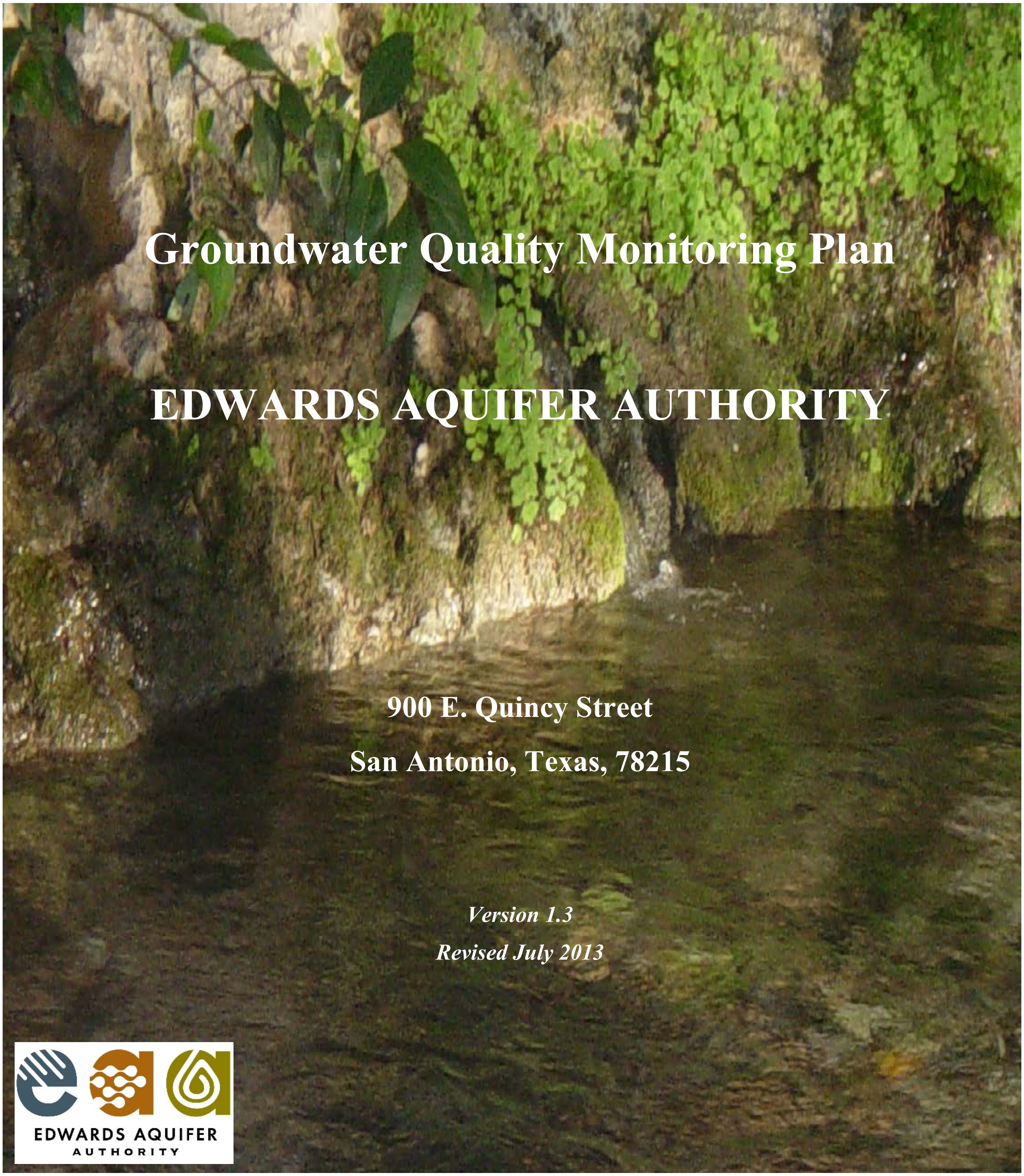
Comments: Discuss (as applicable) significant recharge events during deployment, potential sources of cross contamination if present, problems with sampler or well, etc.

Samplers Initials:

(Use one sheet per deployment, or per deployment interval)

Figure B1. Field Sheet

APPENDIX C—EXCERPT FROM
GROUNDWATER QUALITY MONITORING PLAN



Groundwater Quality Monitoring Plan

EDWARDS AQUIFER AUTHORITY

900 E. Quincy Street
San Antonio, Texas, 78215

Version 1.3
Revised July 2013

EDWARDS AQUIFER
AUTHORITY

CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ASTM	American Society of Testing and Materials
bgs	below ground surface
COC	chain of custody
DQO	data quality objective
EAA	Edwards Aquifer Authority
EAHCP	Edwards Aquifer Habitat Conservation Plan
e-line	electronic water level measurement device
GW	groundwater
MSL	mean sea level
NAWQA	national water quality assessment
PPCP	pharmaceutical and personal care products
psi	pounds per square inch
QA	quality assurance
QC	quality control
SOP	standard operating procedure
TWDB	Texas Water Development Board
USGS	United States Geological Survey
U.S. EPA	United States Environmental Protection Agency
VOA	volatile organic analysis
VOC	volatile organic compound

SECTION 1

PURPOSE AND OBJECTIVES

1.1 PURPOSE AND OBJECTIVES OF THE PLAN

Data derived from water quality sampling and analysis provide the primary indicator of the state of water quality in the Edwards Aquifer. These data are also a key component of assessing water quality changes over time. Water quality data also compose the primary source of information for our understanding and monitoring of contaminant loading and migration in the Edwards Aquifer. As such, analytical samples collected for assessing water quality must be collected under a set of standard operating procedures (SOPs), which are outlined in this plan. Included herein are sections on data quality objectives (DQOs), sampling programs, analytical methods, field procedures, and guidelines for plan review.

The purpose of this plan is to provide an SOP document ensuring that useful, consistent, and defensible water quality data are produced by implementation of appropriate procedures and methods when water quality samples are being collected and analyzed. Water quality samples are currently collected under various sampling programs at the Edwards Aquifer Authority (EAA). Data quality requirements vary by program and are discussed in Sections 2 and 3.

Section 2 of this plan provides a description of DQOs in general, as well as DQOs for this program. Section 3 provides detailed information for each of the sampling programs. Section 4 provides a listing of analytical methods used by the EAA, as well as data-flagging requirements, information for sample containers, hold times, and sample preservation. Section 5 outlines field procedures; Section 6 discusses staff training and field audits. Section 7 provides information regarding annual plan review, and Section 8 provides a list of references cited in the document. The appendices (A–G) provide maps of sample locations, a glossary of terms, instrument operation and calibration information, field forms, information on regulatory limits for various compounds, stormwater sample-collection details, and equipment-decontamination procedures.

The purpose of this plan can be achieved by implementation of the objectives listed below and discussed in detail in Sections 2–7 of the plan. Each EAA staff member charged with the responsibility of collecting water quality or other analytical samples is required to be familiar with this plan, along with the objectives and procedures outlined in it. The objectives of this plan are to

- Obtain quality data that are defensible for their intended purpose,
- Analyze field samples in an appropriate and consistent manner such that the results are accurate and repeatable (see calibration procedures in Appendix C),
- Collect samples for laboratory analysis in an appropriate and consistent manner that will ensure accurate and reliable analytical results with a minimal number of anomalous data,

- Select sample sites and time periods that will provide representative water quality data for a range of aquifer conditions, and
- Review the plan annually and revise as needed.

SECTION 2

DATA QUALITY OBJECTIVES

The U.S. Environmental Protection Agency (U.S. EPA) has developed criteria for data quality objectives utilizing a seven-step process that optimizes sample collection and analysis on the basis of data uses, fiscal budget, sample quantity, and other parameters (U.S. EPA, 2000). The process is iterative and may be modified by the planning team to incorporate changes as required:

1. **State the Problem**
   Define the problem, identify the planning team, and examine the budget and schedule.
2. **Identify the Decision**
   State the decision, identify study questions, and define alternative actions.
3. **Identify Inputs to the Decision**
   Identify information needed for the decision, such as information sources, bases for action level, and sampling and analysis methods.
4. **Define the Boundaries of Study**
   Specify sample characteristics, and define spatial/temporal limits and units of decision making.
5. **Develop a Decision Rule**
   Define parameters for decision rules, specify action levels, and develop logic for action.
6. **Specify Tolerable Limits on Decision Errors**
   Set acceptable limits for decision errors relative to consequences (health effects, costs, other impacts).
7. **Optimize the Design for Obtaining Data**
   Select a resource-effective sampling and analysis plan that meets performance criteria.

