

	<p>Welcome to ITRC's Internet-based Training Program</p>	
<p>Thank you for joining us.</p> <p>Today's presentation is focused on the technical and regulatory guidance document entitled:</p> <p><i>“Users Guide For Polyethylene-Based Passive Diffusion Bag Samplers To Obtain Volatile Organic Compound Concentrations In Wells”</i></p> <p>Sponsored by ITRC, EPA-TIO, and USGS</p>		
1		

INTERNET TRAINING TITLE: Passive Diffusion Bag Samplers for Volatile Organic Compounds in Ground Water

Based on the document: *“Users Guide For Polyethylene-Based Passive Diffusion Bag Samplers To Obtain Volatile Organic Compound Concentrations In Wells”*

Available at: www.itrcweb.org


PRESENTATION OVERVIEW: Passive diffusion bag (PDB) samplers are a simple and inexpensive way to sample ground water monitoring wells for a variety of volatile organic compounds. A typical PDB sampler consists of low-density polyethylene lay-flat tubing that is filled with distilled, deionized water and heat sealed at both ends. The bags are suspended in the monitoring well at the target horizon by a weighted line and allowed to equilibrate with the surrounding water (typically 2-weeks). The PDB samplers are retrieved from the well after the equilibration period and the enclosed water is immediately transferred to appropriate sample containers for analysis [40 ml VOC vials]. Field-tests show good correlation between samples obtained with PDB samplers and samples obtained using traditional methods (i.e. purge 3-5 casing volumes and sample with a bailer). Currently, the samplers are recommended only for long-term ground water monitoring of VOCs at well-characterized sites. The number of sites where they can be appropriately deployed is large and the associated cost savings are significant

The ITRC internet training for this technology will discuss the technical and regulatory considerations associated with deployment of diffusion samplers, and summarize major points of the recently issued USGS document “Users Guide For Polyethylene-Based Passive Diffusion Bag Samplers To Obtain Volatile Organic Compound Concentrations In Wells,” which was developed in cooperation with the ITRC Diffusion Sampler Work Group.


ITRC – Interstate Technology and Regulatory Council (www.itrcweb.org)

EPA-TIO – Environmental Protection Agency – Technology Innovation Office (www.clu-in.org)

ITRC Course Moderator: Mary Yelken – myelken@earthlink.net

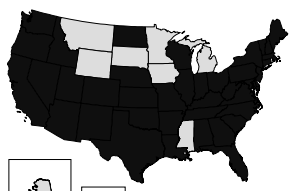


ITRC – Shaping the Future of Regulatory Acceptance




- ★ **Natural Attenuation of Chlorinated Solvents in Groundwater: Principles & Practices**
- ★ **Advanced Techniques for Installation of Permeable Reactive Barriers**
- ★ **Diffusion Samplers**
- ★ **Phytotechnologies**
- ★ **ISCO (In Situ Chemical Oxidation)**
- ★ **Systematic Approach to In Situ Bioremediation (Nitrates, Carbon Tetrachloride, Perchlorate)**
- ★ **Characterization & Remediation of Soils at Closed Small Arms Firing Range**
- ★ **Constructed Treatment Wetlands**
- ★ **Surfactant/CoSolvent Flushing of DNAPL Source Zones**
- ★ **Munitions Response Historical Record Review (MRHRR)**
- ★ **Radiation Risk Assessment: Updates & Tools**

ITRC Membership




■ ITRC Member State

Federal Partners



Sponsors



Industry, Academia, Consultants,
Citizen Stakeholders



2
www.itrcweb.org

The bulleted items are a list of ITRC Internet Training topics – go to www.itrcweb.org and click on “internet training” for details.

The **Interstate Technology and Regulatory Council (ITRC)** is a state-led coalition of regulators, industry experts, citizen stakeholders, academia, and federal partners that work to achieve regulatory acceptance of environmental technologies. ITRC consists of 40 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and streamline the regulation of environmental technologies. Together, we’re building the environmental community’s ability to expedite quality decision-making while protecting human health and the environment. With our network approaching 6,000 people from all aspects of the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.






ITRC originated in 1995 from a previous initiative by the Western Governors’ Association (WGA). In January 1999, it affiliated with the Environmental Research Institute of the States, ERIS is a 501(c)3 nonprofit educational subsidiary of the Environmental Council of States (ECOS). ITRC receives regional support from WGA and the Southern States Energy Board (SSEB) and financial support from the U.S. Department of Energy, the U.S. Department of Defense, and the U.S. Environmental Protection Agency.

To access a list of ITRC State Point of Contacts (POCs) and general ITRC information go to www.itrcweb.org.




	<h2>Today's Presenters</h2>	
<p>★ Don Vroblesky</p> <ul style="list-style-type: none"> ● USGS ● (803-750-6115) ● vroblesk@usgs.gov <p>★ George Nicholas</p> <ul style="list-style-type: none"> ● New Jersey DEP ● (609) 984-6565 ● George.Nicholas@dep.state.nj.us 		
3		

Don Vroblesky is a research hydrologist with the U.S. Geological Survey (USGS). He has worked at the USGS for approximately 20 years. He received an M.S. degree and a Ph.D degree at the George Washington University. He has authored or coauthored over 50 published reports on various aspects of ground-water contamination and hydrology. He is the primary developer of PDB samplers for wells and passive vapor diffusion samplers for mapping contaminant-discharge zones to lakes and streams, and he developed a methodology for mapping VOC contamination in ground water using headspace analysis of tree cores.

George Nicholas is a Supervising Geologist with the New Jersey Department of Environmental Protection. He has over twelve years of experience in overseeing ground water investigations and remedial actions at Superfund sites, RCRA facilities, and privately owned industrial sites throughout the state of New Jersey. He also serves as a Brownfields Coordinator for the NJDEP and works on redevelopment projects with the Hackensack Meadowlands Development Commission and the City of Long Branch. George became involved with the ITRC as a proctor at several of the ITRC Natural Attenuation Training Seminars, and later became the Team Leader for the Diffusion Sampling Team.

	<p>Passive Diffusion Bag Samplers for Volatile Organic Compounds in Ground Water</p>			
<table border="1"><tr><td data-bbox="370 359 824 890"><p>Presentation Logistics</p><ul style="list-style-type: none">✓ Technical Information✓ Questions and answers✓ Technical Information✓ Regulatory Information✓ Questions and answers✓ Links to additional resources✓ Your feedback<p>Course Time = 2 hours</p></td><td data-bbox="857 359 1252 890"><p>Logistical Reminders</p><ul style="list-style-type: none">✓ Phone Audience<ul style="list-style-type: none">● Keep phone on mute● * 6 to mute your phone and again to un-mute● Do NOT put call on hold✓ Simulcast Audience<ul style="list-style-type: none">● Use  at top of each slide to submit questions</td></tr></table>			<p>Presentation Logistics</p> <ul style="list-style-type: none">✓ Technical Information✓ Questions and answers✓ Technical Information✓ Regulatory Information✓ Questions and answers✓ Links to additional resources✓ Your feedback <p>Course Time = 2 hours</p>	<p>Logistical Reminders</p> <ul style="list-style-type: none">✓ Phone Audience<ul style="list-style-type: none">● Keep phone on mute● * 6 to mute your phone and again to un-mute● Do NOT put call on hold✓ Simulcast Audience<ul style="list-style-type: none">● Use  at top of each slide to submit questions
<p>Presentation Logistics</p> <ul style="list-style-type: none">✓ Technical Information✓ Questions and answers✓ Technical Information✓ Regulatory Information✓ Questions and answers✓ Links to additional resources✓ Your feedback <p>Course Time = 2 hours</p>	<p>Logistical Reminders</p> <ul style="list-style-type: none">✓ Phone Audience<ul style="list-style-type: none">● Keep phone on mute● * 6 to mute your phone and again to un-mute● Do NOT put call on hold✓ Simulcast Audience<ul style="list-style-type: none">● Use  at top of each slide to submit questions			



No Associated Notes

	<h2>Presentation Overview</h2>	
<ul style="list-style-type: none">★ PRIMARILY DISCUSSING PASSIVE DIFFUSION BAG (PDB) SAMPLERS, AND TOUCHING ON SOME OTHER TYPES★ Background on diffusion samplers★ Theory – Why diffusion samplers work, field applications of PDB samplers and diffusion samplers for inorganic constituents★ Question and Answer Period 1★ Discussion of User's Guide and practical applications★ Data interpretation – comparison between different methods★ Regulatory Considerations★ Questions and Answer Period 2★ Wrap-up and links to additional information and resources 		

5



Instructor Notes:

None

	<h2 style="text-align: center;"><i>Typical Applications of Passive Diffusion Bag (PDB) Samplers</i></h2>	
<ul style="list-style-type: none">★ Long-term monitoring of VOCs in wells★ Delineating contaminant stratification<ul style="list-style-type: none">● This information can aid in site characterization● More accurate identification of the contaminated horizon can be an aid in optimizing remediation by allowing more accurate targeting by the remediation effort. <p data-bbox="326 909 358 947">6</p>		

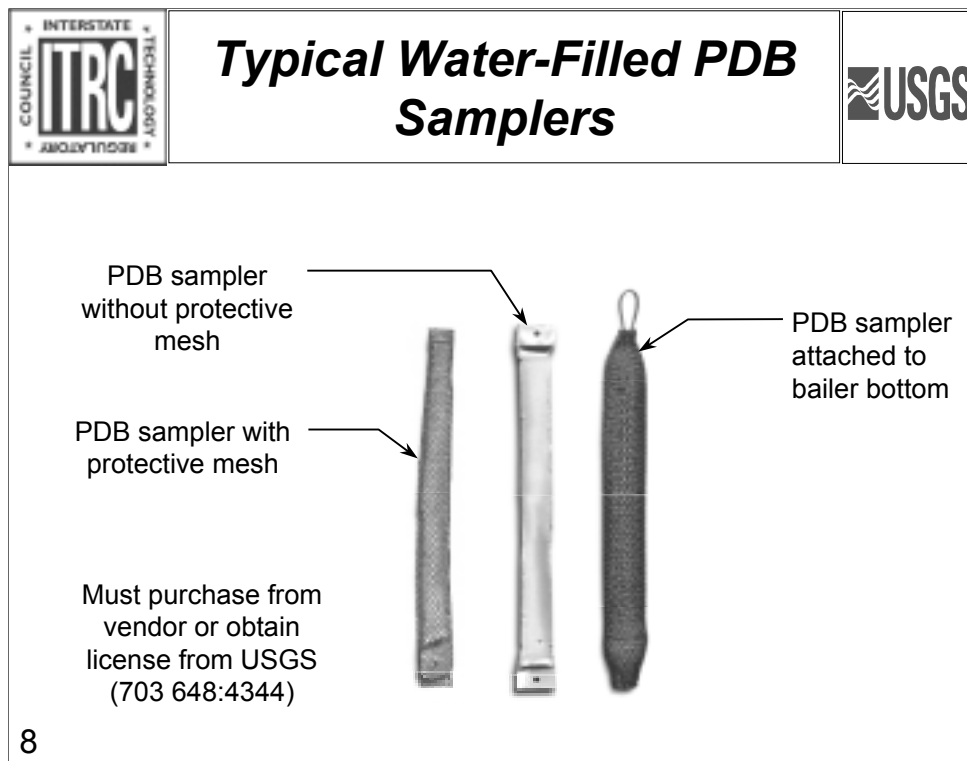
Instructor Notes:

None


	<h2><i>Passive Diffusion Bag (PDB) Samplers</i></h2>	
<ul style="list-style-type: none">★ PDB samplers are used to obtain ambient concentrations of volatile organic compounds (VOCs) in wells.★ Why are they a desirable alternative?<ul style="list-style-type: none">● Very inexpensive (about \$16-\$26 ea) (typically 40-60% cost savings over conventional methods)● Sampling - rapid and easy with minimal field equipment required● Disposable, so no equipment decon is needed between wells● Potential to eliminate pumps and reduce waste water● Sometimes can provide information difficult to obtain with conventional methodologies● Practical for use for access is a problem or discretion is desirable● Not subject to interferences from alkalinity or turbidity. <p>7</p>		

Instructor Notes:


None



Passive Diffusion Bag (PDB) samplers consist of a low-density polyethylene sleeve, filled with laboratory-grade deionized water, and closed at both ends. Pictured here are three types of diffusion samplers commonly used and commercially available. The samplers on the left are supplied prefilled with laboratory-grade deionized water, and the sampler on the right is field-fillable. PDB samplers employ patented technology (U.S. patent number 5,804,743), and therefore, require that the user purchase commercially produced samplers from a licensed manufacturer or purchase a non-exclusive license for sampler construction from the U.S. Geological Survey Technology Enterprise Office, Mail Stop 211, National Center, 12201 Sunrise Valley Drive, Reston, Virginia 20192 (telephone 703 648-4344; fax 703 648-4408).



Principle



★ **Fick's Law of Diffusion:**

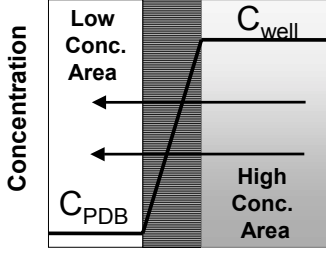
Diffusive flux

Diffusion coefficient

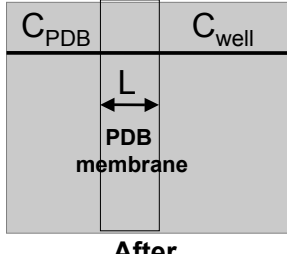
Concentration diff.

