



Polyethylene Diffusion Bag (PDB) Samplers

Sometimes called Passive Diffusion Bag
Samplers

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Presentation Overview






- ★ Background on diffusion samplers
- ★ Theory – Why diffusion samplers work,
field applications of PDB samplers
- ★ Question and Answer Period 1
- ★ Discussion of User's Guide and practical applications
- ★ Data interpretation – comparison between different
methods
- ★ Questions and Answer Period 2




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	<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>3</p>		

	<h2 style="text-align: center;"><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. 		
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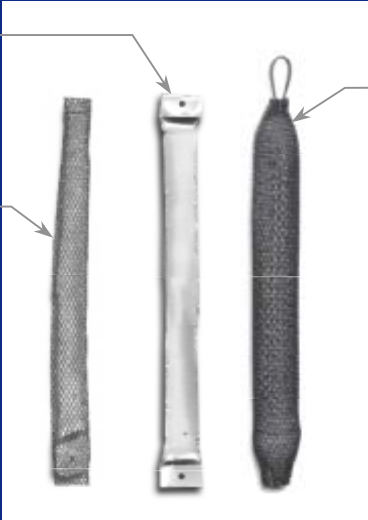
Typical Water-Filled PDB Samplers



PDB sampler without protective mesh


PDB sampler with protective mesh

Must purchase from vendor or obtain license from USGS (703 648:4344)




PDB sampler attached to bailer bottom

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Principle



★ **Law of Diffusion**


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

★ **Fick's Law**

- The rate of diffusive mass transfer through a unit area (J) is proportional to the difference in concentrations ($C_1 - C_2$) divided by the distance separating those concentrations (L). The constant of proportionality is also called the diffusivity, or diffusion coefficient (D).


Fick's Law:
$$J = D \frac{(C_1 - C_2)}{L}$$

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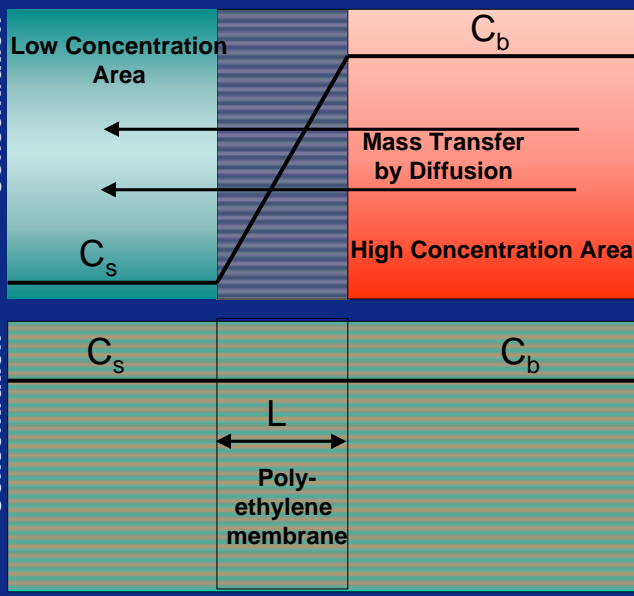


Principle

Law of Diffusion (cont.)



Concentration




Before equilibration


After equilibration

Concentration

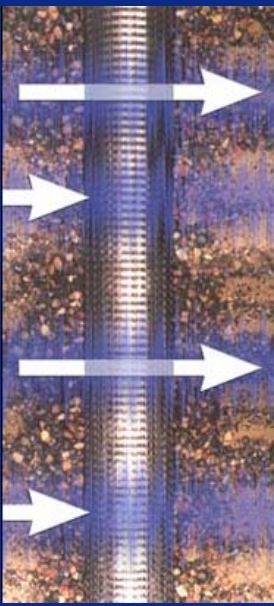
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Groundwater and Contaminant Flow




Concentration




Concentration

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Cross Section View

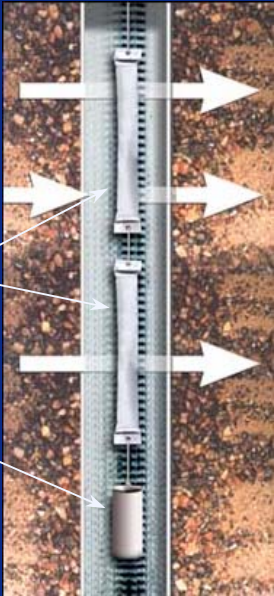


Diffusion Samplers Deployed in Well



Diffusion Samplers


Weight




Cross Sectional
View

Avg. Diffusion
Sampler size 1 to 2
feet in length

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Lab Tested VOCs in PDB Samplers