2.1 U.S. EPA DQO PROCESS AS APPLIED TO EAA ANALYTICAL PROGRAMS

2.1.1 DQO—State the Problem

Collect and analyze groundwater, spring water, and surface water samples that are contained in, issue from, or provide recharge to the Edwards Aquifer. In addition, collect stormwater and sediment samples as needed to satisfy program requirements. Sampling activities are to be conducted such that sufficient funding is held in reserve to collect confirmation samples if needed. In addition, the program must be flexible enough to collect samples in the event of a contingency (spill or other event) that affects or could potentially affect water quality of the Edwards Aquifer. The planning team includes the Chief Technical Officer (CTO) and supervisory staff of the Aquifer Science Team of the EAA. Budget is proposed by the team and presented for board approval annually. The schedule is annual, with a general goal of collecting a minimum of 80 samples from wells, sampling all major springs (monthly or quarterly, depending on hydrologic conditions), and sampling surface waters twice annually while maintaining a budget reserve sufficient to address other needs (confirmation and contingency sampling).

Under a separate budget, the same team is charged with collecting surface water, stormwater, and sediment samples in support of the Edwards Aquifer Habitat Conservation Plan (EAHCP). Surface water, stormwater, and sediment samples are collected upstream, within, and downstream of Comal and San Marcos springs. Comal Springs has five designated sample locations, whereas San Marcos Springs has seven. Surface water and stormwater samples are to be collected twice annually, whereas sediment samples are collected once annually for the first year (to obtain baseline sediment quality information). Subsequent years may vary depending on results. See *Water Quality Monitoring Program Strategy for Comal Springs and San Marcos Springs in Support of the Edwards Aquifer Habitat Conservation Plan* (EAHCP Workplan).

2.1.2 DQO—Identify the Decision

The decision is to collect the samples as described earlier under the sampling programs and protocols outlined in detail in this document. Study questions are:

- Can the quality of water entering into, residing in, and issuing forth from the Edwards Aquifer be representatively monitored?
- For the allowed budget, how many analytical parameters can be collected?
- What analytical parameters are the most informative with regard to water quality?
- Can a relevant data set that provides historical and current water quality information as relates to the Edwards Aquifer, be developed and maintained?
- Can the data indicate trends in water quality over time?
- Can contingency sampling functionally define contaminant flowpaths and ultimately help in the prevention of public exposure to contaminants in the event of a spill?
- How does the EAA functionally share the information collected with stakeholders and the public?

Alternative actions are to

- Modify the analytical parameter list to accommodate budget constraints,
- Reduce the number of sample points and sample frequency if needed to accommodate budget constraints, and
- Continually review results to assess the need for, and feasibility of, modifying the parameter list such that analytical parameters collected

provide the most information for the program, as well as cost-effective information.

2.1.3 DQO—Identify Inputs to the Decision

Sample frequency, sample type, and analytical program are all based on many inputs. The EAA strategic plan dictates minimum sample numbers, for example. Other inputs of importance include findings from karst researchers worldwide regarding the varying nuances of sampling in karst environments (i.e., multiple samples from a single location are generally more valuable than single samples from multiple locations). Assimilating and incorporating information gleaned from EAA sample results annually provide significant inputs to the process as well.

Action levels as defined for this study are not directly comparable to action levels for hazardous waste cleanup. In this program, action levels generally depend on sample type and program: for example, stormwater samples are triggered by specific stormwater events. Action levels may also be related to contingencies. If a contaminant of concern is detected in relation to a contingency, then additional sampling may be triggered. In other cases, an action level may be reached if an anthropogenic compound is detected above a regulatory limit. The resulting action will generally be to utilize additional sampling so as to delineate a possible source if a "contaminant" is the trigger.

Sampling and analysis methods are specific to each sampling program and are designed to provide data on water quality and changes to water quality that may occur over time. Results of each program are reviewed regularly, and changes to the parameters for each program may be made on the basis of these reviews or other needs. All programs are generally analyzed for field parameters (conductivity, dissolved oxygen [DO], turbidity, pH, and temperature) at the time the sample is collected. Other laboratory analytical parameters are then designated on the basis of the program.

2.1.4 DQO—Define Boundaries of the Study

Spatially the study is limited to the Edwards Aquifer Region, which includes contributing area, recharge zone, and artesian zone of the aquifer, as well as contiguous areas that may be pertinent to data collection. Temporal limits are defined by sample program and hydrologic condition. Temporal parameters are described in more detail under sample programs.

2.1.5 DQO—Develop a Decision Rule

Decision rules are defined by multiple factors:

- Strategic plan,
- Board directives,
- Approved budget,
- Data analyses and results,
- Historical data for a particular site, and
- EAHCP requirements.

2.1.6 DQO—Specify Tolerable Limits on Decision Errors

Decision-error limits are dictated by sample program. Whereas all results are considered important, contingency samples have an elevated priority because of the potential to provide a warning to the public in the event water quality is impacted. As such, in the event of a major contingency that requires long-term sampling and analysis, the budget impact would be significant. In some scenarios, additional laboratory funding would be requested from the board to cover these costs. Other sample programs are expected to be well planned and orchestrated such that no budget overruns occur.

The goal of the program in general is to collect a number of samples adequate to monitor the health of the Edwards Aquifer with high confidence that results are representative and accurate. These samples are collected through various sampling programs, as outlined in the next section.

2.1.7 DQO—Optimize the Design for Obtaining Data

The sampling plan as designed provides a resource-effective plan that meets performance criteria through data review, data assessment, and program requirements. The design is optimized by the data needs of each sample program, in which analytical parameters are specific to a program and designed to provide a maximum number of data cost-effectively.

2.2 ADDITIONAL INPUTS FOR DQO PROCESS

Another definition of DQOs is provided by the Air Force Center for Environmental Excellence (AFCEE) in its *Quality Assurance Project Plan* (QAPP), which states that "DQOs specify the data type, quality, quantity, and uses needed to make decisions and are the basis for designing data collection activities" (AFCEE, 2001). The U.S. EPA and the AFCEE both generally utilize DQOs for hazardous waste clean-up sites, which often represent a threat to public health and the environment. However, sampling programs at the EAA differ in that most samples taken are "clean" and are not used to assess the success of a clean-up action.

Therefore, for the purposes of this plan, DQOs are met by assigning a level of precision and procedural techniques and parameter suites that are appropriate for the sample type and monitoring program. Whereas it is the purpose of this plan for all data produced to be representative and fully defensible, all data do not necessarily need to be analyzed by reference methods in the analytical laboratory utilizing a full suite of QA/QC samples. Most water quality samples collected are intended for monitoring the general status of water quality within the Edwards Aquifer, with one potential exception. In some cases, contingency sampling may be used to assess the impact of an event (i.e., a spill) to the Edwards Aquifer that has the potential for public health implications.

Therefore, DQOs developed for this document are designed to provide data of quality and quantity adequate to reflect the needs of the sample program under which a particular sample is collected. Most analytical data collected are designed to assess

- The presence or absence of anthropogenic compounds in the sample.

- Changes to chemical quality of the sample point when compared with prior data,
- Development of data adequate to establish a record of water quality such that future changes to water quality can be measured,
- Measurement of changes to water quality against changes in hydrologic conditions, and
- In the case of confirmation samples, assessment with a high degree of confidence the presence or absence of a compound of interest.

SECTION 3

SAMPLING PROGRAMS AND OBJECTIVES

Water quality samples are collected under one of the EAA sample programs described in detail in this section. Sample parameters vary with the sample program. For a better understanding of the sampling programs and sample distribution, typical water quality sample locations, see Appendix A, which is a listing of sample type and program. EAHCP sample locations are also provided.

3.1 SAMPLE TYPES AND SAMPLE PROGRAMS

Sample type is simply defined by source and media. The EAA collects samples from wells, springs, surface water, and, at times, groundwater in caves. Samples of soil or sediment may also be collected under some circumstances. As such, sample types are:

- Wells (applies to groundwater samples and includes water collected in caves),
- Springs,
- Surface water,
- Soil or sediment, and
- Stormwater.

Sample programs exist for each sample type, driving the DQO process for a given sample. Each sample program has a defined sample frequency and analytical parameter list. However, the analytical parameter list is always subject to future revision to accommodate changing circumstances. Table 3-1 summarizes current sample types and individual sample programs conducted by the EAA.