Distance

Compounds tend to migrate from an area of high concentration to an area of low concentration until equilibrium is achieved





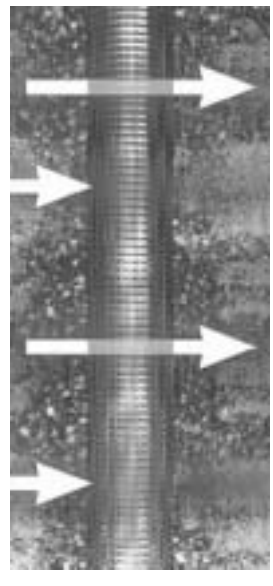
Before equilibration



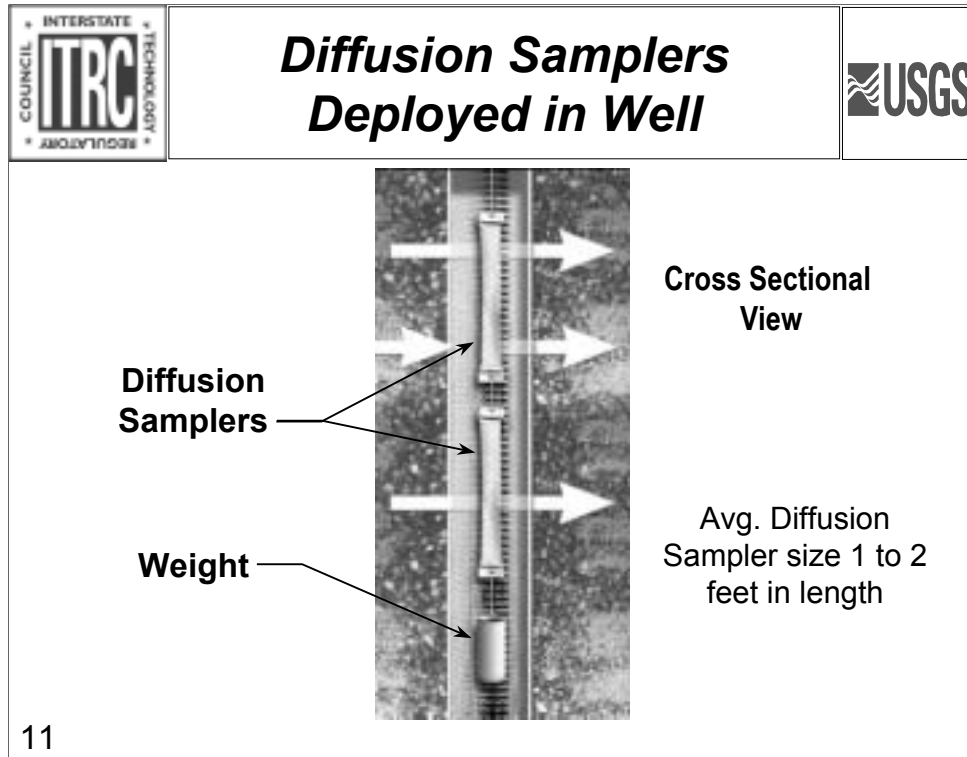
After equilibration

9



Passive Diffusion Bag (PDB) samplers rely on the mass transfer of dissolved gasses through a polyethylene membrane. The rate of diffusion is described by Fick's Law, shown here, which, in simple terms, states that compounds tend to migrate from an area of high concentration to an area of low concentration until equilibrium is achieved. In the case of PDB samples, the VOCs migrate through the membrane into the sampler until the concentrations are the same on both sides of the membrane.

	<h2>Groundwater and Contaminant Flow</h2>	
<p>Cross Section View</p>		<p>In tested wells, water in the screened interval was purged by natural flow, but the cased interval remained stagnant</p> <p>(Robin and Gillham, 1987, <i>GW Mon. & Remed.</i>, Fall, p. 85-93; 3 out of 4 wells in Powell and Puls, 1993, <i>J. of Contam. Hydrol.</i>, v. 12, p. 51-77)</p>



In wells where research has been done, water in the screened interval was found to be purged by natural flow, but the cased interval remained stagnant. Thus, there is a stratification of stagnant water in the cased interval overlying water exchanging with the aquifer in the screened interval. Sampling the water in the screened interval requires inserting a sampling device to the target horizon. However, passing the sampling device through the stagnant water in the cased portion disturbs the stratification in the well. This disturbance mixes the stratified water, resulting in sampled concentrations that may not represent the screened interval. A variety of methods are sometimes used to compensate for this effect, including purging 3 or more casing volumes of water prior to collecting a sample, or low-flow sampling. If, however, a passive sampler is placed in the screened interval and the well and sampler are allowed to re-equilibrate, then there is the potential for collecting a ground-water sample without purging.



That is where the diffusion samplers come in. PDB samplers are deployed in the screened interval and allowed to equilibrate. After sufficient equilibration, the samplers are removed and the enclosed water is transferred to volatile organic analysis (VOA) vials. Thereafter, the samples are treated as ordinary VOA samples.



	<p><i>Results are time-weighted average associated with the most recent part of the deployment period</i></p>	
<ul style="list-style-type: none">★ Reflect primarily the most recent part of the last 48 hrs prior to recovery for compounds like BTEX, TCE, and PCE. ★ Reflect primarily the most recent part of the last 4 to 7 days for VC and 111TCA. <p>12</p>		

1. PDB samplers integrate concentrations over time. But because they constantly seek to maintain equilibration with ambient water, the concentrations are a time-weighted average with the greatest amount of influence coming from the most recent part of the deployment period. Laboratory results obtained indicate that a variety of compounds, such as BTEX, TCE, PCE, and others equilibrated within 48 hours (Vroblesky and Campbell, 2001). Therefore, the concentrations for these compounds in PDB samplers represent the most recent part of the last 48 hours prior to recovery. Vinyl chloride, 1,1,1-trichloroethane, 1,2-dichloroethane, and 1,1-dichloroethane equilibrate more slowly [somewhere between 96 and 168 hours to equilibrate (T.M. Sivavec and S.S. Baghel, 2000, General Electric Company, written commun.]. Therefore, the concentrations for these compounds reflect primarily the most recent part of the last 4 to 7 days prior to recovery.

		Field and Lab Tested VOCs in PDB Samplers			
Good correlation in wells (Study included 322 Wells, 1199 PDB samples :Parsons Eng., 2003.)					
Benzene	Dibromochloromethane	t-1,2-DCE		1,2,4-Trichlorobenzene	
Bromobenzene	1,2-Dibromoethane	1,2-Dichloropropane		1,1,1-TCA	
Bromochloromethane	Dibromomethane	Ethylbenzene		1,1,2-TCA	
n-Butylbenzene	1,2-Dichlorobenzene	Hexachlorobutadiene		TCE	
sec-Butylbenzene	1,3-Dichlorobenzene	p-Isopropyltoluene		Trichlorofluoromethane	
tert-Butylbenzene	1,4-Dichlorobenzene	1-Methylethylbenzene		1,1,2-Trichloro-1,2,2-trifluoroethane	
Carbon disulfide	Dichlorodifluoromethane	1,1,2,2-PCA		Vinyl chloride	
Carbon tetrachloride	1,1-Dichloroethane	PCE		m,p-Xylene	
Chlorobenzene	1,2-Dichloroethane	Toluene		o-Xylene	
Chloroethane	1,1-Dichloroethene	1,2,3-Trichlorobenzene		Xylenes, Total	
Chloromethane	c-1,2-DCE				
Poor correlation in lab tests (USGS, 2000; GE, 2000, 2001)					
Acetone*	MTBE	Styrene		MIBK*	



13

Field and laboratory tests have shown that PDB samplers are applicable to a wide variety of volatile organic compounds. Good correlation was shown for the above compounds under field conditions. The study involved 14 Dept. of Defense installations, 332 wells, and 1,199 PDB samplers (Parsons, 2003. Draft Comprehensive Results Report for a Passive Diffusion Bag Sampler Demonstration. March). Other compounds, such as MTBE, acetone, styrene, and most semivolatiles are transmitted slowly through the polyethylene, but lab tests have shown that the resulting concentrations were lower than in ambient water (Vroblesky and Campbell, 2000; Sivavec, General Electric Co., 2000; 2001, written commun.).

		U.S. Air Force Cost Comparisons at 14 Air Force Bases (Parsons Eng., 2003)		
	Number of Wells Evaluated for Implementation	Cost Difference Between Long - Term PDB and Conventional Sampling per well per event	Percentage Cost Savings of Switching to PDBS	
Average	24	\$259	75%	
Median	20	\$246	77%	
Minimum	10	\$118	63%	
Maximum	56	\$631	80%	

14

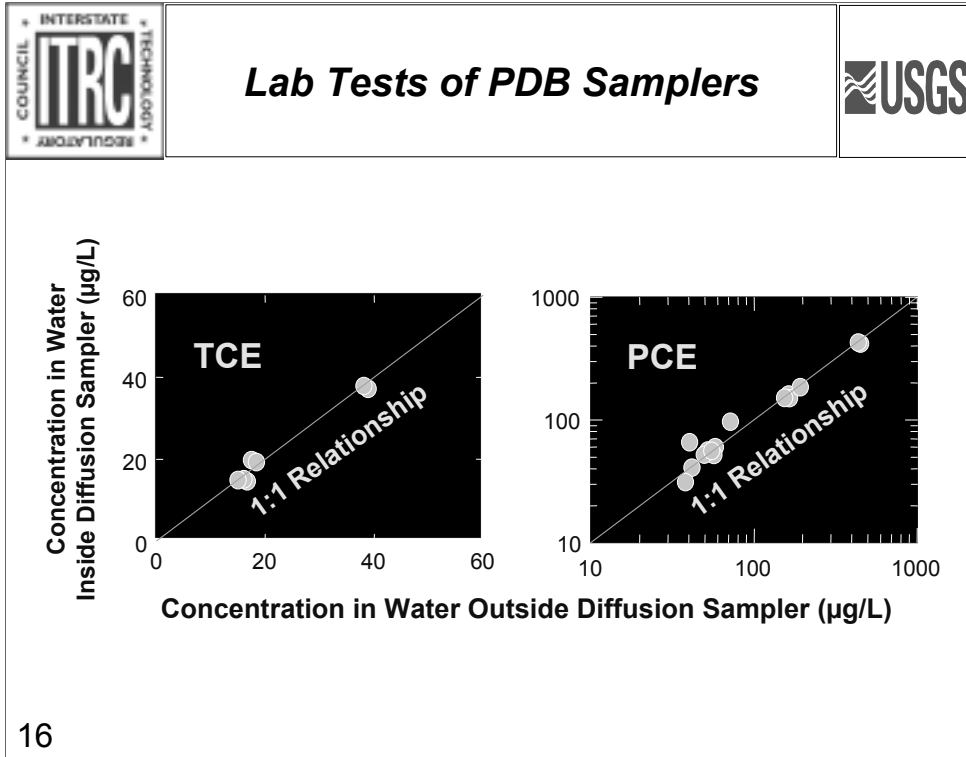
A series of investigations in 2002-2003 by the US Air Force Center for Environmental Excellence showed average cost savings of 75 percent for switching from conventional to PDB samplers at 14 Air Force Bases.

	<h2 style="margin: 0;"><i>Limitations of PDB Samplers</i></h2>	
<ul style="list-style-type: none"> ★ Not appropriate for some compounds <ul style="list-style-type: none"> ● i.e. MTBE, acetone, most semi-volatiles, most ions ★ Rely on water movement through the well 		
<p>15</p>		

1. Water-filled polyethylene PDB samplers are not appropriate for all compounds. For example, although methyl-*tert*-butyl ether and acetone (Vroblesky, 2000; Paul Hare, 2000, General Electric Company, oral commun.) and most semivolatile compounds are transmitted through the polyethylene bag, laboratory tests have shown that the resulting concentrations were lower than in ambient water. A variety of factors influence the ability of compounds to diffuse through the polyethylene membrane. These factors include the molecular size and shape and the hydrophobic nature of the compound. Compounds having a cross-sectional diameter of about 10 angstroms or larger (such as humic acids) do not pass through the polyethylene because the largest (transient) pores in polyethylene do not exceed about 10 angstroms in diameter (Flynn and Yalkowsky, 1972; Comyn, 1985; Hwang and Kammermeyer, 1975). The samplers are not appropriate for hydrophilic polar molecules, such as inorganic ions. A detailed discussion of the relation between hydrophobicity and compound transport through polyethylene can be found in Gale (1998). Unpublished laboratory test data (D.A. Vroblesky, 1998, U.S. Geological Survey, written commun.) of semivolatile compounds in contact with PDB samplers showed a higher concentration of phthalates inside the PDB sampler than outside the PDB sampler, suggesting that the polyethylene may contribute phthalates to the enclosed water. Thus, the samplers should not be used to sample for phthalates.



2. PDB samplers rely on the free movement of water through the well screen. In situations where ground water flows horizontally through the well screen, the VOC concentrations in the open interval of the well probably are representative of the aquifer water in the adjacent formation (Vroblesky and Hyde, 1997; Gillham and others, 1985; Robin and Gillham, 1987; Powell and Puls, 1993; Kearn and others, 1992). In these situations, the VOC concentration of the water in contact with the PDB samplers, and therefore, the water within the diffusion samplers, probably represents local conditions in the adjacent aquifer. However, if the well screen is less permeable than the aquifer or the sandpack, then under ambient conditions, flowlines may be diverted around the screen. Such a situation may arise from inadequate well development or from iron bacterial fouling of the well screen. In this case, the VOC concentrations in the PDB samplers may not represent concentrations in the formation water because of inadequate exchange across the well screen. PDB samplers have not yet been adequately tested to determine their response under such conditions.

3. VOC concentrations in PDB samplers represent ground-water concentrations in the vicinity of the screened or open well interval that move to the sampler under ambient flow conditions. This is a limitation if the ground-water contamination lies above or below the well screen or open interval, and requires the operation of a pump to conduct contaminants into the well for sampling. In cases where the well screen or open interval transects zones of differing hydraulic head and variable contaminant concentrations, VOC concentrations obtained using a PDB sampler may not reflect the concentrations in the aquifer directly adjacent to the sampler because of vertical transport in the well. However, a vertical array of PDB samplers, used in conjunction with borehole flow meter testing, can provide insight on the movement of contaminants into or out of the well. This information can then be used to help determine if the use of PDB samplers is appropriate for the well, and to select the optimal vertical location(s) for the sampler deployment. In wells with screens or open intervals with stratified chemical concentrations, the use of a single PDB sampler set at an arbitrary (by convention) depth may not provide accurate concentration values for the most contaminated zone. However, multiple PDB samplers distributed vertically along the screened or open interval, in conjunction with pump sampling (as appropriate), can be used to locate zone(s) of highest concentration in the well. Multiple PDB samplers also may be needed to track the zone of maximum concentration in wells where flow patterns through the screened interval change as a result of ground-water pumping or seasonal water-table fluctuations.





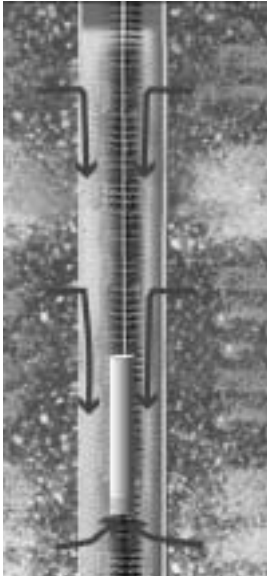
16

Shown here are some laboratory data for trichloroethene (TCE) and tetrachloroethene (PCE) showing a close comparison of concentrations between water inside and outside the PDB samplers for a range of concentrations.