Tested compounds showing good correlation (11 or less percent difference)

Benzene	2-Chlorovinylether	<i>cis</i> -1,2-Dichloroethene	1,1,1-Trichloroethane
BDCMethane	DBChloroMethane	<i>trans</i> -1,2-Dichloroethene	1,1,2-Trichloroethane
Bromoform	DibromoMethane	1,2-Dichloropropane	Trichloroethene
Chlorobenzene	1,2-DCBenzene	<i>cis</i> -Dichloropropene	TCFMethane
Carbon Tet.	1,3-DCBenzene	EDB	1,2,3-TCPA
Chloroethane	1,4-DCBenzene	<i>trans</i> -1,3-DCPE	1,1,2,2-PCA
Chloroform	DCFMethane	Ethyl benzene	Tetrachloroethene
Chloromethane	1,2-Dichloroethane	Naphthalene	Vinyl chloride
	1,1-Dichlorethene	Toluene	Xylenes

Tested compounds showing poor correlation (> 20 percent difference)

Acetone*	MTBE	Styrene	MIBK*
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Vroblesky and Campbell (2000), *Sivavec (2000, 2001, GE Corp., written commun.)



Limitations of PDB Samplers



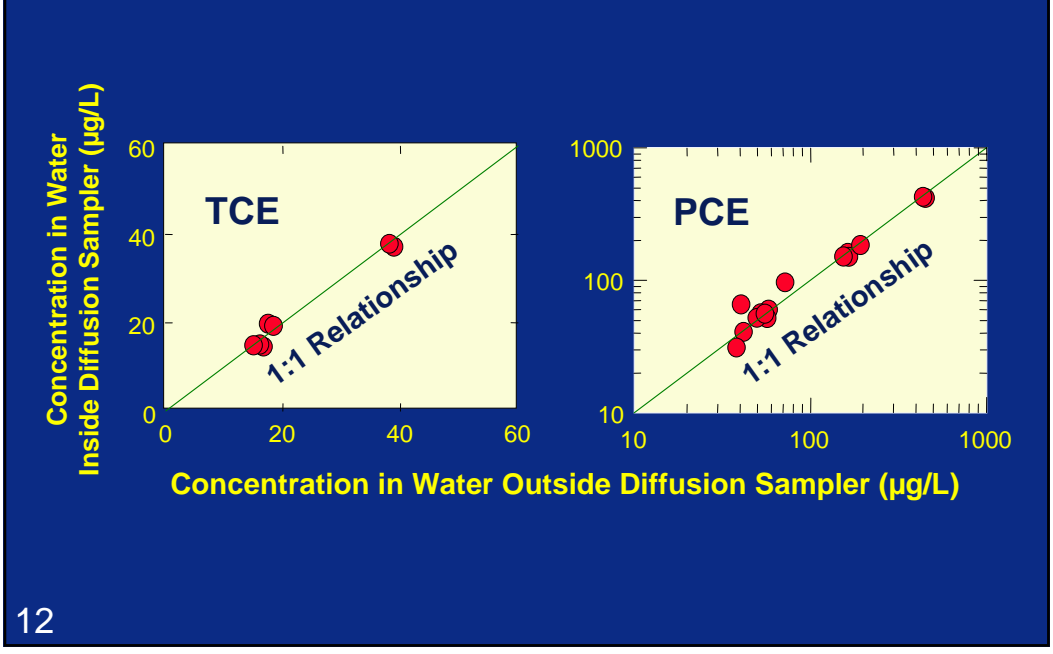
- ★ PDB sampler results are an integration of concentrations over the equilibration time associated with the most recent part of the deployment period

- ★ Not appropriate for some compounds
 - i.e. **MTBE, acetone, most semi-volatiles, most ions**
- ★ Rely on water movement through the well
- ★ Constitute point samples
 - **not necessarily a disadvantage**



Lab Tests of PDB Samplers







Conventional Well Sampling Methods



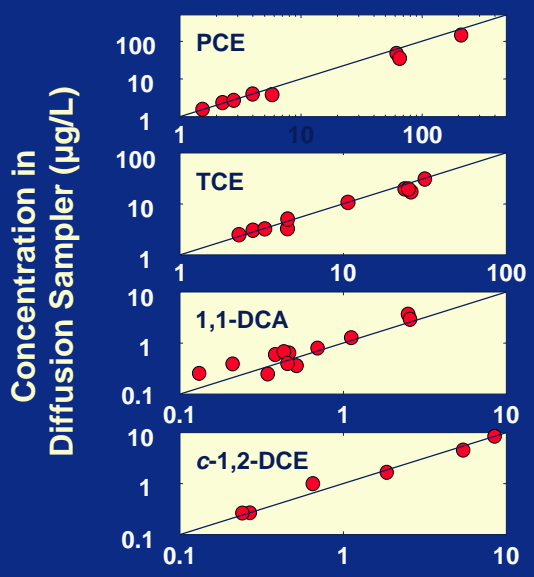
Two standard methods

- ★ Purge-and-Sample
 - Remove 3 or more casing volumes of water prior to collecting a sample