Table 3-1. Sample Types and Sample Programs

Sample Type	Sample Program	Sample Frequency	Analytical Parameters
Wells	Passive	Quarterly	FP, GWQP, VOC, TPH, TOC, PAH, metals, bacteria
	NAWQA	Annually	FP, GWQP, VOC, 8081B, 8141A, 8151A, 8082A, TOC, PAH, metals, bacteria
	Routine	Annually	FP, GWQP, VOC, 8081B, 8141A, 8151A, TOC, PAH, metals, bacteria
	TWDB	Annually	FP, GWQP, VOC, 8081B, 8141A, 8151A, TOC, PAH, metals, bacteria
	PPCP	Annual	FP, PPCP (limited to nine wells annually)
	Contingency	As needed	Defined by contingency event
	Confirmation	As needed	Defined by detection needing confirmation
	QA/QC	Per QA needs	Defined by QA program
	EAHCP	Water level dependent	FP, GWQP, TOC, TDS
Springs	Primary	Quarterly (noncritical period) Monthly (critical period)	FP, GWQP, SVOC, VOC, 8081B, 8141A, 8151A, 8082A, TOC, metals, total phosphorous, bacteria, orthophosphate as P
	Secondary	Annually	FP, GWQP, SVOC, VOC, 8081B, 8141A, 8151A, 8082A, TOC, metals, total phosphorous, bacteria
	PPCP	Annually	FP, PPCP (limited to six spring samples annually)
	Contingency	As needed	Defined by contingency event
	Confirmation	As needed	Defined by detection needing confirmation
	QA/QC	Per QA needs	Defined by QA program
Surface water	Primary	Twice annually	FP, GWQP, 8081B, 8141A, 8151A, 8082A, TOC, PAH, metals, total phosphorous, bacteria
	Secondary	Annual	FP, GWQP, 8081B, 8141A, 8151A, 8082A, TOC, PAH, metals, total phosphorous, bacteria
	EAHCP	Twice annually	FP, GWQP, VOC, SVOC, 8081B, 8141A, 8151A, 8082A, TOC, metals, total phosphorous, bacteria, TKN, DOC
	PPCP	Annually	FP, PPCP (limited to two surface water samples annually)
	Contingency	As needed	Defined by contingency event
	Confirmation	As needed	Defined by detection requiring confirmation
	QA/QC	Per QA needs	Defined by QA program
Soil/sediment	EAHCP	Annually	FP, GWQP, VOC, SVOC, 8081B, 8141A,

Sample Type	Sample Program	Sample Frequency	Analytical Parameters
			8151A, 8082A, TOC, metals, total phosphorous
	Contingency	As needed	Defined by contingency event
	Confirmation	As needed	Defined by detection requiring confirmation
	QA/QC	Per QA needs	Defined by QA program
Stormwater	EAHCP	Twice annually	FP, GWQP, VOC, SVOC, 8081B, 8141A, 8151A, 8082A, TOC, metals, total phosphorous, bacteria, TKN
	Confirmation	As needed	Defined by detection requiring confirmation
	QA/QC	Per QA needs	Defined by QA program

FP=field parameter, GWQP=general water quality parameters, SVOC=semivolatile organic compound, VOC=volatile organic compound, TOC=total organic carbon, TKN=total Kjeldahl nitrogen, PPCP=personal care and pharmaceutical products., PAH=polynuclear aromatic hydrocarbons, TPH=total petroleum hydrocarbons, DOC=dissolved organic compounds

3.2 SAMPLE PROGRAM DETAIL

The sample types and programs summarized in Table 3-1 comprise the various analytical samples collected and analyzed by the EAA. Specific details of each program are provided in this section.

Sample Programs for Well Sample Types

1. **Passive Sampling Program**

   The passive sampling program is a program to provide continuous monitoring of particular wells (referred to as sentinel wells) through the use of a passive sampling device. The device currently used is the Amplified Geochemical Imaging (AGI), LLC passive diffuse sample module (aka, Gore Module). This device utilizes a sorbent material encased in GoreTex® fabric that is capable of detecting certain analytes for volatile and semivolatile compounds, as well as petroleum hydrocarbon compounds. The Gore Modules are hung at specific intervals continuously in a sentinel well and replaced each month. The module is then shipped to AGI, LLC. for analysis (which is included as part of the module cost). Currently six wells designated as sentinel wells are located in Medina, Bexar, and Hays counties. These wells are sampled via grab sample quarterly. Sample parameter selection for this sample type is generally based on collecting parameters that are also detectable by the Gore Module, plus some additional parameters of value to an understanding of long-term trends in water quality. Sample frequency is also selected to detect temporal changes in water quality at a single sample point.

2. **National Water Quality Assessment (NAWQA) Program**

The NAWQA wells are a series of thirty wells installed by the USGS for long-term assessment of water quality on a regional and national scale. Ten of these wells (all in the recharge zone of Bexar County) are sampled annually. The sample parameter list is selected on the basis of the NAWQA program and is used to contribute data to that study, as well as to build a historical record of water quality for the EAA data set. Ten out of 30 NAWQA wells are sampled annually, and every well must be sampled within a three-year period.

3. Routine Water Quality Monitoring

Routine water quality samples are collected from a variety of well types (monitoring, domestic, agricultural, industrial, and municipal) to provide a data set for water quality region-wide for different well types. Sample parameters are broad in spectrum and designed to detect the most common anthropogenic compounds, as well as to document changes in concentrations of common cations and anions. These wells are generally sampled annually or less frequently.

4. Texas Water Development Board (TWDB)

Twenty TWDB samples are collected at designated wells using a split-sample technique, such that a sample set is sent to the TWDB contract laboratory (at no cost to the EAA). The remaining sample is sent to the EAA contract laboratory and analyzed for some of the same (TWDB) parameters, as well as additional parameters. This sample type provides a cost-effective tool for evaluation and comparison of analytical results for certain parameters (metals and anions). These wells (or springs, in some cases) are sampled annually under this program for a wide variety of parameters and are also used to assess the health of the system and to establish potential changes or trends in quality.

5. Pharmaceuticals and Personal Care Products (PPCPs)

These parameters detect various compounds found in common personal care products, as well as medications and household items. The primary value in this sample group is the conclusiveness of the data. Because the detection limits are low and the percentage of detections (at low concentrations) to date is high, this sample program appears to provide the most conclusive evidence of anthropogenic impacts on the Edwards Aquifer. The current sample budget allows for nine wells, six springs, and two surface waters to be sampled annually for these parameters. The same locations are sampled each year (with some exceptions) to provide a temporal record of water quality changes associated with the compounds. This program is being evaluated for an increase in sample frequency at some locations.

6. Contingency Samples

Contingency samples are collected only on an as-needed basis to assess potential contamination events related to spills or similar contingencies that have a high potential for affecting water quality in the Edwards Aquifer. Sample parameters and sample frequency are determined on the basis of type of spill (or other contingency), as well as the size of the event. Sample parameters and frequency are decided on by management. EAA staff members are subsequently directed to an appropriate course of action on the basis of assessment of the event by management.

7. **Confirmation Samples**
   Confirmation samples are samples collected in response to an unexpected detection at a site where additional confirmation is needed in order to assess the probability that detection is not a sampling artifact or otherwise false detection. Confirmation detections are method and analyte specific and are taken at the direction of management.

8. **QA/QC Samples**
   QA/QC samples are discussed in detail in Section 3.3.

9. **EAHCP Drought Contingency-Sampling of transect wells and Springs**
   Well samples collected for the EAHCP are collected only when certain springflow criteria are met—specifically, low-flow situations at Comal and San Marcos springs. For Comal Springs, when flows fall below 30 cubic feet per second (cfs), weekly monitoring at three wells is to be conducted for DO, conductivity, pH, and temperature. The next trigger at Comal Springs is 20 cfs, and weekly monitoring is conducted using the same parameters plus nutrients, TDS, and TOC. For San Marcos Springs, the first trigger is 50 cfs, and the second trigger is 30 cfs.

Sample Programs for Spring Sample Types

1. **Primary Springs**
   Primary springs are Comal, Hueco, and San Marcos. They are sampled monthly during critical periods (critical period = a ten-day average when water levels at Bexar, County, index well J-17 of below 660 feet msl, and/or a ten-day average springflow rate at either Comal or San Marcos springs is less than 225 cfs for Comal Springs and less than 96 cfs for San Marcos Springs). During noncritical periods, sampling is generally conducted quarterly. Sample parameters are extensive because the springs represent a composite sample of aquifer water and are directly associated with habitat for threatened and endangered species.

2. **Secondary Springs**
   Secondary springs generally produce a smaller volume of springflow and may or may not be located within the San Antonio Segment of the Edwards Aquifer. These springs are Las Moras (Fort Clark Springs), San Pedro, San Antonio, Government Canyon, and other springs that may be designated for infrequent sampling. Las Moras is generally sampled annually, whereas the others are sampled quarterly or annually if flowing. Sample parameters are the

same as those for the primary springs, except that sample frequency differs between primary and secondary.