	<h2 style="margin: 0;">Conventional Well Sampling Methods</h2>	
<p><u>Two standard methods</u></p> <ul style="list-style-type: none"> ★ Purge-and-Sample: Remove 3 or more casing volumes of water prior to collecting a sample <ul style="list-style-type: none"> ● By 5 well volumes, even in heterogeneous wells, concentrations are within 5% of the flow weighted average concentration. (Martin-Hayden, 2000, <i>Ground Water</i> 38, no. 1: 12-19) ★ Low-Flow (LF) or Low-Volume Sampling: Slowly purge with no drawdown until field parameters stabilize prior to collecting a sample <ul style="list-style-type: none"> ● During purging, the highest deviation from flow-weighted average concentration is between ½ and 1 well volume purged. (Martin-Hayden, 2000, <i>Ground Water</i> 38, no. 1: 12-19) 		
<p>17</p>		

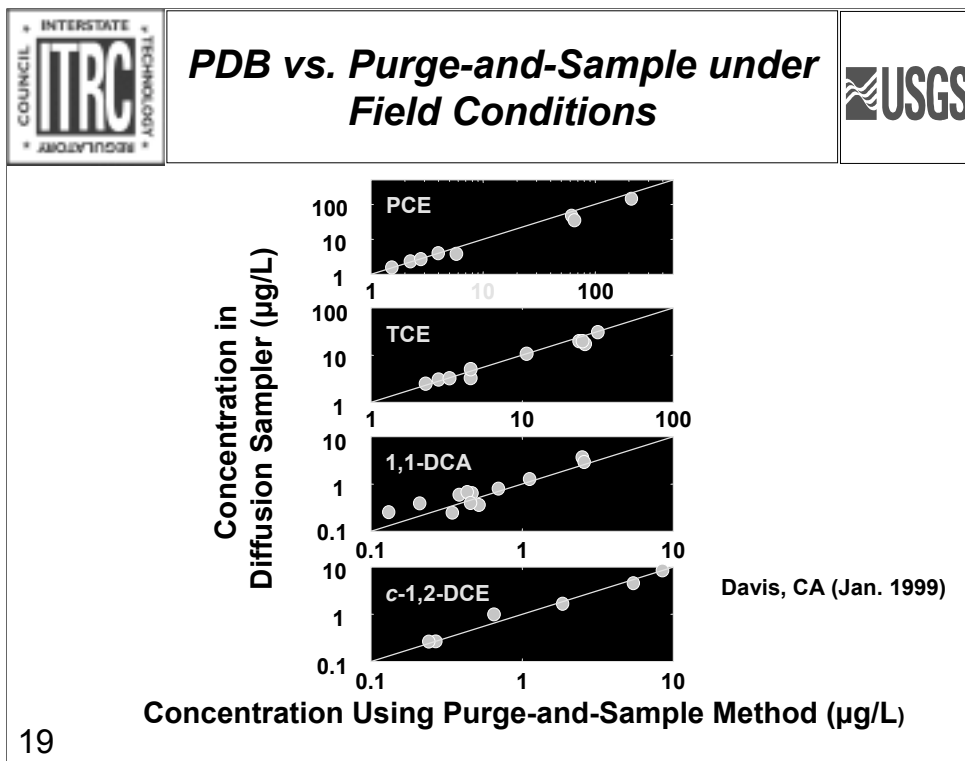
Instructor Notes:

In the field, we usually compare the diffusion samplers to a pumped sample. There are two standard pumping methods: purge-and-sample and low-flow sample. In Purge-and-sample, three or more casing volumes of water are removed prior to collecting a sample. In low-flow sampling, the pump is typically placed in the center of the well screen and the well is purged slowly with minimal drawdown until field parameters stabilize prior to collecting a sample. A characteristic of pumping in a heterogeneous system is that concentrations change during pumping. Transient responses of concentration to pumping lead to various amounts of variability depending on the screen length and position relative to hydraulic and chemical heterogeneities. Typically, the 3-casing-volume purge ends up being a flow-weighted average. Indications of contaminant stratification are lost. By 5 well volumes, even in heterogeneous wells, concentrations are approximately the flow-weighted average. The highest deviation from flow-weighted average concentrations occurs between ½ and 1 well volume purged (*Martin-Hayden, 2000, GroundWater*), which means that low-flow purging is not necessarily a flow-weighted average, depending on the amount of purging and whether the well was naturally mixed prior to purging.

	<h2><i>Water movement toward pump</i></h2>	
18		<p>When a pump is turned on, water enters the well through all permeable zones and moves toward the pump.</p>




The complexity during pumping is because when a pump is turned on, water enters the well through all permeable zones and moves toward the pump. Concentrations change as increasingly distal parcels of water become incorporated into the mix. Solute concentrations in a purged well may vary by over an order of magnitude depending on well construction, purging procedure, vertical concentration distributions in the aquifer, and aquifer hydrogeology. Presumably, given long enough pumping, all pumped samples eventually should produce a flow-weighted-average concentration. Then, the depth of the pumping should have little influence on the sample concentrations.

Regardless of these complexities, a pumped sample is the typical standard against which we compare PDB results in the field. The methods often agree, but sometimes disagree.

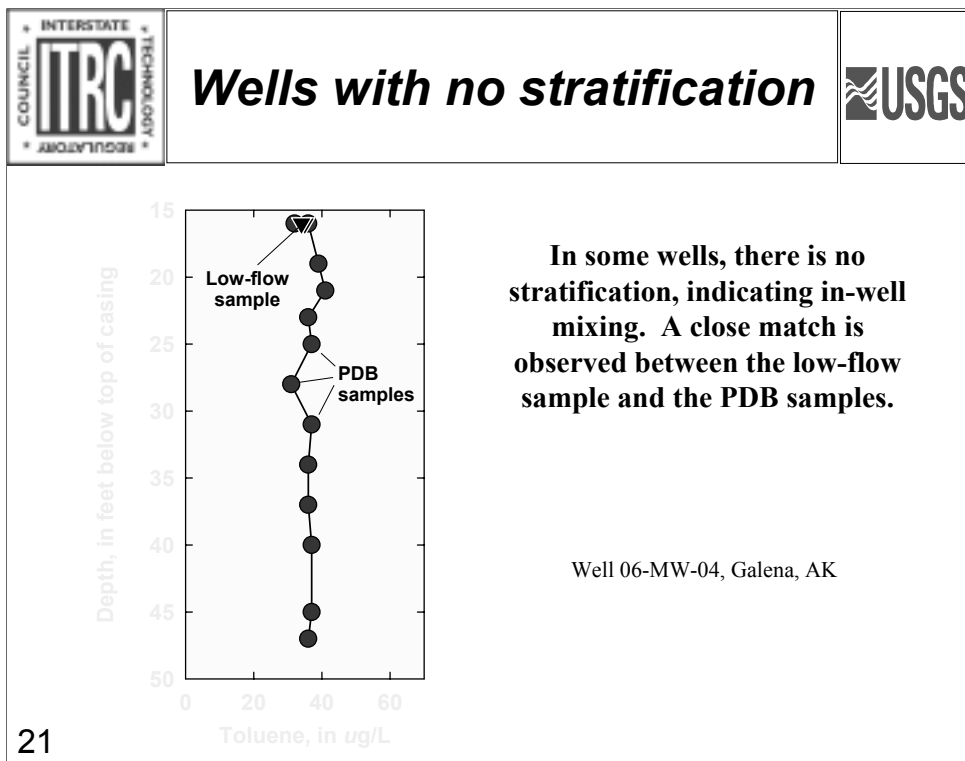


19

When compare VOC concentrations from PDB samplers under field conditions to VOC concentrations from pumped samples, we usually see a close relation. In this case, the comparison is made to a purge-and-sample methodology.

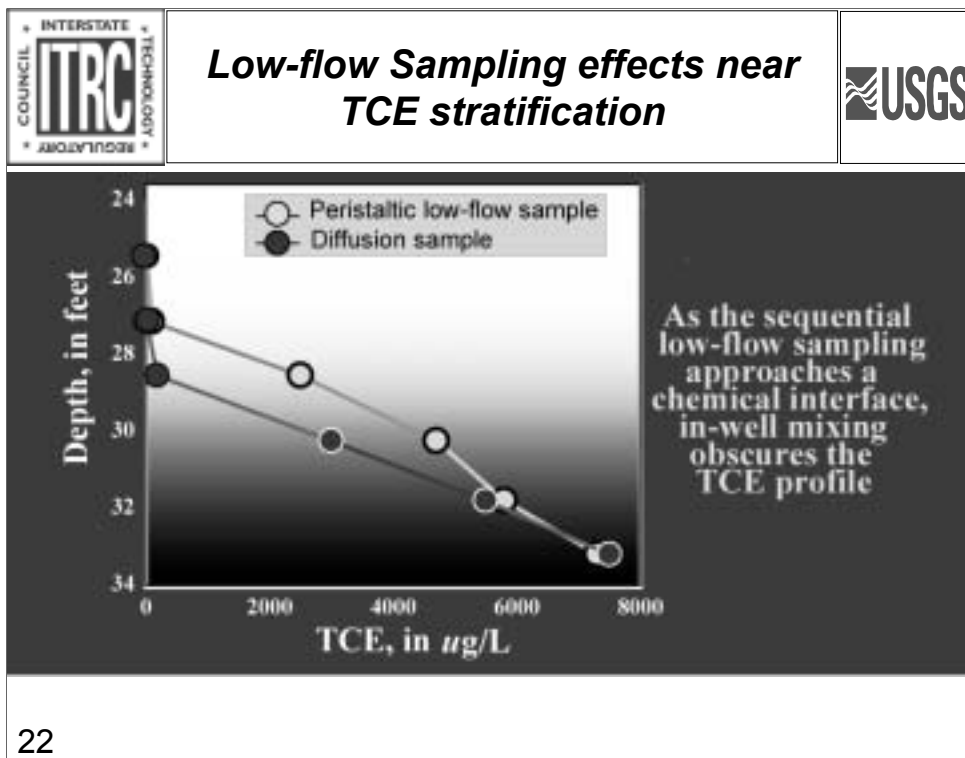
	<h2><i>Multiple PDB Samplers</i></h2>	
		
20		

To examine the potential for heterogeneity in wells, we can use multiple PDB samplers attached to a weighted line. There are a number of factors in a screened interval or open borehole that can cause mixing and make a uniform concentration within the screened interval despite the presence of stratification in the aquifer. These include dispersion, in-well vertical flow, and thermal convection.



So, in some wells, we see no apparent contaminant stratification. In these wells, the simplest explanation is that there are factors that cause in-well mixing. A close match is observed here between the low-flow sample and the PDB sample from any depth. Therefore, in this well, a PDB sampler placed at any random depth can provide sample concentrations comparable to low-flow sampling.

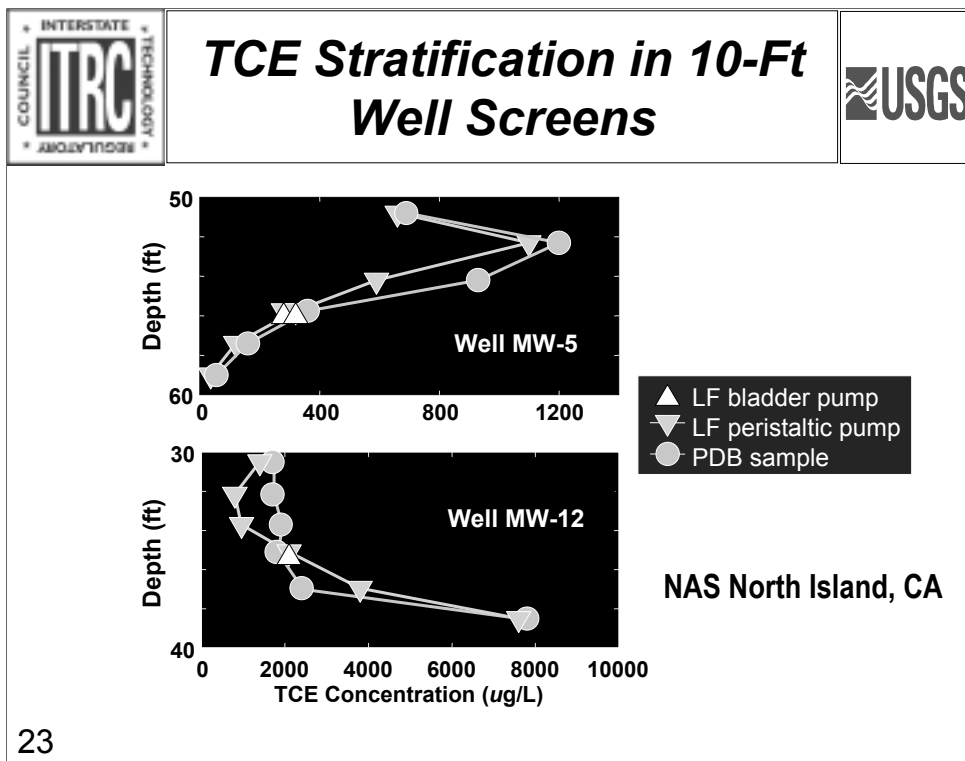
But, despite the potential for in-well mixing, we sometimes see contaminant stratification within the well bore using multiple PDB samplers. The next slide is an illustration.



22



This is well with substantial vertical stratification of TCE. The yellow is from low-flow sampling and the red is from PDB sampling. A very close match between the two methods was found for the first two (uppermost) sampling points. However, in the vicinity of stratification interface, the concentrations between the two methods diverged by parts per million. The samples collected deeper in the zone of high concentrations again matched up. The data strongly suggest that the PDB samplers represent a point sample, and the low-flow samples in this well represent a mixing over some relatively small interval. The mixing is more obvious near the chemical-stratification interface. The difference between the sampling methods at the interface is because the PDB sample presumably shows what is actually there, and the pumped sample collects a mixture of some highly contaminated deep water and much less contaminated shallow water. Therefore, it appears from the pumped sample that there is more than 2000 ppb TCE at about 28 ft, but the PDB sample tells us that we are still above the interface.

Thus, although the results from the two methods don't match well at certain points, the reason is not that either method is deficient. They are simply telling two different things. The PDB samplers are providing a high-precision delineation of the contaminant stratification. The low-flow sampling is providing a somewhat obscured delineation of the contaminant stratification.