- ★ Low-Flow (LF) or Low-Volume Sampling
 - Slowly purge with no drawdown until field parameters stabilize prior to collecting a sample

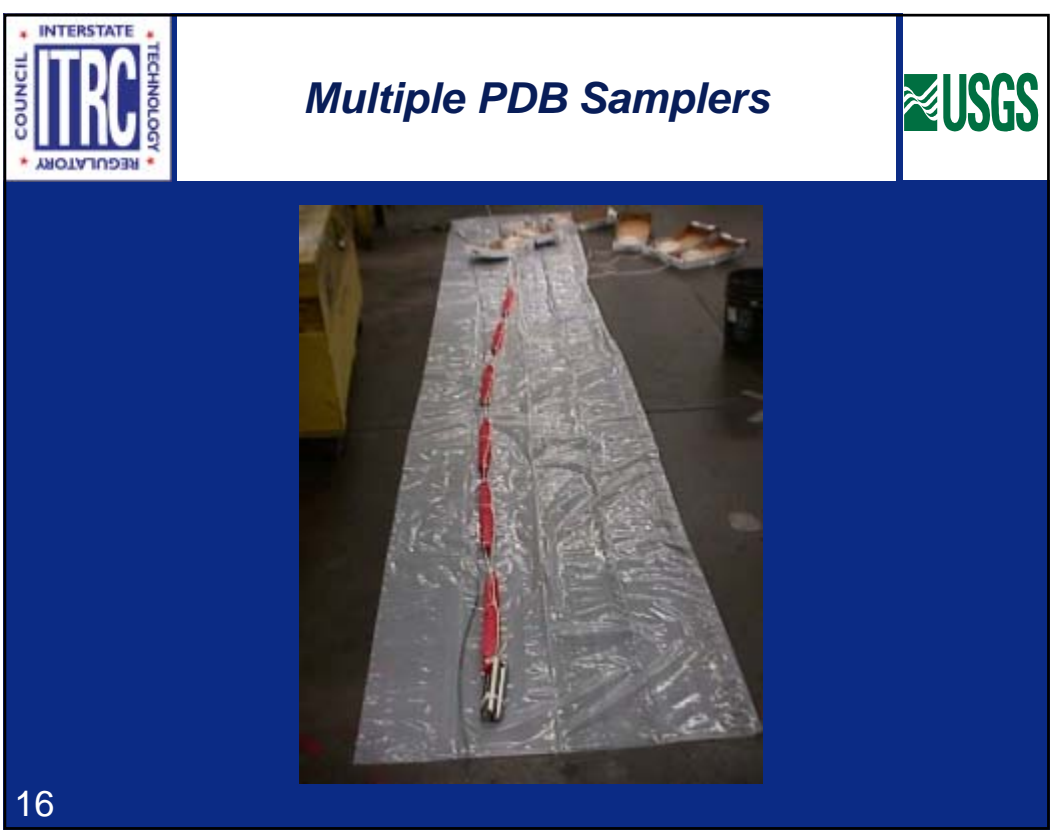
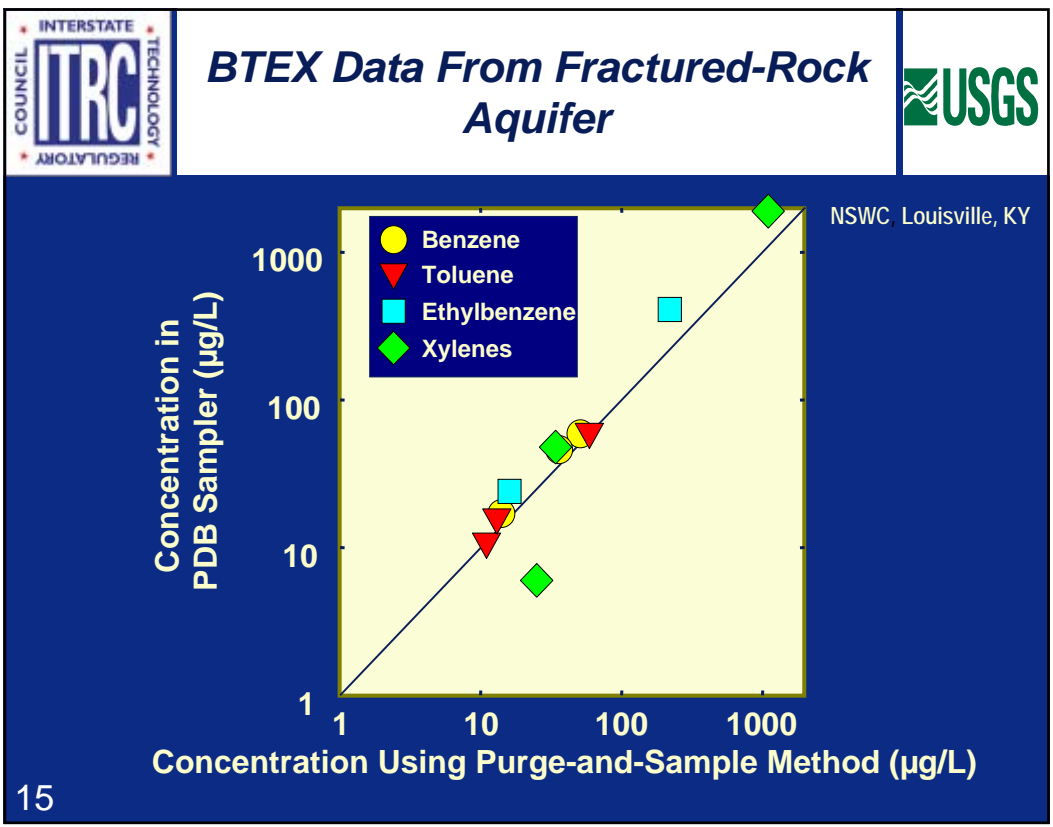