3. **Pharmaceuticals and Personal Care Products (PPCPs)**
   These parameters detect various compounds found in common personal care products, as well as medications and household items. The primary value in this sample group is the conclusiveness of the data. Because the detection limits are low and the percent of detections (at low concentrations) to date are high, this sample program appears to provide the most conclusive evidence of anthropogenic impacts on the aquifer. The current sample budget allows for nine wells, six springs, and two surface waters to be sampled annually for these parameters. The same locations are sampled each year (with some exceptions) to provide a temporal record of water quality changes associated with the compounds. This program is being evaluated for an increase in sample frequency at some locations.

4. **Contingency Samples**
   Contingency samples are collected only on an as-needed basis to assess potential contamination events related to spills or similar contingencies that have a high potential for affecting water quality in the Edwards Aquifer. Sample parameters and sample frequency are determined on the basis of type of spill (or other contingency), as well as the size of the event. Sample parameters and frequency are decided on by management. EAA staff members are subsequently directed to an appropriate course of action on the basis of assessment of the event by management.

5. **Confirmation Samples**
   Confirmation samples are samples collected in response to an unexpected detection at a site where additional confirmation is needed in order to assess the probability that detection is not a sampling artifact or otherwise false detection. Confirmation detections are method and analyte specific and are taken at the direction of management.

6. **QA/QC Samples**
   QA/QC samples are discussed in detail in Section 3.3.

7. **Drought Contingency-Sampling of transect wells and Springs**

Sample Programs for Surface Water Sample Types

1. **Primary Surface Water**
   Primary surface waters are collected twice annually from eight locations: Nueces River at Laguna, Dry Frio River at Reagan Wells, Frio River at Concan, Sabinal River near Sabinal, Seco Creek at Miller Ranch, Hondo Creek near Tarpley, Medina River at Bandera, and Blanco River at Wimberley. These sample locations have a significant historical sample record

and provide information regarding the quality of waters that effectively provide recharge to the Edwards Aquifer. Sample parameter lists are fairly significant, but do not generally include VOCs because of the low probability of detection of these compounds in a surface water environment.

2. **Secondary Surface Water**
   Secondary surface water sites may have varying locations and are generally sampled only annually. They are generally sites of interest because of their ability to provide recharge to the aquifer, or they may be indicators of water quality from springs issuing forth from the Trinity Aquifer. Sample parameter lists are fairly significant but do not generally include VOCs because of the low probability of detection of these compounds in a surface water environment.

3. **EAHCP Surface Water Samples**
   EAHCP surface water samples are collected at Comal and San Marcos springs; Comal Springs has five sample locations, whereas San Marcos has seven sample locations, which are situated upstream and downstream of the spring orifice locations. Parameters provide a broad spectrum of analyses so that water quality might be better understood in detail at these locations. The parameters list will also be used to study trends in water quality at these locations over time. Sample frequency is twice annually.

4. **Pharmaceuticals and Personal Care Products (PPCPs)**
   These parameters detect various compounds found in common personal care products, as well as medications and household items. The primary value in this sample group is the conclusiveness of the data. Because the detection limits are low and the percent of detections (at low concentrations) to date high, this sample program appears to provide the most conclusive evidence of anthropogenic impacts on the aquifer. The current sampling budget allows for nine wells, six springs, and two surface waters to be sampled annually for these parameters. The same locations are sampled each year (with some exceptions) to provide a temporal record of water quality changes associated with the compounds. This program is being evaluated for an increase in sample frequency at some locations.

5. **Contingency Samples**
   Contingency samples are collected only on an as-needed basis to assess potential contamination events related to spills or similar contingencies that have a high potential for affecting water quality in the Edwards Aquifer. Sample parameters and sample frequency are determined on the basis of type of spill (or other contingency), as well as the size of the event. Sample parameters and frequency are decided on by management. EAA staff members are subsequently directed to an appropriate course of action on the basis of assessment of the event by management.

6. **Confirmation Samples**
   Confirmation samples are samples collected in response to an unexpected detection at a site where additional confirmation is needed in order to assess the probability that detection is not a sampling artifact or otherwise false detection. Confirmation detections are method and analyte specific and are taken at the direction of management.

7. **QA/QC Samples**
   QA/QC samples are discussed in detail in Section 3.3.

Sample Programs for Sediment Sample Types

1. **EAHCP Sediment Samples**
   EAHCP sediment samples will be collected for a broad spectrum of parameters to establish a base-line data set for sediments in and around Comal and San Marcos springs. These sample data are important to an understanding of potential issues with disturbing sediments in these areas.

2. **Contingency Samples**
   Contingency samples are collected only on an as-needed basis to assess potential contamination events related to spills or similar contingencies that have a high potential for affecting water quality in the Edwards Aquifer. Sample parameters and sample frequency are determined on the basis of type of spill (or other contingency), as well as the size of the event. Sample parameters and frequency are decided on by management. EAA staff members are subsequently directed to an appropriate course of action on the basis of assessment of the event by management.

3. **Confirmation Samples**
   Confirmation samples are samples collected in response to an unexpected detection at a site where additional confirmation is needed in order to assess the probability that detection is not a sampling artifact or otherwise false detection. Confirmation detections are method and analyte specific and are taken at the direction of management.

4. **QA/QC Samples**
   QA/QC samples are discussed in detail in Section 3.3

Sample Programs for Stormwater Sample Types

1. **EAHCP Stormwater Samples**
   EAHCP stormwater samples are collected twice annually for a broad spectrum of parameters to establish a base-line data set for stormwater quality in and around Comal and San Marcos springs. Stormwater samples are collected across the hydrograph at three points (rising, peak, and recession) to ascertain changes in water quality associated with storm flow.

2. **Confirmation Samples**
   Confirmation samples are samples collected in response to an unexpected detection at a site where additional confirmation is needed in order to assess the probability that detection is not a sampling artifact or otherwise false detection. Confirmation detections are method and analyte specific and are taken at the direction of management.

3. **QA/QC Samples**
   QA/QC samples are discussed in detail in Section 3.3

3.3 QUALITY CONTROL AND QUALITY ASSURANCE SAMPLES (QA/QC)

So that the data quality process is adhered to, additional samples for QA/QC must be taken and analyzed on occasion so that the quality of the sample collection and analysis process might be assessed. The various types of QA/QC samples applicable to this plan are outlined in the following paragraphs. Approximately ten percent of all samples will be QA/QC samples.

3.3.1 Matrix Spike and Matrix Spike Duplicate

Matrix spike and matrix spike duplicate samples (MS/MSD) are used to assess the effects of the sample matrix on the analytical process. The MS/MSD is a split (or replicate) of a parent sample collected in the field concurrently during the normal sample-collection process. Ideally, one MS/MSD is collected for each media type (soil, water, sludge, etc.) every 20 samples for each analysis being performed. For most sampling, no media changes will be encountered; i.e., most samples will be water. However, should the samples vary significantly in turbidity, collection of a specific MS/MSD for a sample with elevated turbidity may be advisable.

The MS/MSD is spiked and analyzed, and if the spiked analytes are recovered within a method-specific percentage, then matrix effects will be deemed minimal and no matrix data flag will be attached to the results. However, if spike recovery does not fall within the designated percentage, then analytical results will be flagged with an M-flag, indicating that a matrix effect is present. The sample name for MS/MSDs is identical to that of the parent sample, with the MS/MSD attached as a modifier at the end of the sample name. The MS/MSD will also be noted on the chain of custody (COC).

3.3.2 Ambient Blanks

Ambient blanks are taken to assess the possibility of site-specific atmospheric contamination of VOC samples. Ambient blanks are taken only when an area is suspected of having detectable quantities of atmospheric VOCs present (e.g., if VOC samples are being collected near a fueling operation). Ambient blanks are prepared by pouring ASTM II, reagent-grade water directly into a 40-mL, VOA container at the sample site during collection. The VOA is allowed to remain open and exposed to the atmosphere for the duration of the sample-collection process. The water is treated and analyzed as a sample from this point forward, with the designation *AB* on the COC. Ambient blanks are applicable to VOC samples.

3.3.3 Equipment Blanks

Equipment blanks consist of ASTM II, reagent-grade water poured over/through any sampling equipment used for collection of definitive samples. Most sample-collection equipment is disposable; however, in some cases, an equipment blank may be required. Equipment blanks are used to assess the effectiveness of decontamination procedures (for new materials provided to the EAA or from EAA decontamination processes) and are designated as *EB* on the COC. The frequency of collection of equipment blanks will depend on the sampling routine and sampling equipment in use.