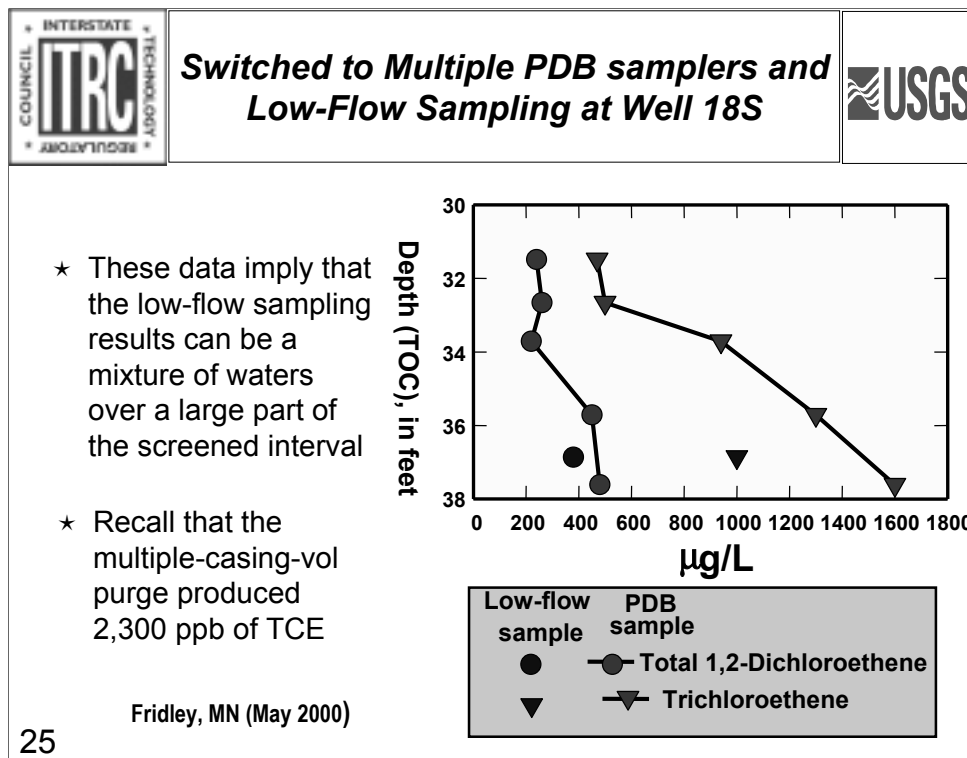
23

This is a comparison between low-flow sampling and diffusion (PDB) sampling in two wells having 10-ft well screens. In both wells at most depths, the two methods approximately agreed. Because PDB samplers represent a “point” sample in a well, these data imply that the low-flow sampling in these wells represented only a narrow interval of mixing. Typically, these wells are sampled by using a commonly accepted approach of placing a low-flow bladder pump in the center of the screened interval. These data suggest that, given the same purge time and flow rate, if the low-flow pump in well MW-5 was lowered about 3 ft, the pump would sample almost clean water, but if raised about 3 ft, it would sample water having concentrations of about 1,200 ug/L. If the pump at well MW-12 were lowered about 3 ft, it would sample concentration of TCE about 6,000 ug/L more than at its present position.



		Comparison of PDB and Purge Sampling Methods at Well 18S <i>(deployment of single PDB sampler in approximate center of screened interval)</i>			
		PDB Sampler Method ($\mu\text{g/L}$)			
				Purge-and-Sample Method ($\mu\text{g/L}$)	
Total 1,2-DCE	130	650			
TCE	570	2,300			
Fridley, MN (Nov. 1999)		4-casing-volume purge			

24

This is a situation in which the PDB sampler method did not agree with a traditional method. In this case, the standard method by which the well usually was tested was a 3 or more casing-volume well purge prior to sample collection. The chlorinated solvent concentrations from the single PDB sampler were substantially lower than the concentrations from the purge-and-sample method. To determine the source of the difference, we reinstrumented the well with multiple diffusion samplers and tried sampling using low-flow methodology as a less invasive conventional approach.





When we recovered and analyzed water from the multiple PDB samplers in well 18S, it became apparent that there was stratification in the well screen. The TCE and total 1,2-DCE concentrations substantially increased with increasing depth in the 10-ft well screen. The increase implies that the highest concentrations are at the base of or below the depth of the well. Thus, the sphere of water sampled during the the 4-casing-volume-purge sampling method previously used in this well probably included water from a more contaminated horizon immediately below the well, while the PDB sampler showed concentrations in the immediate vicinity of the well screen. In this slide, the low-flow sampling results (about 1,000 $\mu\text{g/L}$ for TCE) are substantially lower than the previous purge-and-sample results (2,300 $\mu\text{g/L}$ for TCE), supporting the hypothesis that the water sampled by the purge-and-sample method differed from the water in the immediate vicinity of the well screen. Although the low-flow sample and the adjacent PDB sample differ in concentration, the low-flow sample visually appears to be an approximate average of the concentrations across the screened interval. Thus, it appears that the low-flow sample mixed water over a larger interval than in the previous examples at NAS North Island.

	<i>Varying degrees of mixing during sampling</i>	
<ul style="list-style-type: none">★ Thus, diffusion samplers typically constitute a point sample, sometimes revealing stratification. In a well where in-well mixing has homogenized the chemistry, choice of a sampling depth is not critical. ★ The amount of mixing in low-flow samples is variable, sometimes mixing over a small vertical interval (selected horizons at NAS North Island) and sometimes mixing over larger intervals, including a flow-weighted average of the screened interval. ★ 3 or more casing-volume purge sampling averages aqueous concentrations even more by mixing, sometimes inducing flow from horizons not in the vicinity of the well screen. <p data-bbox="326 905 375 947">26</p>		

Thus, diffusion samplers typically constitute a point sample. Useful for targeting the high concentrations in wells where contaminant stratification is present. Avg. concentrations for a screened interval are obtained by multiple samplers. In a well where in-well mixing has homogenized the chemistry, the depth from which the sample is obtained is much less important than in a well containing stratification.

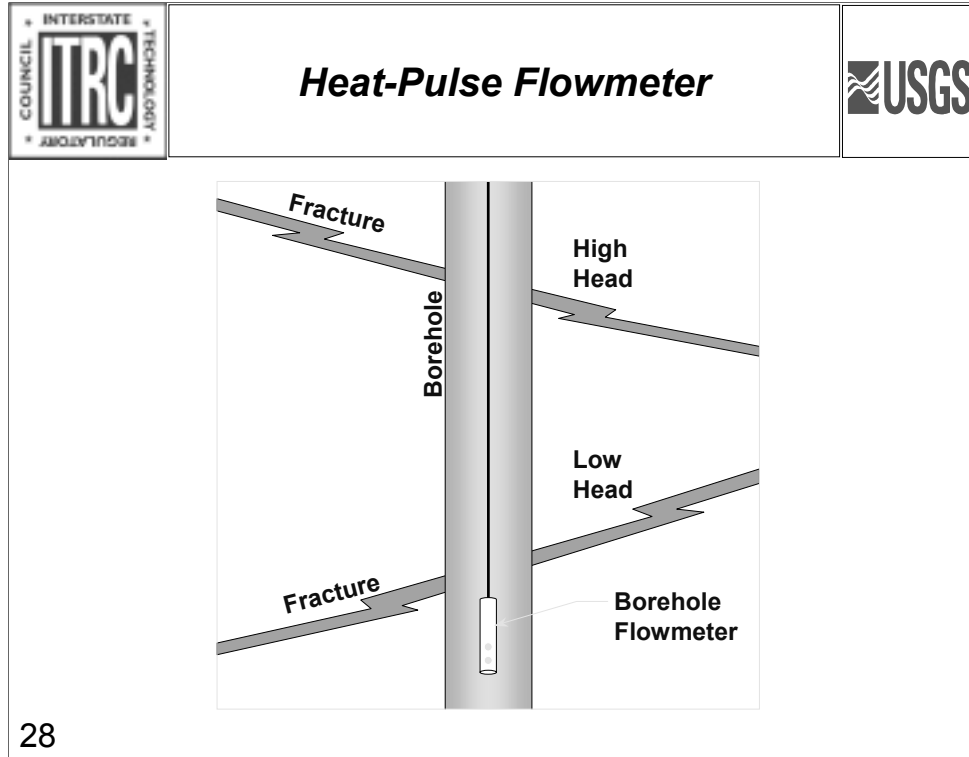
Pumped samples always produce some degree of mixing. The amount of mixing in low-flow samples is variable, sometimes mixing over a small vertical interval (selected horizons at NAS North Island) and sometimes mixing over larger intervals, including a flow-weighted average of the screened interval.

3 or more casing-volume purge sampling averages aqueous concentrations even more by mixing, sometimes inducing flow from horizons not in the vicinity of the well screen.

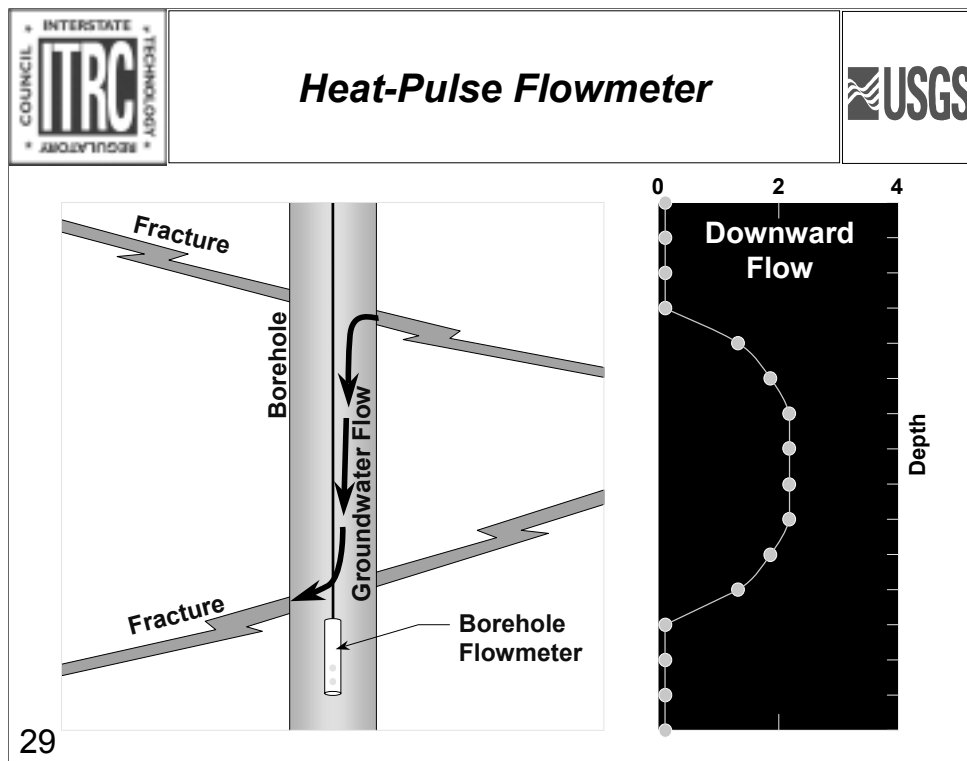
	<p><i>Relation between well sampling and well construction</i></p>	
<ul style="list-style-type: none">★ In some cases, disagreement between sampling methods can result from long-screened wells.★ Long-screened wells are wells that connect zones of significantly different hydraulic head or contaminant concentration.★ CONSIDER THE FOLLOWING EXAMPLE: <p>27</p>		

Instructor Notes:

None

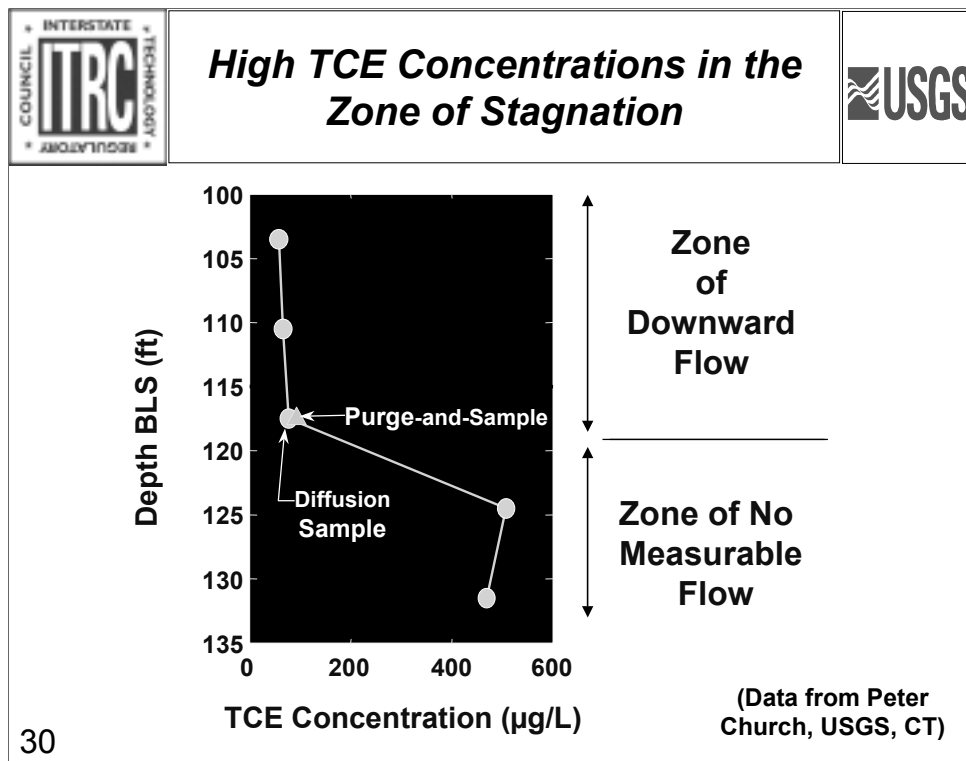


In a well intersecting two fractures of differing hydraulic head, the well may provide a conduit of water movement between the two horizons. Although the example here is a fractured-rock system, the same logic applies to an unconsolidated system, where two zones of differing head may be separated by a confining unit. We can gain some information of the vertical component of water movement by using a borehole flowmeter. Consider the situation in which the upper zone is a higher hydraulic head than the lower zone.



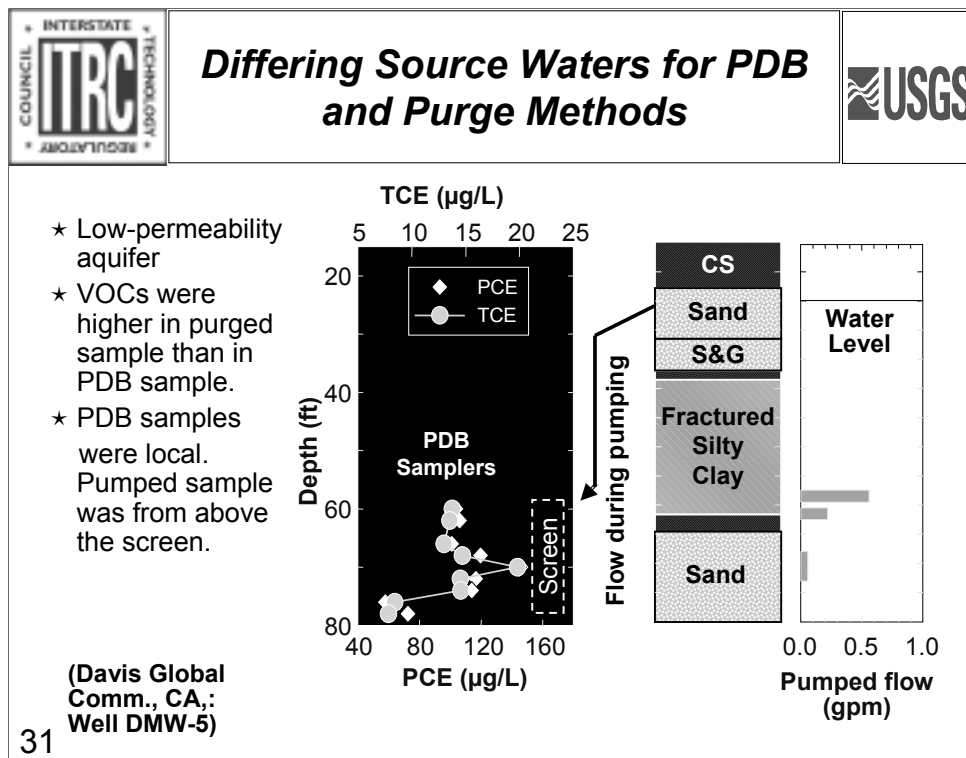
In this case, water can move into the well from the zone with the higher head, move downward (or upward, depending the direction of the hydraulic gradient) and discharge out of the well into the zone with the lower hydraulic head. By taking a series of readings with the borehole flowmeter, the zones of inflow and outflow can be identified. The readings typically are taken under static and pumping conditions. Identifying this situation is important because if VOC-contaminated water is flowing into the well and is exiting the well at a different horizon, then VOCs will be present along the screened interval at the same concentration between the two horizons. In this case, VOC concentrations in the screened interval may be representative of aquifer concentrations at the inflow horizon, but may not be representative of aquifer concentrations near the outflow horizon. Coupling multilevel PDB sampling with flowmeter measurements can be used to clarify this situation.

Even more insidious, however, is when clean water is entering the well and exiting at the contaminated horizon. In this case, you may not be able to obtain representative concentrations from the contaminated zone no matter what sampling methodology that you use. The reason is that the contaminated horizon does not contribute water to the well under static conditions in this well. Instead, water from other horizons with higher hydraulic head will invade the contaminated horizon by way of the well screen. Under pumped conditions, the majority of the extracted water will be from the most permeable interval, which may not be the contaminated zone. Even when pumping induces inflow from the contaminated interval, much of that inflow will be a reflection of the residual invaded water from other horizons. In this situation, a substantial amount of purging would be required before water representative of the aquifer could be obtained. Such sampling is not likely to reflect a significant contribution from the contaminated zone, and concentrations in the contaminated zone probably will be underestimated.

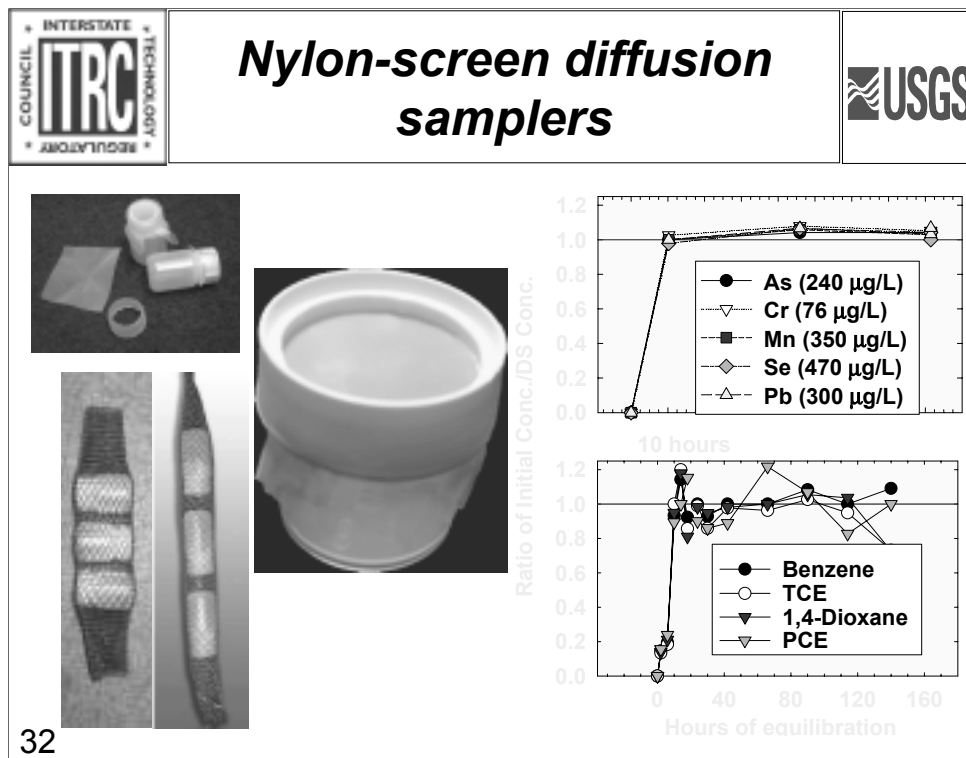


30

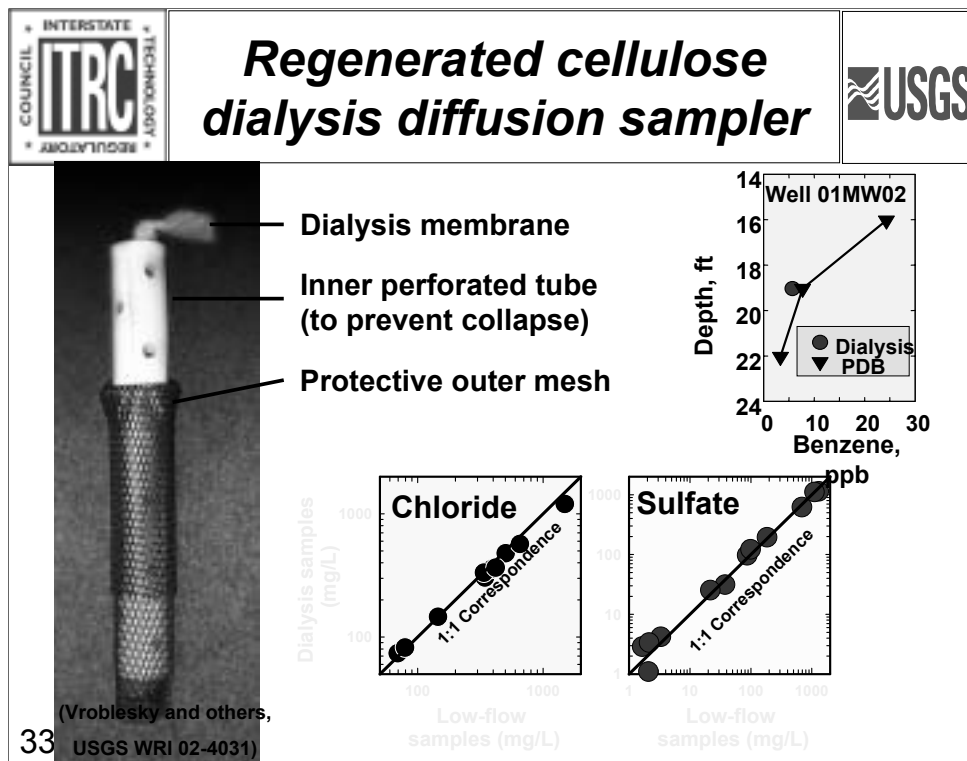
This slide illustrates the point. TCE stratification was present in well PO2-2R, with the highest concentrations below a fracture zone identified from the boring log near the bottom of the well. Borehole flowmeter data showed that no measurable movement of water into or out of the well in the zone of highest contamination. In the upper, less contaminated, part of the well, water was entering the well from some shallower zone and flowing downward, exiting the well in the vicinity of the fracture. Thus, water sampled by using either the purge-and-sample method or the PDB method in the well near the fracture at 115 ft represented concentrations from a shallower horizon rather than in the vicinity of the fracture. A simple explanation for the high concentrations detected by the PDB samplers below the fracture is that these represent equilibrium concentrations in that poorly connected part of the aquifer, and they may represent the concentrations that would be seen in the fracture zone at 115 ft if the actual concentrations were not obscured by the downward movement of less contaminated water from a shallower horizon. The high TCE concentrations between 120 and 135 ft probably would not be seen by using purge-and-sample methodology because the purge would remove the static water and replace it with water from the shallower, more permeable part of the well.



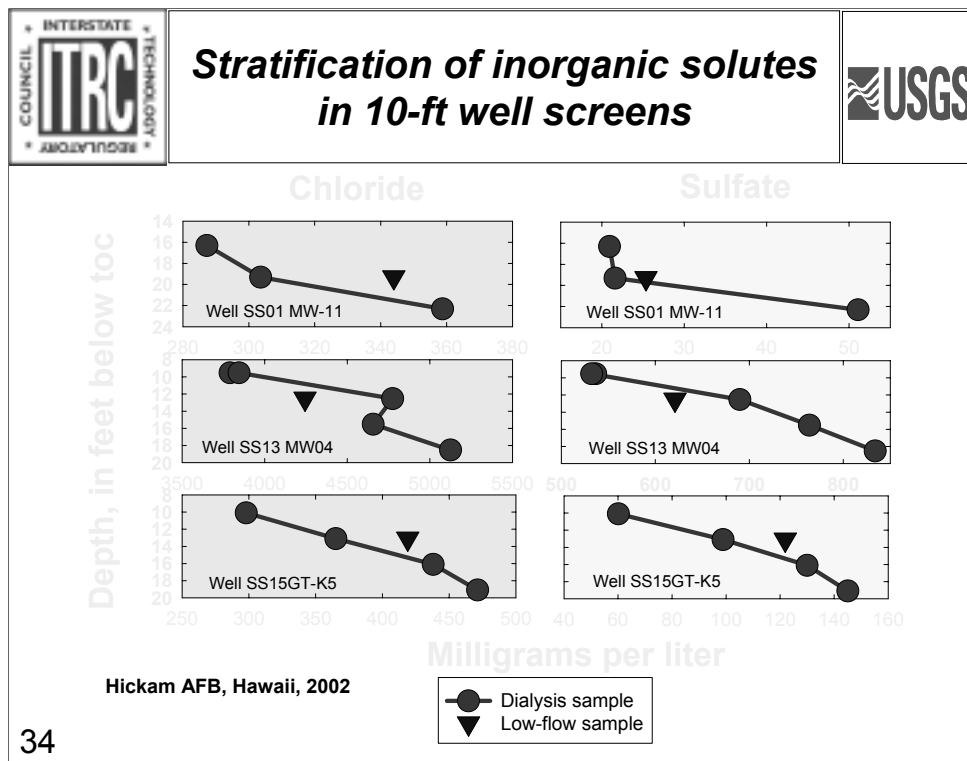
This is another site where a higher concentration was observed in the pumped sample than in the PDB sample. The maximum concentration of tetrachloroethene (PCE) from the PDB samplers was 145 $\mu\text{g/L}$, while the concentration from the purge-and-sample approach was 211 $\mu\text{g/L}$. Results from the PBD samplers implied that the maximum concentration under static conditions was in the center of the well screen in a sand formation. However, flowmeter testing showed that under pumped conditions, most of the water entered the well from the top of the well screen in a silty clay. In a situation when most of water flow to a well is derived from the top of the screen in a clay, the simplest explanation is that the water is derived from a shallower horizon and is moving downward outside the casing through leaking well seals or fractures in the silty clay. Other investigations showed that the shallower horizon at this site was contaminated with PCE. Thus, it is probable that, in this well, the PDB samplers represent PCE concentrations in the screened horizon under non pumping conditions, and the pumped sample represents a mixture of water from the screened interval and from a shallower, possibly more contaminated water-bearing zone. In this case, the PDB samplers probably provide concentrations more representative of the screened interval than the pumped sample.



Up to now, we have been looking exclusively at PDB samplers. We also can construct various other types of samplers if we wish to look at inorganic solutes. The samplers shown here are simply 30-mL and 175-mL wide-mouth plastic jars filled with deionized water and with the opening covered by a nylon screen. The screen shown here is about 125-micron mesh. It is secured onto the mouth of the jar by screwing on the cap over the mesh after the top of the cap has been drilled or cut open. The samplers can then be slid vertically or horizontally into a mesh sleeve and deployed down wells. The equilibration time is less than about 20 hours, but again it is prudent to leave them in for 2 weeks to account for well equilibration. The graphs show rapid equilibration to VOCs and metals. This type of sampler has been used primarily in marsh, lakebed pore-water studies, and in wells.





Dialysis membranes have been used to sample inorganic and organic solutes. In this slide, the membrane is regenerated cellulose, which is commercially available as tubing in various diameters. Both water and solutes move through dialysis membranes. When the sampler is filled with deionized water, equilibration with the well water is achieved by well-water solutes moving into the sampler and sampler-deionized water moving out of the sampler into the well. The dialysis bag collapses as the water moves out. The inner perforated tube shown here prevents bag collapse and water loss, so the equilibration is dominated by solute movement rather than water loss. The graphs show a close correspondence between low-flow and dialysis-sample chloride and sulfate concentrations. And a close match for benzene between dialysis and PDB samples.