3.3.4 Trip Blanks

Trip blanks are applicable only to VOC samples and are prepared and supplied by the contracted analytical laboratory. Trip blanks are to be shipped from the laboratory and maintained along with the VOC samples collected in the field. The purpose of trip blanks is to assess any potential contamination that may be introduced during shipping and sample handling. Trip blanks are designated on the COC as *TB*. Trip blanks are not to be opened in the field.

3.3.5 Duplicate or Replicate Samples

Duplicate and replicate samples are intended to assess the precision or repeatability of the analytical process. Typically one in ten samples should have a duplicate sample collected. The collection frequency of one duplicate per ten samples is generally acceptable. Note, however, that if a confirmation sampling event involves only three wells, then the duplicate (as well as other) QA/QC samples are still required. In other words, duplicates compose 10% of the sample set such that a sample population of ten would contain one duplicate. However, a sample population of 11 would contain two duplicates. The calculated number of duplicates is always rounded to the next whole number. Duplicates will generally be collected only at the 10% level for EAHCP analysis. For other programs, duplicate analysis is covered generally by the application of a TWDB sample set. Exceptions may apply and will be designated by management.

A duplicate sample is a second sample collected at the same location as that of the parent, either simultaneously or immediately following collection of the first sample (AFCEE, 2001). Both samples are collected, stored, and transported identically. A replicate sample, sometimes called a *split sample* is defined as a single sample divided into two samples (AFCEE, 2001). As with a duplicate, collection, storage, and transport of the resulting samples must be identical. Duplicate and replicate samples each have unique identifiers (see Section 4).

3.3.6 Spike Samples

Spike samples are used as part of EAA’s quality control on the contracted laboratory. EAA sampling staff members collect and subsequently spike twelve liters of water at one of the major springs, the spike containing a known percentage of a substance (contaminant). The spiked sample is then submitted to the contracted laboratory for analysis. If the contracted laboratory reports the findings within the specified amount, then EAA has confidence in their data. However, if the contracted laboratory is unable to detect or report the spikes, then EAA will pursue corrective action with the help of laboratory personnel to resolve the discrepancy. The corrective-action process will be initiated by the Hydrogeology Supervisor.

3.3.7 Recording QA/QC Samples in Analytical Workbook

Samples collected for QA/QC or spiked samples are to be recorded in chronological order in the laboratory notebook. The laboratory notebook is to be kept in the EAA Camden Building in the water quality area with the calibration notebook.

SECTION 4

ANALYTICAL METHODS, SAMPLE IDENTIFICATION, AND CUSTODY PROCEDURES

This section will discuss analytical methods applicable to the EAA sampling program, as well as provide a summary of analytical hold times, acceptable sample containers, and preservation techniques. In addition, a discussion of proper identification and sample custody procedures is provided herein.

4.1 ANALYTICAL METHODS

A variety of analytical methods are used in the various water quality and sediment sampling programs. Table 4-1 lists standard analytical reference methods that have possible application to the various programs. Recall, too, that Table 3-1 provides a current listing of analytical methods/parameters for each sample type and program.

Table 4-1. Analytical Reference Methods

Analysis	Method
VOC	SW-8260b
SVOC	SW-8270c
Chlorinated herbicides	SW-8151a
Organophosphorus compounds	SW-8141a
Nonvolatile compounds by HPLC	SW-8321
Organochlorine pesticides	SW-8081b
Polychlorinated biphenyls (PCBs)	SW-8082a
PAH	SW-8310
Determination of triazine pesticides	EPA-619
Organonitrogen pesticides in industrial/municipal wastewater	EPA-633
Oryzalin in industrial/municipal wastewater	EPA-638
TPH	TX-1005
Metals (except mercury)	SW-6010b or SW-6020
Mercury	SW-7470A
Cyanide	SW-9010B
Alkalinity	EPA-310.1
Common anions	SW-9056
Sulfate (SO4)	EPA 300.0
pH	SW-9040B
Total dissolved solids (TDS)	EPA 160.1
Total suspended solids (TSS)	EPA 160.2
Ortho-phosphate	EPA 365.3
Nitrate/nitrite (both as N)	EPA 353.2
Ammonia (as N)	EPA 350.3
Kjeldahl (as N)	EPA 351.3

Table 4-1. Analytical Reference Methods (continued)

Analysis	Method
Total organic carbon (TOC)	EPA 415.1 or SW-9060
Sulfide	EPA 376.2
Dissolved organic compound	SM 5310C-2000
E-coli most probable number (MPN)	SM9223B-2004
Dissolved orthophosphate lab	EPA 365.3-1978
Ammonia as N-nondistilled	SMA4500 NH3D-1997
Bromide	EPA 300.0-1993
Chloride	EPA 300.0-1993
Nitrate as N	EPA 300.0-1993
Total phosphorous	EPA 365.3-1978
Enterococci	ENTEROLERT
Eshcerichia coli-colilert	SM 9223B 20Ed
Total coliform_colilert	SM 9223B 20Ed
TWDB anions	EPA 300.1
TWDB cations	EPA 200
TWDB nitrate	EPA 353.2
Anti-bacterial agents	1694
Pharmaceuticals	1694
Steroids/hormones	1698
SIM analysis	MS-SIM-GX/MS
Nonylphenols	WS-MS-0010
General water quality parameters (GWQP), general chemistry—(alkalinity, bicarbonate, carbonate, Ca, Mg, Na, K, Cl, SO_4, F, Si, Sr, bromide, nitrate as N, pH, TDS, and TSS)	Methods listed in table

4.2 DATA-FLAGGING CONVENTIONS

Analytical data must be qualified by the EAA-contracted analytical laboratory, which is done summarily by the addition of data flags to the data result. Table 4-2 provides a summary of the data-flagging convention used in this plan (modified from AFCEE, 2001).

Table 4-2. Data Flags

Flag	Description
J	Analyte positively identified. Quantitation is an estimation because the associated numerical value is below the reporting limit (RL).
U or ND	Analyte analyzed for, but not detected. Associated numerical value at or

	below method detection limit (MDL).
R	Data rejected because of deficiencies in ability to analyze sample and meet QC criteria.
B	Analyte found in associated blank, as well as in sample.
M	Matrix effect present.
T	Tentatively identified compound (using GC/MS).
No flag	Analyte detected at reported concentration.

4.3 SAMPLE CONTAINERS AND HOLD TIMES

Samples sent to the analytical laboratory must be properly containerized, preserved, and analyzed within specified hold times for the method for the data to be of defensible quality. In addition to the requirement for samples to be chilled to 4°C, ±2°, some analytical methods require the sample to be maintained at specific pH values. As such, Table 4-3 lists acceptable container types, preservatives, and hold times for common analytical methods. The table includes all scheduled analyses for the various sampling programs. In the event an analysis is required that is not included in the table, Aquifer Science Team members listed herein (hydrogeology supervisor or hydrologic data coordinator) will communicate with the EAA contracted laboratory regarding appropriate containers, preservatives, and hold times for the methods in question.

Table 4-3. Sample Containers, Preservatives, and Hold Times

Analyte or Method[1]	Container	Preservation	Minimum Sample Volume	Holding Times
Volatile organic compounds (SW8260B)	G, Teflon®-lined septum, T	4°C, HCl to pH <two	3× 40 mL with no head space or (1) 250 mL amber bottle with no head space	14 days (water and soil); seven days if unpreserved by acid
Semivolatile organic compounds (SW8270C)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Chlorinated herbicides (SW8151a)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organophosphorus compounds (SW8141A)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Organochlorine pesticides (SW8081)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Polychlorinated biphenyls (SW8082)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)

Analyte or Method[1]	Container	Preservation	Minimum Sample Volume	Holding Times
Polynuclear aromatic hydrocarbons (SW8310)	G, Teflon®-lined cap, T	4°C	1L or 8 ounces/soil	Seven days until extraction and 40 days after extraction (water); 14 days until extraction and 40 days after extraction (soil)
Total petroleum hydrocarbons (TX1005)	G, Teflon®-lined septum, T	4°C, HCl to pH <2	3× 40 mL with no head space or (1) 250 mL amber bottle with no head space	14 days (water); to extraction, and 14 days after extraction
General water quality parameters (alkalinity, bicarbonate, carbonate, Ca, Mg, Na, K, Cl, SO_4, F, Si, Sr, bromide, nitrate (as N), pH, TDS, and TSS)	P, G	4°C	250 mL	28 days
Cyanide	P, B	4°C; NaOH to pH >12	500 mL or four ounces /soil	14 days (water and soil)
Ortho-phosphate (as P)	P, G	4°C	50 mL	48 days
Nitrate (as N) and nitrite (as N)	P, G	4°C	250 mL	48 days
Ammonia (as N)	P, G	4°C	250 mL	28 days
Kjeldahl (as N)	P,G	4°C	250 mL	28 days
Total organic carbon	P,G	4°C, H_2SO_4 to pH <2	250 mL	28 days
Dissolved organic carbon	P,G	4°C, H_2SO_4	400 mL	28 days
Phosphorus	P,G	4°C, H_2SO_4	500 mL	28 days
Alkalinity E310.1	P, G	4°C	50 mL	14 days
Common anions SW9056	P, G	None required	50 mL	28 days for Br^-, F^-, Cl^-, and SO_4^{-2}; 48 hours for NO_3^-, NO_2^-, and PO_4^{-3}

Analyte or Method[1]	Container	Preservation	Minimum Sample Volume	Holding Times
Cyanide, total and amenable to chlorination SW9010A SW9012	P, G, T	4°C; NaOH to pH >12, 0.6 g ascorbic acid	500 mL or four ounces /soil	14 days (water and soil)
Total dissolved solids (TDS) E160.1	P, G	4°C	100 mL	Seven days
Total suspended solids (TSS) E160.2	P, G	4°C	100 mL	Seven days
Biological oxygen demand (BOD), five-day	P, G	4°C	1L	48 hours
Sulfide	P, G	4°C	1L	Seven days
Total inorganic carbon	P, G	4°C	250 mL	28 days
Escherichia coli-colilert	P, G, WP	4°C, dark, sodium thiosulfate, one-inch headspace	100–250 mL	Six + two h (this holding time represents six field hours and two lab hours
Enterococci	P, G, WP	4°C, dark, sodium thiosulfate, one-inch headspace	100–250 mL	Six + two h (this holding time represents six field hours and two lab hours
Total coliform-colilert	P, G, WP	4°C, dark, sodium thiosulfate, one-inch headspace	100–250 mL	Six + two h (this holding time represents six field hours and two lab hours
TWDB anions	P, G	4°C, filtered on site	500 mL	28 days
TWDB cations	P, G	4°C, HNO_3, filtered on site	250 mL	28 days
TWDB nitrate	P, G	4°C, H_2SO_4, filtered on site	500 mL	28 days

Analyte or Method[1]	**Container**	**Preservation**	**Minimum Sample Volume**	**Holding Times**
1694 Pharmaceuticals (LCMS/MS) Acetaminophen Caffeine Carbamazepine Cotinine DEET Diltiazem Fluoxetine Gemfibrozil Ibuprofen Lincomycin Naproxen Sulfamethoxazole Trimethoprim Tylosin Iopromide	G, Teflon®-lined cap, T	4^oC	1L or 8 ounces/soil	Seven days (unpreserved), 14 (days preserved)
1694 Antibacterial (LCMS/MS) Triclobarban Triclosan	G, Teflon®-lined cap, T	4^oC	1L or 8 ounces/soil	Seven days (unpreserved), 14 (days preserved)
1698 Steroids/hormones (LCMS/MS) 17a-Estradiol 17a-Ethynyl estradiol 17b-Estradiol Equilenin Estriol Estrone Progesterone Testosterone	G, Teflon®-lined cap, T	4^oC, H_2SO_4	1L or 8 ounces/soil	Seven days (unpreserved), 14 (days preserved)

Analyte or Method[1]	Container	Preservation	Minimum Sample Volume	Holding Times
Nonylphenols/ethoxylates/bisphenol-A (GCMS) Bisphenol-A Nonylphenol diethoxylate (tech.) Nonylphenol monoethoxylate (tech.) p-Nonyphenol (tech.) p-tert-octylphenol para-n-nonylphenol	G, Teflon®-lined cap, T	4°C, H_2SO_4	1L or 8 ounces/soil	Seven days (unpreserved), 14 (days preserved)
Selected metals—6020 (Al, Sb, As, Ba, Be, Cd, Cr (total), Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Tl, and Zn)	P, G, T	HNO_3 to pH <2, 4°C	500 mL or 8 ounces/soil	180 days (water and soil)
Hg—Cold vapor 7470.7471	P, G	HNO_3 to pH <2, 4°C	250 mL	28 days (14 days if in plastic bottle)
Selected metals—(ICP unless otherwise noted) 6020/7470/7471 (Al, Sb-ICP-MS or GFAA, As, Ba, Be, Cd, Cr (total), Cu, Fe, Pb, Mn, Hg-ICP-MS or CVAA, Ni, Se-ICP-MS or GFAA, Ag, Tl-ICP-MS or GFAA, and Zn)	P, G, T	HNO_3 to pH <2, 4°C	500 mL or 8 ounces/soil	180 days (water and soil)
Hg- ICP-MS or CVAA **7470/7471**	P, G	HNO_3 to pH <2, 4°C	250 mL	28 days (14 days if in plastic bottle)

a. Polyethylene (P); glass (G); brass sleeves in sample barrel, sometimes called California brass (T).

b. No pH adjustment for soil.
c. Preservation with 0.008 percent $Na_2S_2O_3$ only required when residual chlorine present.

4.4 SAMPLE IDENTIFICATION

Each sample must have a unique identifier so that it can be differentiated from other samples. In addition, sample names must meet the required criteria for entry into the data base and subsequent electronic storage and retrieval of the data. Therefore, sample names must conform to the guidelines herein.

4.4.1 Sample Identification, for Non-EAHCP Samples

The primary method for non-EAHCP sample identification will be to use the state well registration number for wells (and springs as applicable) or the site name for surface water samples. When no well number is available for a spring, then an abbreviation for the spring name and orifice will be used. For example,

- The unique identifier, for use on the COC for Comal Springs, Orifice 1 is DX-68-23-301,
- The unique identifier for use on the COC for Comal Springs Orifice 3 (no state well number) is CS3,
- The unique identifier for use on the COC for the Nueces River at Laguna is Nueces@Laguna, and
- For wells that are sampled in more than one location within the borehole, the interval number is attached to the well name. For example, well LR-67-09-101 is regularly sampled at two intervals, so the COC name is LR-67-09-101-1 (interval 1 or upper interval) and LR-67-09-101-4 (interval 4, or the deepest interval).

Note that to the extent possible, custody forms and sample-container labels will be preprinted by the laboratory.

In some cases no well number or other recognized registration number will exist for the sample point. Then documentation for the sample location will require location (latitude/longitude and address if available) and name of well owner. Photographic documentation is also required. The subsequent sample name will be a *pseudo* state well number derived from the well location and owner name. For example,

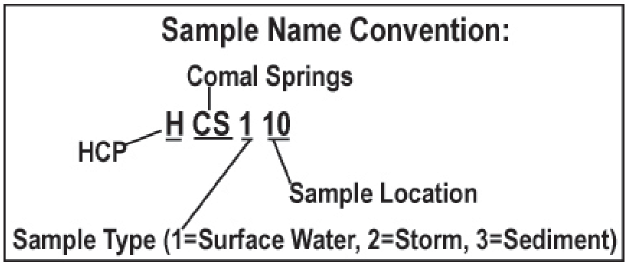
> The unique identifier for a sample taken from the Mary Smith residence in San Antonio, a private well with no state well registration number and located in

Bexar County (abbreviation AY) at state well grid location 68-23-8, would be AY-68-23-8MS.

When wells of this type are sampled, proper documentation to include collection location, sample name, sample parameters, date, and time is extremely important and will be recorded in the field log for cross reference to the COC.

4.4.2 Sample Identification, for EAHCP Samples

For samples collected under the EAHCP, sample names are designed to provide additional data regarding sample type. Specifically the sample name will indicate the sample as an EAHCP-related sample, the spring group (Comal or San Marcos), sample type (surface water, stormwater, or sediment), and sample location. In the example below, the sample name refers to an EAHCP sample at Comal Springs, collected for surface water, at location 10. Sample locations are noted on the sample-collection maps for the EAHCP (included in Appendix A with calendar year 2013 non-EAHCP sample locations.



4.4.3 Sample Identification, QA/QC

For QA/QC samples, a modifier is added to the sample name to indicate the QA/QC type, for example, DX-68-23-301 (Comal Spring 1). If an MS/MSD sample were collected, a separate set of samples named DX-68-23-301MS/MSD would be collected. The appropriate modifier for each QA/QC sample is listed in Table 4-4.

Table 4-4. QA/QC Sample Nomenclature

Sample Type	Modifier
Matrix spike/matrix spike duplicate	MS/MSD*
Ambient blank	AB#
Equipment blank	EB#
Trip blank	TB#
Duplicate	FD*
Replicate	FR*

* Requires sample, with same sample name as parent + modifier at end.