34

Diffusion samples show that, like VOCs, inorganic constituents can show substantial stratification across 10-ft screened intervals. Chloride and sulfate are shown here in three wells. It is clear that the low-flow sample (blue triangle) represents some mixing of the concentrations found in the dialysis samples (red circles). However, the concentrations in the low-flow sample and the single dialysis sample from the low-flow sampling depth do not always agree. This is because the diffusion sample represents a point (about 1-ft long) and the low-flow sample represents a mixture. The important thing to note here is that simply because concentrations in a single diffusion sampler and a low-flow sample do not agree does not mean that the sampler is inaccurate.

	<i>Advantages and limitations of dialysis and nylon-screen samplers</i>	
<p>★ Advantages:</p> <ul style="list-style-type: none">• They can sample a broad range of solutes: including VOCs; 1,4-dioxane; perchlorate; MTBE, and inorganics. It is probable that they can sample semivolatiles, but we haven't tested it yet.• Nylon-screen samplers are extremely durable. <p>★ Disadvantages:</p> <ul style="list-style-type: none">• Regenerated cellulose biodegrades over time, so they cannot be deployed as long as PDB or nylon-screen samplers. The membrane has to remain wet once you begin to use it.• In anaerobic wells, iron and some other metals can precipitate in both nylon-screen and dialysis samplers if the samplers are filled with aerobic water or the well water becomes oxygenated. Therefore, unfiltered water from the samplers can overestimate total iron and some other metals if the precipitate is included in the analysis.		

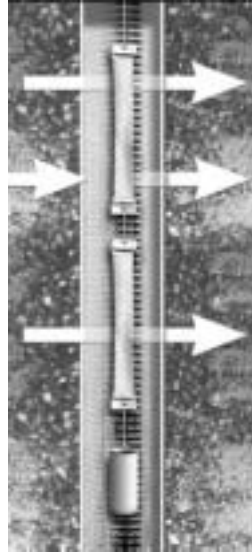
35

	<h2><i>Diffusion-Sample Parameters</i></h2>	
<ul style="list-style-type: none">★ VOCs, Inorganic solutes, and a number of non-VOC organics can be sampled with diffusion samplers.★ Diffusive sampling redox-sensitive inorganic compounds in wells is still a matter of research because of the oxidation potential.★ However, VOCs in particular are very easy to sample with diffusion samplers. Use of PDB samplers can provide significant cost and time savings in long-term monitoring. <p data-bbox="326 905 375 947">36</p>		

No associated notes





Questions and Answers





37

No associated notes



	<p>“Users Guide For Polyethylene-Based Passive Diffusion Bag Samplers To Obtain Volatile Organic Compound Concentrations In Wells”</p>											
<table><tr><td data-bbox="397 415 787 541"><p>Available for download from: In the links page at the end of this presentation</p></td><td data-bbox="824 415 1182 877"><p>Multi-Agency Document ★ U.S. Geological Survey ★ U.S. Air Force ★ U.S. Naval Facilities Engineering Command ★ U.S. EPA ★ Federal Remediation Technologies Roundtable ★ Defense Logistics Agency ★ U.S. Army Corps of Engineers ★ Interstate Technology Regulatory Cooperation Work Group (ITRC)</p></td></tr><tr><td colspan="2" data-bbox="565 556 613 588"><p>OR</p></td></tr><tr><td data-bbox="443 611 737 646"><p>http://www.itrcweb.org</p></td><td></td></tr><tr><td data-bbox="467 663 711 699"><p>http://www.frtr.gov</p></td><td></td></tr><tr><td data-bbox="423 716 756 804"><p>http://www.sc.er.usgs.gov/ publications</p></td><td></td></tr></table>			<p>Available for download from: In the links page at the end of this presentation</p>	<p>Multi-Agency Document ★ U.S. Geological Survey ★ U.S. Air Force ★ U.S. Naval Facilities Engineering Command ★ U.S. EPA ★ Federal Remediation Technologies Roundtable ★ Defense Logistics Agency ★ U.S. Army Corps of Engineers ★ Interstate Technology Regulatory Cooperation Work Group (ITRC)</p>	<p>OR</p>		<p>http://www.itrcweb.org</p>		<p>http://www.frtr.gov</p>		<p>http://www.sc.er.usgs.gov/ publications</p>	
<p>Available for download from: In the links page at the end of this presentation</p>	<p>Multi-Agency Document ★ U.S. Geological Survey ★ U.S. Air Force ★ U.S. Naval Facilities Engineering Command ★ U.S. EPA ★ Federal Remediation Technologies Roundtable ★ Defense Logistics Agency ★ U.S. Army Corps of Engineers ★ Interstate Technology Regulatory Cooperation Work Group (ITRC)</p>											
<p>OR</p>												
<p>http://www.itrcweb.org</p>												
<p>http://www.frtr.gov</p>												
<p>http://www.sc.er.usgs.gov/ publications</p>												
<p>38</p>												

Instructor Notes:

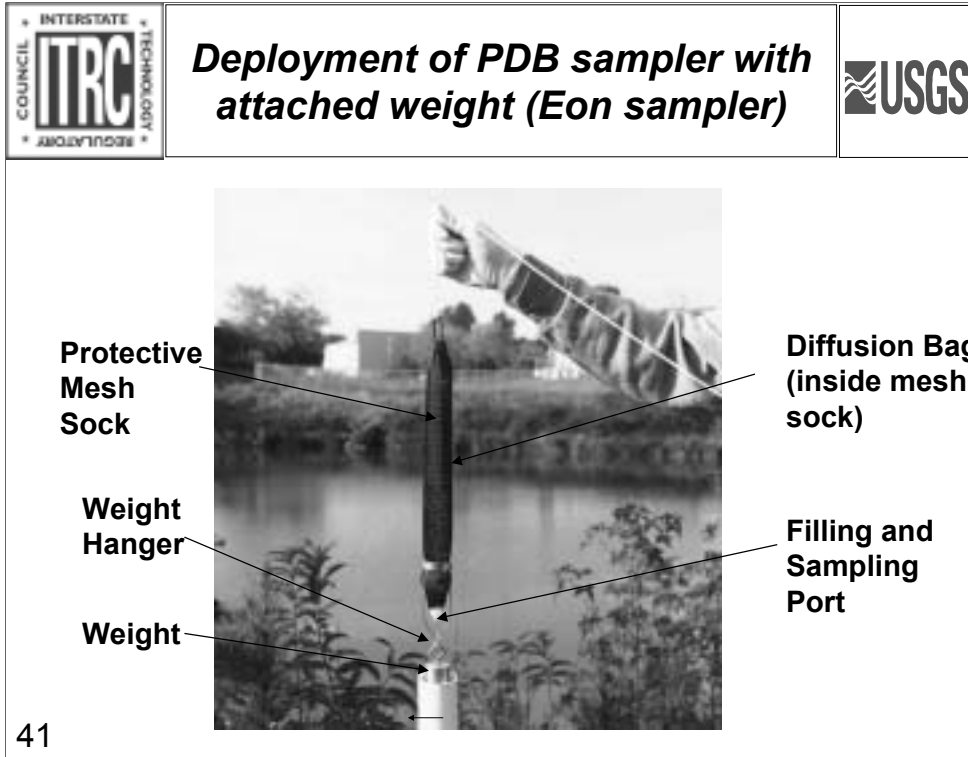
None

	<i>PDB Sampler User's Guide. Part 1</i>	
<ul style="list-style-type: none">★ Executive summary★ Introduction<ul style="list-style-type: none">● Summary of limitations and advantages★ PDB sampler deployment★ Sampler and sample recovery★ Determining applicability<ul style="list-style-type: none">● Influences of hydraulic and chemical heterogeneity on sample quality● Comparison of PDB sampling to conventional methodologies★ Quality control and assurance★ Summary★ References <p>39</p>		




Part 1 of the document covers deployment, recovery, data interpretation, and quality control and assurance.

	<h2><i>User's Guide Part 2: Field Tests</i></h2>	
<ul style="list-style-type: none">★ Comparison to purge-and-sample<ul style="list-style-type: none">● Davis Global Commun., CA (Vroblesky and others)● McClellan AFB, CA (McClellan AFB EMD)● NIROP Fridley, MN (Vroblesky and Petkewich)★ Comparison to low-flow sampling<ul style="list-style-type: none">● NAS North Is., CA (Vroblesky and Peters)● Hanscom AFB, MA (Church)● NIROP Fridley, MN (Vroblesky and Petkewich)★ Comparison to a variety of methods<ul style="list-style-type: none">● (Tunks and others) <p>40</p>		



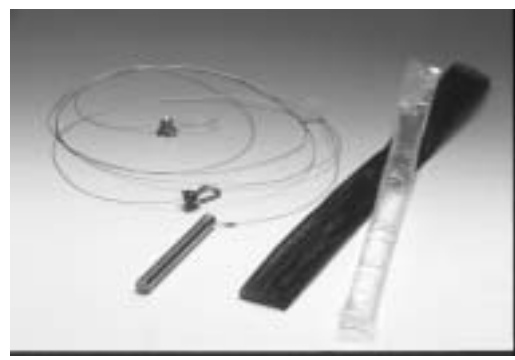


Part 2 of the “User’s guide for polyethylene-based passive diffusion bag samplers to obtain volatile organic compound concentrations in wells” is a series of field tests. This section includes 6 field investigations. PDB- sampler methodology was compared to conventional purging methods (purging at least three casing volumes) used at McClellan AFB and Davis Global Communications, and to low-flow methods used at NAS North Island and Hanscom AFB. Both conventional purging and low-flow purging were compared with using PDB samplers at NIROP Fridley. The study by Tunks and others at McClellan AFB compared the PDB samplers to conventional and low-flow techniques, as well as another type of diffusion device, the DMLS sampler.







This is an example of one of the types of commercially available PDB samplers. This one is supplied unfilled and can be filled by the user.

	<h2 style="text-align: center;"><i>Field Filling PDB Sampler</i></h2>	
		
42		

The unfilled samplers can be filled in the field by pouring deionized water into the sampler directly or through a funnel (provided).



	<p>Commercially Available Prefilled PDB Sampler</p>	
   <p data-bbox="893 840 1015 882">Sampler</p> <p data-bbox="1063 840 1193 882">Weight</p>		
<p>43</p>		

PDB Samplers also are available prefilled with laboratory-grade deionized water.

	<h2>Methods of Attaching PDB Samplers to the Line or Weight</h2>	
<ul style="list-style-type: none">★ The PDB sampler can be attached to the weighted line by a variety of methods.<ul style="list-style-type: none">• Wire ties through a knot• Stainless steel clamp• Direct attachment to the weigh★ Nonbuoyant nonstretch rope can be used as the line, however, stainless steel line is preferable★ Sufficient weight should be added to counterbalance the buoyancy of the PDB samplers <div data-bbox="821 428 1248 877" style="display: flex; justify-content: space-around;"></div>		
<p>44</p>		



Instructor Notes:

None

	<i>Two Approaches to Measuring the Line to Determine the PDB Attachment Point</i>	
<ul style="list-style-type: none">★ Weight suspended above the well bottom<ul style="list-style-type: none">● Measure the line and attach the PDB sampler at a distance corresponding to the depth of the target zone● Be careful that the line doesn't slip or stretch★ Rest weight on the well bottom<ul style="list-style-type: none">● Attach the PDB sampler to the line at a distance from the bottom of the weight equal to the distance from the well bottom to the target horizon● Usually this involves less measuring than measuring the line from the top down. <p data-bbox="337 911 375 940">45</p>		



Instructor Notes:

None

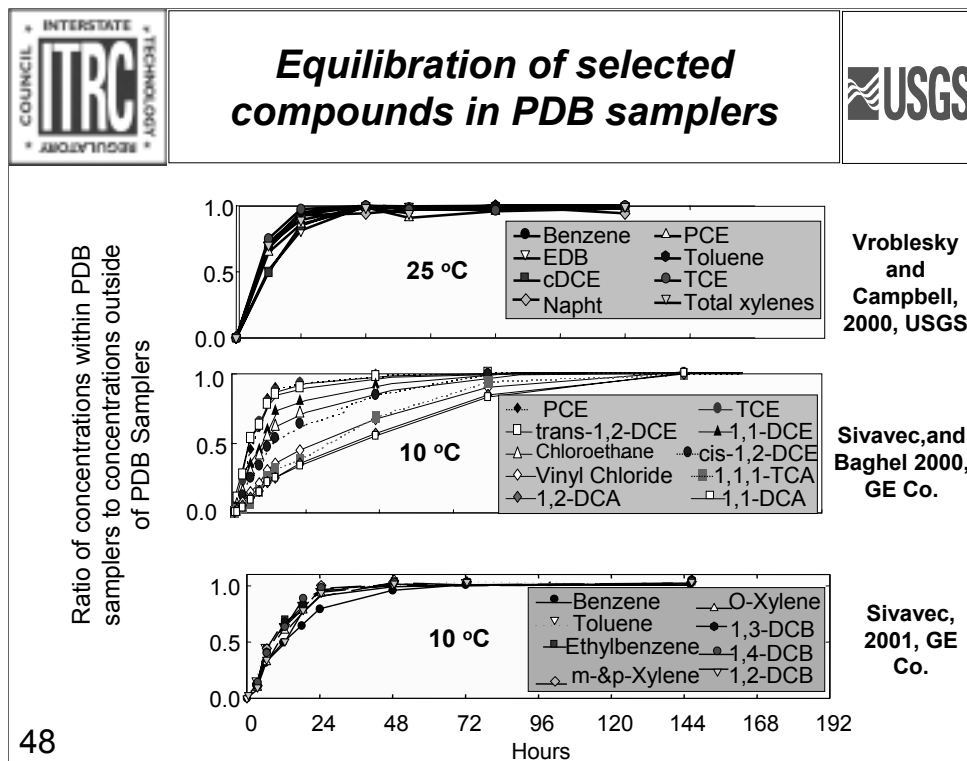
	<p style="text-align: center;"><i>Things to Consider When Measuring From the Bottom Upward</i></p>	
<ul style="list-style-type: none">★ Measure the well depth<ul style="list-style-type: none">● Compare measured and reported (from well logs) depths to the well bottom● This is to check on whether<ul style="list-style-type: none">➢ sediment has accumulated in the bottom of the well,➢ there is a non-screened section of pipe (sediment sump) below the well screen, and➢ on the accuracy of well-construction records.★ If there is an uncertainty regarding length or placement of the well screen, then an independent method, such as video imaging of the well bore, is strongly suggested. <p>46</p>		

Instructor Notes:

None



	<i>Consider the Screen Length Deploying PDB Samplers</i>	
<ul style="list-style-type: none">★ Screen length/saturated interval 5 ft or less<ul style="list-style-type: none">● PDB sampler in the center★ Screen length 5-10 ft<ul style="list-style-type: none">● Advisable initially to use multiple PDB samplers to ascertain the presence of contaminant stratification★ Screen length >10 ft<ul style="list-style-type: none">● Only use in conjunction with borehole flow meters or other techniques to characterize vertical variability in hydraulic conductivity and contaminant distribution or use strictly for qualitative reconnaissance purposes		
47		

In well screens >10 ft long, the caution is because of the increased potential for cross contamination of water-bearing zones and hydraulically driven mixing effects that may cause the contaminant stratification in the well to differ from the contaminant stratification in the adjacent aquifer material. If it is necessary to sample such wells, then multiple PDB samplers should be installed vertically across the screened or open interval to determine the zone of highest concentration and whether contaminant stratification is present.