\# Numerical suffix to be attached and referenced in laboratory notebook; suffix starts at 1 at beginning of each calendar year. Details for location, etc. included in field notebook documentation.

4.5 SAMPLE CUSTODY

All samples shipped to the analytical laboratory must have proper custody documentation. One person on each sampling team is to have primary responsibility for sample custody (generally the lead sampler). This person will be designated as the *sample custodian* for sample collection. A person has custody of a sample group if samples are (1) in his/her possession, (2) in his/her view after being in his/her possession, (3) placed in a secure area by the sample custodian.
Furthermore, the laboratory COC form is to be filled out completely by the sample custodian in the field. The form must contain all required information for proper sample identification (if not preprinted) and must contain appropriate signatures. In addition, samples must remain in control of the sample custodian. Once collected, samples must be under the supervision of the sample custodian or secured in a manner such that no reasonable chance of unauthorized access to the samples exists. Furthermore, samples shipped by a common courier (i.e., Federal Express), require that the sample custodian note on the COC when the samples were released to the courier and why. The contracted analytical laboratory will sign the COC upon receipt. A breach of sample custody can invalidate the defensibility of the sample set.

4.6 DATA VALIDATION

Analytical data require review in order to be validated prior to publication. The amount of review (or level of review) is a function of the sample type. Field-collected data results are reviewed in the field by the analyst. One of the best ways for the field analyst to assess the acceptability of field data and subsequently validate them is to compare the results with historical data. This comparison, combined with proper equipment calibration, maintenance, and analytical technique, will provide an adequate validation process for field-parameter data. In the event that the analyst finds a discrepancy in the field data, a second analysis for the parameter in question should be performed. If the analyst feels that the data may be inaccurate because of issues with the field analysis, this fact is to be noted on the sample field sheet.

Contract analytical-laboratory data will receive a 100% analyst review at the analytical laboratory prior to posting of analytical results. A subsequent analytical laboratory review by the QA/QC section is required prior to the analytical laboratory's certification of the results. A subsequent 10% review by EAA staff of the analytical data is required upon receipt of the final analytical report. The analytical report will contain numerical analytical results for the laboratory QA/QC samples (i.e., LCS, method blanks, etc.). These laboratory analytical data are to have data flags assigned by the analytical laboratory.

SECTION 5

FIELD PROCEDURES AND SAMPLE COLLECTION

Possibly the most significant part of any successful sample collection is the field procedures and documentation that occur in the field. Field procedures to include sample equipment decontamination; sample-collection procedures for well, spring, surface water, and sediment samples; a listing of potential sources of contamination; and the proper use of field notebooks are included in this section.

5.1 RESPONSIBILITIES

The CTO and hydrogeology supervisor for the data-collection program will ensure that the samples obtained represent the environment being investigated. The hydrologic data coordinator will ensure that all field crews are provided with the necessary information, equipment, and supplies to successfully schedule and complete sampling. The hydrologic data coordinator will also be the primary point of contact between the contract analytical laboratory project manager and the EAA sampling team(s). The hydrologic data coordinator will report sampling deviations to the CTO and hydrogeology supervisor. Sample-collection staff (generally, environmental science technicians) are responsible for being familiar with the instructions provided in this SOP and for collection of samples in accordance with this SOP. For most sample-collection events, a sample team of two people will be utilized. Teams will have a lead sampler (according to experience level) who is directly responsible for adherence to directives of the SOP.

5.2 EQUIPMENT DECONTAMINATION

In order to obtain samples that are reliable and defensible, all (nondisposable) sample-collection equipment must be decontaminated prior to use. When possible, sample collection from a wellhead valve directly to a sample container is best. When this kind of collection is not possible, disposable equipment is preferable.

If neither option is plausible, then nondisposable sample-collection devices (constructed of Teflon® when possible) must be used. Sampling equipment that is exposed directly to sample media (pumps, peristaltic or submersible pump tubing, reusable bailers, or other devices) will be washed in a nonphosphate, laboratory-grade detergent such as Alconox®, followed by a double rinse in potable water. A final rinse of deionized or distilled water will be applied after completion of the initial decontamination process.

Equipment that will not be used immediately must be kept clean by wrapping in aluminum foil or placed inside clean plastic bags. Such storage will prevent contamination of the equipment prior to use. See Appendix G for additional detail regarding equipment-decontamination procedures.

5.3 SOURCES OF SAMPLE CONTAMINATION

Samples can easily become contaminated during the sample-collection process. It is the responsibility of the sampler to prevent contamination from occurring. A multitude of potential cross-contamination sources are present in the field environment. Because many of the analytical methods used can quantify various analytes in parts per billion or less, even minute sources can potentially contaminate a sample. For example, Table 5-1 summarizes some of the potential sources that can cause a false-positive reading in a sample. These should be considered when samples are collected in the field. Also note that water has a strong affinity for many anthropogenic compounds. Use of good judgment is another aspect of collecting defensible data. Steps should be taken to avoid cross-contamination of samples. If the sampler suspects the possibility of cross-contamination, he/she should note it in the field log for the sample set in question, or the site should be sampled again if necessary.

Table 5-1. Potential Sources of Cross-Contamination

Source	Possible Contaminant
Fuels—generators, work vehicles	BTEX/TPH/VOC/ SVOC
Exhaust fumes—generators, vehicles, heavy roadway traffic, overhead air traffic	BTEX/TPH/VOC/ SVOC
Oil/grease residue on tools, gloves, etc.	TPH/SVOC
Tape	VOC
Insect spray	VOC/SVOC/ pesticides
Insect repellent	SVOC/VOC/ pesticides
Sunscreen	VOC/SVOC/ PPCP
Soil/debris	Bacteriological/ metals/SVOCs
Foods/drinks/medications and other personal care products such as soap, makeup, deodorant, etcetera.	PPCPs

5.4 FIELD NOTEBOOKS

The field notebook is a legal document and should be treated as such. All pertinent site information should be in the notebook, including site name, weather information, site conditions, well condition (if applicable), equipment problems, sample-collection notes such as approximate sample times, and any other information that may be deemed valuable. The names of individuals on the sample team, as well as visitors to the site, should also be recorded in the notebook. All information recorded in the field notebook should follow the format described herein. No blank spaces are to be left on pages. All blank areas should be marked through with a single line and initialed by the author. The top of each page should have the date and sample site. The base of each page should contain the initials of the author. Mistakes are to be crossed out with a single line and initialed. Field notebooks are to be recorded in black ink only.

5.5 SAMPLE COLLECTION

Field personnel must wear clean (disposable) nitrile gloves during the sample-collection process. Generally samples for field water quality parameters are to be collected first, followed by VOC, SVOC, and metals samples. Any required information is to be recorded in the field notebook before, during, and after sampling.

5.5.1 Well Samples

Each well must be gauged and sounded (if possible). The general condition of the well will be noted in the field notebook. After the water level is gauged, the purge volume for the well will be calculated by the following equation,

$$V = H \times F,$$

where V is one well volume, H is the difference between depth of the well and depth to water in feet (i.e., length of water column in well), and F is the number of gallons per foot of water for the well size (Table 5-2).

Table 5-2. Well-Casing Volume in Gallons per Foot

Casing Diameter (in inches)	F (gallons per foot of water in well)
2	0.16
4	0.65
6	1.47
8	2.6
10	4.1
12	5.9
16	10.4

The relationship $F = \pi (D/2)^2 \times 7.48$ gallons/ft^3 can be used to calculate pipe volumes not listed in the table. Note that D = pipe diameter in feet and F = volume per foot.

A well may be sampled upon achieving *one* of the following: a minimum of three well volumes are purged from the well <u>or</u> field-parameter readings are stabilized for a minimum of three parameter measurements. Wells that go dry prior to purging the three well volumes, or the field-parameter readings have not stabilized, shall be purged to dryness (except for drinking-water supply or irrigation wells). During purging, water will be monitored for the following field parameters: *temperature, pH, DO, conductivity, and turbidity.*

Stabilization is defined as

- Temperature fluctuations limited to ±1° C,
- pH fluctuations ±0.1 unit,
- DO fluctuations ± 0.3 milligrams per liter (mg/L),
- Conductivity fluctuations ±5%, and
- Turbidity ±10 NTU.

In the event that these parameters do not stabilize (after purging of three well volumes), a maximum of six well volumes will be purged prior to sample collection (if the field parameters stabilize at any point, the well is considered ready to sample, and purging may cease). Once the well has stabilized or the maximum purge volume is reached, and the well has recovered to at least 80% of its initial level, it is ready to sample.

5.5.2 Spring Samples

Springwater samples should be as representative of the actual water issuing forth from the spring as possible and not be “contaminated” by surrounding surface waters. As such, various sample-collection techniques may be necessary. For spring orifices located below surface water, samplers should use a peristaltic pump to collect the spring water sample by placing the intake part of the pump tubing in the spring orifice. This placement allows for filling of sample bottles without introducing surface waters or overflowing the bottles and losing any preservatives inside. This technique is not feasible or necessary for all spring sites but should be utilized as appropriate. When a spring that can be sampled without a pump is being sampled, then a typical grab sample may be collected. In some cases (high flow volume) it may be necessary to collect samples in a clean bottle (such as a clean 1,000-mL amber glass bottle, clean Teflon beaker, or something similar) and the container used to transfer water into subsequent containers. Doing so will prevent the loss of any preservatives that may be in sample bottles. However, the action should be performed with as little agitation to the sample as possible to preserve potential VOCs in the parent sample.

Note: If preservatives in the sample container are diluted or lost because of the collection technique, a new bottle should be used. If a new bottle is unavailable, the lack of preservatives must be communicated to the laboratory to ensure that the sample remains valid by being analyzed within the appropriate hold time.

Current information and observations concerning springflow at the time of sample collection should be entered in the field notebook. For example, approximate springflow volume (can be listed as low, medium, high) is the flow representative of an extreme volume (high or low); observed water quality should be noted (clear, cloudy, or murky), along with other observations deemed appropriate by the lead sampler.

5.5.3 Surface Water Samples

Surface water samples should be collected without disturbing the sediment, if at all possible. The presence of sediment in the sample may bias the results. Samples should be collected from the flowing parts of the stream on the upstream side of the sample collector. Samples are not to be collected from stagnant areas, and they should also be taken from approximately the same location for each sample event. Sample bottles should be filled by collecting the water sample in a clean bottle or by using a peristaltic pump and transferred into the final sample bottle. Caution should be used to prevent overfilling of the sample bottle and diluting any preservatives that may be in the bottle.

Note: If preservatives in the sample container are diluted or lost because of the collection technique, a new bottle should be used. If a new bottle is unavailable, the lack of preservatives must be communicated to the laboratory to ensure that the sample remains valid by being analyzed within the appropriate hold time.

Information regarding the sample point in the stream, streamflow, and water conditions, as well as other information deemed appropriate by the sampler, should be entered into the field notebook at the time of sample collection.

5.5.4 Sediment Samples

Sediment samples are scheduled for collection by the EAHCP sampling program. Furthermore, the possibility exists that EAA staff may be required to collect samples of this type on occasion for other programs. As such, a brief discussion of this type of sample is included herein. Sediment samples may be collected from below the water line, from a dry stream bed, or from any other source in which sediments or soils may collect. The collection technique will depend on conditions. For example, a push tube for collection of sediments below the water surface is generally needed. However, if sediments are being collected from a dry area, then they may be collected using a trowel, hand auger, or push tube of some type. As with all sediment/soil-related samples, VOC samples must be collected in a manner that will minimize the loss of in situ volatiles. As such, sediment samples for VOC analysis will not be composited or homogenized in the field. Samples for VOC analysis are to be collected first.

In the event that the discreet-interval sediment sampler is used for collection of sediments, the procedure for device operation is as follows:

1. Insert the lower-half of the lead internal rod using a ⅜-inch coupler (first stage) into the internal drive tip. Pull down on the brass ring, push the grooved end of the lead internal rod into the recess, and gently release the brass ring.
2. Insert the internal drive tip and lead internal-rod assembly into the external drive tip.
3. Connect the upper lead internal rod using the ⅜-inch coupler (second stage) to the lower lead internal rod (first stage).
4. Insert a four-ft liner, with the hole in the liner oriented to the top, into the sample tube (the sample tube has a two-inch outside diameter and consists of two parts, a double female lead section and a male × female extension). If the EAA staff chooses to use a two-ft liner instead of a four-ft liner, the process is the same, except that the male × female upper extension is not used.
5. Insert a plastic core catcher (white) in the bottom of the sample tube, with the dome pointing toward the top.
6. Insert the internal drive tip/external drive tip assembly into the sampler tube.
7. Insert the metal core catcher into the top of the main sampler tube, with the dome pointing upward.
8. Install the internal tip chamber to the top of the main sampler tube.
9. Install the top drive head adapter to the top of the internal tip chamber.
10. Install the thread protector cap or internal rod with external drive extensions (if using 1⅛ × 3 ft external extensions with ⅜-inch internal rods, place a ⅜-inch coupler on the top of the internal rods prior to installing the top drive head adapter). Install the thread protector cap at the top of the internal rod prior to connecting the vented drive head (install the correct number of internal/external extensions necessary to lower the sampler to the surface and arrive at the desired sampling point).
11. Install the vented hammer adapter, already attached to the slide hammer.

The field notebook will note details related to the sediment samples; for example, was the sediment dry or below water, how was it collected, was it discolored, at what depth (from the surface) was the sample collected? If sediments are field screened with a photoionization detector (PID), readings from the various intervals will be recorded. Other details will be recorded as deemed appropriate by the sampler.

Also, if a hand trowel is used, it must be constructed of stainless steel, and it must be decontaminated prior to each use. For sites at which multiple samples will be collected, multiple hand trowels may be used, or a single trowel may be used if it is decontaminated in the field (Alconox wash, double rinse in potable water, followed by a DI water rinse).

5.5.5 STORMWATER SAMPLES

Stormwater samples are scheduled for collection under the EAHCP program at each spring group, twice annually. Stormwater sample collection offers additional challenges and safety issues, as compared with that of other samples collected under EAA programs. This section provides a general summary of stormwater sampling, additional detail regarding this sample type being provided in Appendix F.

Stormwater samples are scheduled for collection across three points on the storm hydrograph. One sample collected from the initial rise on the hydrograph, a second sample from the peak area of the hydrograph, and a final sample along the recession limb of the graph. In addition, water quality parameters obtained from EAA-installed real-time water quality monitors, flow data from the U.S.G.S. springs gauges, and local weather radar maps will be used to define the behavior of the systems and help guide sample-collection timing. The real-time monitors collect data at 15-minute intervals for conductivity, DO, pH, temperature, and turbidity.

A stormwater event will be dictated by a rainfall event sufficient to cause a significant rise in springflow at either Comal or San Marcos springs. The significant rise in springflow is to be further defined in conjunction with real-time data systems. See Appendix F for details on stormwater sampling procedures.

SECTION 6

ANNUAL REVIEW OF PLAN

6.1 ANNUAL REVIEW OF GROUNDWATER QUALITY PLAN

Data collection described in this plan will be reviewed by May 31 each year. The review will be directed at ensuring that all data collection herein is necessary, properly performed, and properly staffed. Furthermore, the review will ascertain whether the methodologies in use remain appropriate for their intended purpose. The review process will include all sample types and programs, as well as methods used to collect and analyze these samples.

Post review: modifications will be made, if needed, to accommodate changes to EAA sampling. Changes will be imitated by the management and staff of the EAA Aquifer Science Team.

SECTION 7

CONTINUING EDUCATION CREDITS FOR SAMPLE-COLLECTION PERSONNEL

7.1 Continuing Education

Staff members assigned to sample-collection teams must attain a minimum of 12 hours of continuing education each year. Opportunities for continuing education will be provided either in-house by the EAA, or, in some cases, staff may be sent to an offsite facility to attend a class. One hour of credit is considered to be one classroom or contact hour. Staff may also carry credits over into the following year if more than 12 hours of credit are obtained in a calendar year. It is the responsibility of each staff member to document his/her credit hours annually and submit them to the hydrogeology supervisor by December 1 of each year.

SECTION 8

REFERENCES CITED

AFCEE, 2001, Quality Assurance Project Plan, Version 3.1: Air Force Center for Environmental Excellence, Brooks AFB, Texas.

EAA, 2012, Water Quality Monitoring Program Strategy for Comal Springs and San Marcos Springs in Support of the Edwards Aquifer Habitat Conservation Plan.

SARA, 2013, Watershed Monitoring, San Antonio River Authority.

U.S. EPA, 2000, EPA QA/G-4, Guidance for the Data Quality Objectives Process.

SECTION 9

REFERENCES NOT CITED

Driscoll, F.G., 1995, Groundwater and Wells: St. Paul, Johnson Screens, 1089 p.

Nielsen, D.M., 2006, Environmental Site Characterization and Ground-Water Monitoring: New York, Taylor and Francis, 1318 p.