48



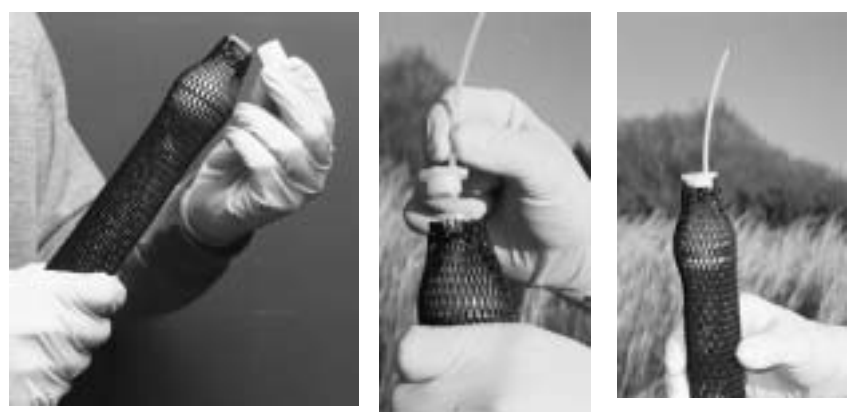
Laboratory tests of PDB samplers showed relatively rapid equilibration. The compounds shown here equilibrated at about 24 to 48 hours at 21 °C in tests vials (top graph). A subsequent test at 10 °C showed that PCE and TCE were mostly or completely equilibrated by 48 hours, while other tested compounds required longer equilibration times (center graph). Vinyl chloride, 1,2-dichloroethane, 1,1,1-trichloroethane, and 1,1-dichloroethane were not equilibrated at 93 hours but were equilibrated by 166 hours. Further tests at 10 °C by General Electric Co. showed that most BTEX compounds and the tested dichlorobenzene isomers were approximately equilibrated by about PCE and TCE were mostly or completely equilibrated by 48 hours, with benzene equilibrating slightly more slowly (bottom graph). Benzene appeared to not quite be equilibrated at 48 hours but was equilibrated by 72 hours.

	<i>PDB Sampler Equilibration in Lab Studies</i>	
<ul style="list-style-type: none">★ 48 hours for TCE and several tested compounds at 25 C (Vroblesky, 2000, USGS) ★ 93 to 166 hours for VC and some chloroethenes and 48 to 72 hours for BTEX compounds and selected dichlorobenzenes at 10 C (Sivavec and Baghel, 2000, 2001 General Electric Company) ★ But samplers should equilibrate long enough for well water, contaminant distribution, and flow dynamics to restabilize (2 weeks for permeable formations, possibly longer for poorly permeable formations) <p>49</p>		

The data indicate that the PDB samplers equilibrate rapidly to the tested VOCs (48 to 166 hours). However, the samplers should be left in place long enough for the well water, the contaminant distribution, and the flow dynamics to restabilize following sampler deployment. In many wells, these factors may restabilize in minutes to hours. However, other wells may require days to reequilibrate. As a simple guideline to encompass a variety of situations, a minimum equilibration time of two weeks should be adequate for most wells in permeable formations. In poorly permeable formations, longer equilibration times may be needed.




	<p><i>One water-transfer method is to insert a discharge tube through the polyethylene</i></p>					
<p>50</p>	<table border="0"><tr><td data-bbox="446 367 734 798"></td><td data-bbox="844 367 1182 766"></td></tr><tr><td data-bbox="462 808 698 945"><p>Inserting the tube through the polyethylene into the PDB sampler</p></td><td data-bbox="885 808 1128 892"><p>Transferring water to a VOA vial</p></td></tr></table>			<p>Inserting the tube through the polyethylene into the PDB sampler</p>	<p>Transferring water to a VOA vial</p>	
						
<p>Inserting the tube through the polyethylene into the PDB sampler</p>	<p>Transferring water to a VOA vial</p>					

One method of transferring water from the PDB sampler to VOA vials is by piercing the sampler near the base with a discharge tube. The rate of water flow can be controlled by tilting or manipulating the sampler.



	<h3>Attaching a Bottom-Discharge Device</h3>	
		

51

The water also can be removed from the PDB sampler by attaching a bottom-discharge device.



	<p><i>Water Also can be Removed Simply by Cutting the Sampler Open and Gently Pouring into VOA Vials</i></p>	
		
52		

Water also can be recovered from the PDB sampler simply by cutting open with a clean pair of scissors and pouring it into vials in a manner that minimizes agitation. Good comparisons to conventional sampling have been shown using all three water-transfer methods.



	<h2 style="text-align: center;"><i>Determining applicability of PDB Samplers</i></h2>	
<ul style="list-style-type: none">★ Common approach is to do a side-by-side comparison to conventional technology<ul style="list-style-type: none">● Particularly important in wells with high temporal chemical variability ★ In Wells with low temporal chemical variability, comparison of PDB-sampler results to historical concentrations may be adequate. <p>53</p>		

Instructor Notes:

None



	<h2><i>Data Evaluation</i></h2>	
<ul style="list-style-type: none">• In general, if the results agree in a range deemed acceptable by local, state, and Federal regulatory agencies and meet the site-specific data-quality objectives, then a PDB sampler may be approved for use in that well to monitor ambient VOC concentrations.		
<p>54</p>		

Notice that specific criteria for acceptable concentration ranges are not given. This is done for a variety of reasons. The primary reason is to allow regulatory flexibility in designing sampling programs to meet site-specific data-quality objectives. Thus, the specific ranges of acceptable values may vary from site to site. When reporting the comparisons, it probably is appropriate to consider the differences in terms of percent difference at high concentrations (for example, >50 micrograms per liter) and in terms of differences in actual micrograms per liter at lower concentrations (for example, < 15 micrograms per liter). This is because a relatively high percent difference can be reported for two samples differing by only 2 or 3 micrograms per liter in the low-concentration range.

	<p><i>If PDB-sampler VOC concentrations are higher than VOC concentrations from the conventional method</i></p>	
<ul style="list-style-type: none">• Then the PDB sampler probably adequately represent ambient conditions<ul style="list-style-type: none">- This is because there is a greater potential for dilution from mixing during sampling using conventional technology		
<p>55</p>		

Instructor Notes:



None

	<p><i>If the conventional method VOC concentrations are higher than PDB-sampler VOC concentrations – then:</i></p>	
<ul style="list-style-type: none">• Uncertain whether the PDB sampler or the conventional sampler conc.'s represent local conditions.<ul style="list-style-type: none">- Further testing (borehole flowmeter and/or multiple PDB samplers) can be used to clarify the situation.• PDB samplers may be more locally representative if the pumped samples<ul style="list-style-type: none">- Mixed chemically stratified zones- Incorporated water containing higher concentrations from other areas not adjacent to the screened interval<ul style="list-style-type: none">➢ along inadequate well seals➢ through fractured clay		

56




Instructor Notes:

None

	<p><i>The decision on whether to use PDB samplers in such situations depends on the data quality objectives</i></p>	
<ul style="list-style-type: none">• If the goal is to determine and monitor higher concentrations or to examine contaminant stratification within the screened interval<ul style="list-style-type: none">- PDB samplers may be appropriate• If the goal is to determine the average concentrations for the entire screened interval<ul style="list-style-type: none">- An average of multiple PDB samplers may be appropriate.- In a naturally mixed well, a single PDB sample may provide a flow-weighted average.- A pumped sample produces a flow-weighted average across intervals that may vary from well to well and even within the same well depending on lithology, well construction, and sampling methodology.		
57		

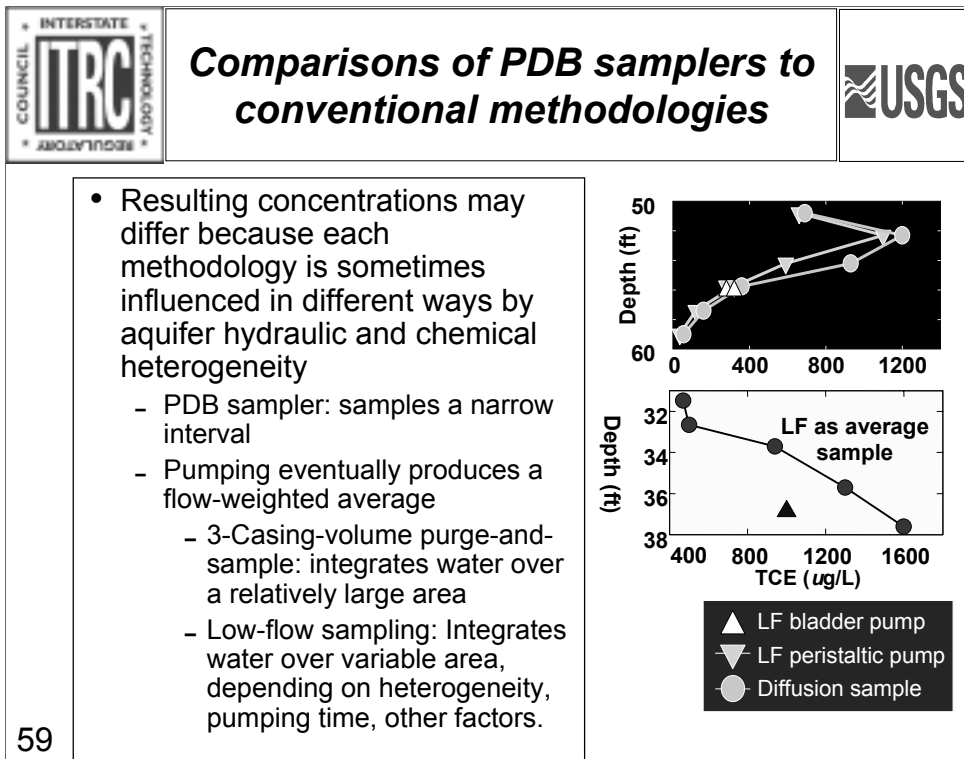
Instructor Notes:

None

	<h2><i>Vertical stratification of VOCs</i></h2>	
<ul style="list-style-type: none">• Stratification of VOCs sometimes is observed in unpumped wells. In such cases, using multiple PDB samplers may more fully characterize the contaminated horizon than using a single PDB sampler.<ul style="list-style-type: none">- Particularly true in well screens 10 ft or longer, but significant VOC stratification has been observed in intervals less than 5 ft• Because of the influences of chemical and hydraulic heterogeneity, discussed earlier, it is advisable that both the vertical distribution of VOCs and the potential for intra-borehole flow be determined in wells having screens longer than 10 ft. 		
<p>58</p>		

Instructor Notes:



None



59

Instructor Notes:

None

	<h2>Quality control and assurance</h2>	
<p><u>Replicate samples</u> At least 10 percent are recommended.</p> <p><u>Fill water blank</u> Tests should be done on the PDB sampler fill water since some VOCs introduced in the fill water (such as acetone) will not readily diffusion out (false positive).</p> <p><u>Trip blanks</u> Required for lab filled PDBS to determine whether contaminants have affected the samplers during shipment or prior to deployment.</p> <p><u>Equipment blanks</u> Required for field-filled PDBS.</p> <div style="border: 1px solid black; padding: 5px; text-align: center;"> <p>Note: Blanks are taken at the time of sampler deployment and sent immediately for analysis</p> </div>		
60		



Instructor Notes:

Replicate (a.k.a. duplicate) samples should be collected at a rate of 10 per cent of the total number of samples collected. A replicate sample must be obtained from the same bag as the original sample or from another PDB sampler that has been deployed side-by-side at the same sampling interval.

Fill water blank: The fill water blank is required to detect any sample bias due to the quality of the water used to fill the sampler. It also checks the quality of the water being sent down the well which could potentially add to existing impact if it is contaminated.

Trip blanks are required for bags shipped pre-filled from a lab or vendor. One “extra” PDBS should be ordered and shipped to the site in the same container and stored in the same manner as the PDB samplers that will be deployed during the sampling event. When all bags have been deployed, a trip blank is taken from the “extra” PDBS and sent to a NJ Certified lab for analysis. Trip blanks are collected at a rate of one per sampling shipment, however, if there is more than one sampling crew separately, one should be collected for each sampling crew.

Equipment blanks: Equipment blanks are taken to identify any bias in sampling results attributable to the PDB samplers themselves. The equipment blank is obtained by filling a PDB sampler using the same procedure used for filling all the samplers at the site (e.g., if other samplers are filled using a funnel, follow the same procedure to fill the equipment blank sampler). After filling the sampler, seal it as you would other samplers before deployment, and then gently invert the sampler once to mix the contents. Open the PDBS and transfer a sample into a VOA vial in the same manner as will be used to obtain samples when they will be retrieved after the equilibration period.



	<h2 style="margin: 0;">Regulatory Aspects of Passive Diffusion Bag Samplers</h2>	
<p><u>Regulatory Considerations / Requirements</u></p> <ul style="list-style-type: none"> • No regulatory requirements identified that would prevent their use • Major deterrents to deployment include: <ul style="list-style-type: none"> - Lack of standard operating procedure (SOP) in state Sampling Procedures Manuals - Strong reluctance to switch from methods already in use - Concerns about comparability with other sampling methods, and interpretation of data <p><u>Regulatory Acceptance</u></p> <ul style="list-style-type: none"> • Widely deployed across the Nation. Known to be approved and implemented for LTM at several sites (FL, MO, NJ) <p>61 • A May 2003 survey indicated widespread acceptance by State regulators for LTM</p>		

No specific regulatory barriers or regulations were identified that would prevent the use of Passive Diffusion Samplers. However, there are some issues unrelated to specific regulations that impeded the use of PDBS.

One problem is the lack of standardized operating procedures for PDBS in State Field Sampling Procedures Manuals. Because of this many regulators are unfamiliar with the sampling method and reluctant to approve it without acceptable guidance. The USGS User's Guide was written with strong input from the ITRC and other agencies including the DOD, EPA Army Corp of Engineers. It was the first document available that provided a standardized approach for evaluating the appropriateness of PDBS and instructions on how to deploy them. The ITRC engaged Member States to review this document and provide a concurrence letter to indicate whether the State will use and test the document as a decision making tool. To date, we have received positive responses from the States of Alaska, Illinois, Louisiana, North Dakota, New Hampshire, New Jersey, New York, Oklahoma, Oregon, South Carolina, Tennessee, Virginia, and Vermont. Other States are still reviewing the document and may respond in the future. In addition to this, the States of Arizona and New Jersey are currently developing guidance on the use of PDB samplers.



Another deterrent for using PDB samplers is the strong reluctance on the part of regulators and the regulated community in general, to switch from a traditionally accepted sampling method to a potentially controversial new technique. There is also a potential for detecting higher concentrations of contaminants as compared to purge and sample techniques, so there are concerns regarding data use regulatory response as well. The ITRC has issued a position paper to identify some of these issues and to develop a framework to evaluate data generated with PDB samplers.

Passive Diffusion Bag samplers have been deployed at many sites throughout the country by the Navy, Air Force, and to a lesser extent, private industry. Some of the States where PDBS are being deployed include Arizona, California, New Jersey, South Carolina, and Tennessee and likely many others we're not currently tracking. Several sites (NJ and FL) have approved PDBS as a replacement technology. Here in New Jersey we've been receiving increased interest and proposals from sites undergoing long term ground water monitoring, so the number of sites where they're being used is expected to increase significantly in the near future.

	<h2><i>PDB Samplers</i></h2> <p><i>A Different Way To “Collect” A Sample</i></p>	
<ul style="list-style-type: none">- Another tool for the sampling tool box - Once the PDB Sampler is retrieved from the well, all other sampling issues (i.e., sample containers, preservation, chain of custody, analysis, etc....) are identical to conventional sampling methodologies - Focus carefully on deployment aspects to ensure they are used properly		
62		

It needs to be realized that the difference between conventional ground water sampling methods and PDB samplers ends once the sample is removed from the well. After that, the process is identical to convention methods in regard to sample containers, preservation, chain of custody, etc...).

After listening to Don Vroblesky’s presentation, it should be apparent that there is sufficient data to demonstrate that the samplers work. The main focus then, should be on the applicability of the site in relation to sampler capabilities, how the samplers will be deployed and retrieved, and how the performance of the samplers will be evaluated . Data use is a separate consideration, and clearly different for each site.



	<h2><i>PDBS Applicability</i></h2>	
<p style="text-align: center;"><u>Recommended for Long Term Monitoring</u></p> <ul style="list-style-type: none"> - At well characterized sites - Contaminants must be VOCs <div style="border: 1px solid black; padding: 5px; margin: 10px 0;"> <p><u>Sentinel Wells ???</u></p> <ul style="list-style-type: none"> - Problem w/unknown depth & movement of plume front - Usually long screens, so at what depth interval do you set PDBs?? <p><u>Monitored Natural Attenuation ???</u></p> <ul style="list-style-type: none"> - PDBs unable to detect iron, sulfate, nitrate & manganese - Not recommended for evaluation of Natural Attenuation processes - But... PDB samplers can detect DO, Methane, and breakdown prod.; <li style="padding-left: 20px;">may potentially be used to evaluate some MNA conditions </div>		
<p>63</p>		

1. PDB samplers are recommended for long term monitoring of VOC contaminated ground water at well characterized sites. This is due to the limited parameter capability of the samplers (selected VOCs), which makes it inappropriate for work associated with remedial investigations. In addition, most sites undergoing long term monitoring have a good amount of historic ground water sampling data available to help evaluate sampler performance.

2. Sentinel wells are located downgradient of contaminant plumes and designed to detect downgradient movement of the plume into clean aquifer zones. Since sentinel wells typically have well-screens greater than five-feet, and since they are predominantly installed in ground water that is not impacted by site related constituents, there is no way to vertically profile the well to determine the most appropriate sampling interval. It is also difficult to accurately estimate at what depth the contaminated ground water might be moving at when it reaches the well. As such, the well would need to be vertically profiled each sampling event to ensure that impact, if present, was detected.

3. Contaminants of concern at the site must be compatible with the capabilities of the PDB samplers (i.e. most VOCs but not acetone, styrene or MTBE).



4. Due to the inability of the samplers to detect many major electron acceptors such as iron, nitrate, sulfate, and manganese, the use of the samplers for evaluating natural attenuation processes is not recommended. However, the samplers are capable of detecting dissolved oxygen, methane, and volatile breakdown products so there is a potential for using the samplers to provide some information on contaminant degradation.

	<h2 style="margin: 0;">Deployment Issues</h2>	
<p><u>PDB samples represent a “point sample”</u></p> <ul style="list-style-type: none"> - Use “as built” well diagrams for most accurate well information - Measure total depth of well before deployment, compare to “as built” - Must accurately measure PDB sampler position in well (measure attachment point of PDB on deployment line from bottom up) <p><u>Must assess potential for vertical stratification</u></p> <ul style="list-style-type: none"> - At least initially, deploy multiple bags to vertically profile well (recommended: one PDB for every five feet of saturated screen) - Based on site conditions, may need to re-assess <p><u>Important to evaluate potential for vertical flow in well</u></p> <ul style="list-style-type: none"> - High potential in bedrock formations - High potential in unconsolidated formations that have clay & silt layers - Can use heat pulse flow meter or similar device to measure flow <p>64</p>		

1. Where there is horizontal ground water flow through the well screen, PDB samplers represent a point sample at the exact depth interval within the well-screen where they are suspended. Because of this, it is essential to know exactly where the sampler was located within the well when evaluating resulting data. Since it is common for proposed well installation specifications to be modified in the field due to drilling difficulties, borehole cave-in or lack of desired well construction materials, it is necessary to use “as built” well diagrams to help assess the appropriate depth for PDB deployment. Occasionally wells are constructed with “sediment traps” or “sumps” which are pieces of blank casing attached to the bottom of a well-screen intended to provide an area where sediment can accumulate without obscuring the well-screen. Care must be taken to identify and account for wells that have sumps below the well-screen when determining PDBS position in the well.

2. Contaminants do not always flow uniformly through an aquifer. Studies presented in Part 2 of the U.S.G.S. Water Resources Report, “*User’s Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells*”, clearly identify common detection of a high degree of chemical variability along the vertical portion of 10-foot well-screens. PDB samplers represent a point source sample from an exact section of screen where the sampler is positioned. If contaminants are migrating through the aquifer above or below where the sampler is positioned, the PDB sampler will not detect it. It is, therefore, necessary to vertically profile a well using multiple PDB samplers to identify the presence of contaminant stratification and to document the most appropriate depth interval for future single sampler deployment.



3. As previously mentioned, in some instances vertical flow can be present within the well. This condition is more common in bedrock aquifers, but it can also be present in unconsolidated formations where the screened interval intersects zones of differing hydraulic head. If vertical flow is present in a well, the VOC concentration in the PDB sampler will be more representative of the water flowing vertically past it from another portion of the aquifer rather than from horizontal ground water quality in the adjacent formation. In these cases, it is necessary to know where the water is coming from and where it is going. This can be accomplished by using a heat-pulse borehole flow meter to take readings at multiple intervals within the well-screen or open borehole. This data can be used in conjunction with vertical profiling to provide a better understanding of contaminant distribution within the aquifer. It will also ensure that generated data is not misinterpreted.

	<h2><i>EQUILIBRATION TIMES</i></h2>	
---	--	---



2-week minimum

- After PDB deployment and well re-stabilization, equilibration of VOCs generally occurs within 1-4 days
- May need longer timeframe in tight formations to allow stabilization of water column
- Field studies show longer deployments, up to 3-months, did not encounter problems [i.e. no loss of bag integrity or bio-fouling]





	<h2><i>Performance Evaluation</i></h2>	
<p><u>Simple site conditions</u> (simple geology, low variability in sampling results and water levels)</p> <ul style="list-style-type: none"> - Comparison to historic data acceptable. Side by side won't necessarily provide better evaluation data. <p><u>More complicated site conditions</u> (complicated geology, high variability in sampling results and water levels)</p> <ul style="list-style-type: none"> - Side-by-side comparisons appropriate to evaluate current conditions for comparison purposes <p><u>Poor correlation DOES NOT indicate failure</u></p> <ul style="list-style-type: none"> - Indicates more work needed to understand problem <p><u>Discuss evaluation criteria before PDBS deployment</u></p> <ul style="list-style-type: none"> - Reduces potential for problems when data is submitted <p>66</p>		

1. When evaluating the appropriateness of PDB use at a particular well, a common approach is to do a side-by-side comparison with a conventional sampling method. In wells where there is little variation in concentration and ground water elevation, comparison of PDB sampler results to historical sampling results may provide enough information to determine whether PDB samplers are appropriate for the application.
2. At sites where the hydrogeology and ground water flow is more complicated, and/or where there is considerable variability in contaminant concentrations over time, the use of historic data should be supplemented with side-by-side comparisons using conventional ground water sampling methods.
3. It should be emphasized that poor correlation does not indicate the samplers are inappropriate for use. Poor correlation with the sampling method already deployed at the site may merely mean additional investigation is needed to determine the cause of the discrepancy. However, it must also be kept in mind that there are inherent problems with every ground water sampling method. When pumping a well, contaminants could be drawn into the well from locations that would not naturally flow into the well. As such, results from pumping and passive sampling could be significantly different. Considering this, it would not be unusual for results to differ slightly since different sampling methods may be telling different stories. It's more important to look at the magnitude of the difference and the data trends.
4. It is best to identify the criteria which will be used to evaluate sampler performance prior to deployment. As a regulator, I'd might have a tendency NOT to approve use of PDB samplers if there is poor correlation to historic data or side-by-side comparisons. But as you've seen with some of Don Vroblesky's work, the poor correlation may be the result of a problem with the method you are using for comparison, not necessarily the PDB sampler.

	<h2 style="margin: 0;"><i>Future Work for ITRC Diffusion Sampler Team</i></h2>	
<p><u>Website Maintenance</u></p> <p>[http://diffusionsampler.itrcweb.org]</p> <ul style="list-style-type: none"> - Continue to update and revise the ITRC Diffusion Sampler Information Center <p><u>Technical and Regulatory Guidance Document</u></p> <p><i>"Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater"</i></p> <ul style="list-style-type: none"> - Includes Decision Tree, Technical Issues, Regulatory Survey, Cost Performance Template, Case Studies - Complements Users Guide published in 2001 - Scheduled for release in December 2003 <p>67</p>		

1. The ITRC Diffusion Sampler Team has developed a website designed to provide up to date information on passive sampling techniques. Information is provided on deployment locations, guidance documents, field reports and lessons learned. The current focus is on the use of PDBS, however, work is currently being conducted on methods for other passive sampling approaches that would permit the collection of samples for semi-volatile and inorganic analysis. As additional information becomes available, it will be posted on the website.

2. The ITRC's mission in general is to assist in the development and use of innovative technology so contaminated sites can be cleaned up more more efficiently and more cost effectively. In this respect, the ITRC-DS Team will continue to act as an information resource to State Regulators, Stakeholders, and interested parties to assist in the successful deployment of diffusion sampler technology.

	<h2><i>Future Work for ITRC Diffusion Sampler Team</i></h2> <p><i>(Continued)</i></p>	
<p style="text-align: center;"><u>Other Passive Sampling Approaches</u></p> <p>Look at other passive sampling approaches for evaluating ground water and ground water discharges to surface water</p> <ul style="list-style-type: none">- Dialysis Samplers- Vapor Phase Diffusion Samplers- Peeper Samplers- PDBs <p style="text-align: center;"><u>Continue to Serve as Information Resource</u></p> <p>Track and evaluate emerging theories and technologies on well hydraulics and PDBs performance to help better understand what the data means and how it relates to other sampling methods</p> <p>68</p>		

1. The ITRC Diffusion Sampler Team has developed a website designed to provide up to date information on passive sampling techniques. Information is provided on deployment locations, guidance documents, field reports and lessons learned. The current focus is on the use of PDBs, however, work is currently being conducted on methods for other passive sampling approaches that would permit the collection of samples for semi-volatile and inorganic analysis. As additional information becomes available, it will be posted on the website.

2. The ITRC's mission in general is to assist in the development and use of innovative technology so contaminated sites can be cleaned up more more efficiently and more cost effectively. In this respect, the ITRC-DS Team will continue to act as an information resource to State Regulators, Stakeholders, and interested parties to assist in the successful deployment of diffusion sampler technology.



Helpful Hint:
Securely Attach
the Line at the
Well Head

Thank you for
attending this ITRC
training course.

69

Instructor Notes:

None

	<h2><i>Thank You!</i></h2>	
<div data-bbox="540 562 1089 684" style="border: 1px solid black; padding: 5px; display: inline-block; margin: 20px auto; width: fit-content;"> <p><u>Links to Additional Resources</u></p> </div> <p data-bbox="453 846 1154 915" style="margin-top: 40px;">ITRC – Shaping the Future of Regulatory Acceptance www.itrcweb.org</p> <p data-bbox="337 909 375 940">70</p>		

Links to additional resources: <http://www.clu-in.org/conf/itrc/diffusion/resource.htm>

Your feedback is important – please fill out the form at: <http://www.clu-in.org/conf/itrc/diffusion/feedback.cfm>

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

- helping regulators build their knowledge base and raise their confidence about new environmental technologies
- helping regulators save time and money when evaluating environmental technologies
- guiding technology developers in the collection of performance data to satisfy the requirements of multiple states
- helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations
- providing a reliable network among members of the environmental community to focus on innovative environmental technologies

•How you can get involved in ITRC:

- Join a team – with just 10% of your time you can have a positive impact on the regulatory process
- Sponsor ITRC’s technical teams and other activities
- Be an official state member by appointing a POC (Point of Contact) to the State Engagement Team
- Use our products and attend our training courses
- Submit proposals for new technical teams and projects
- Be part of our annual conference where you can learn the most up-to-date information about regulatory issues surrounding innovative technologies