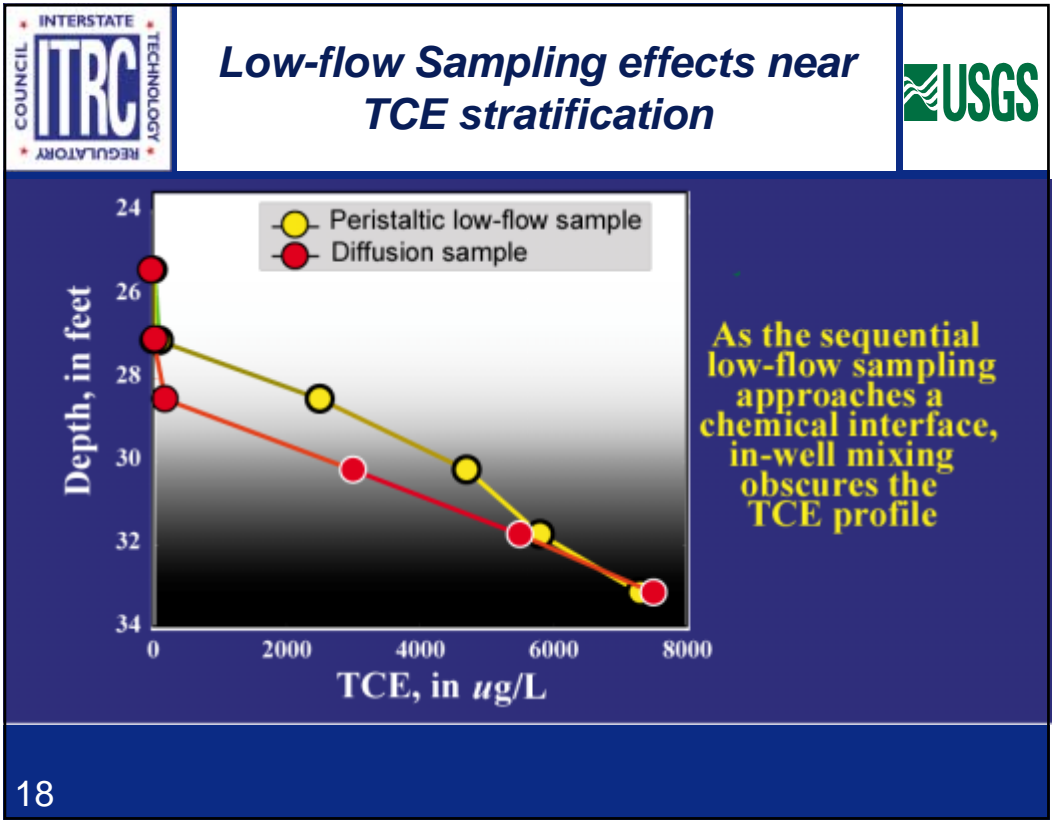
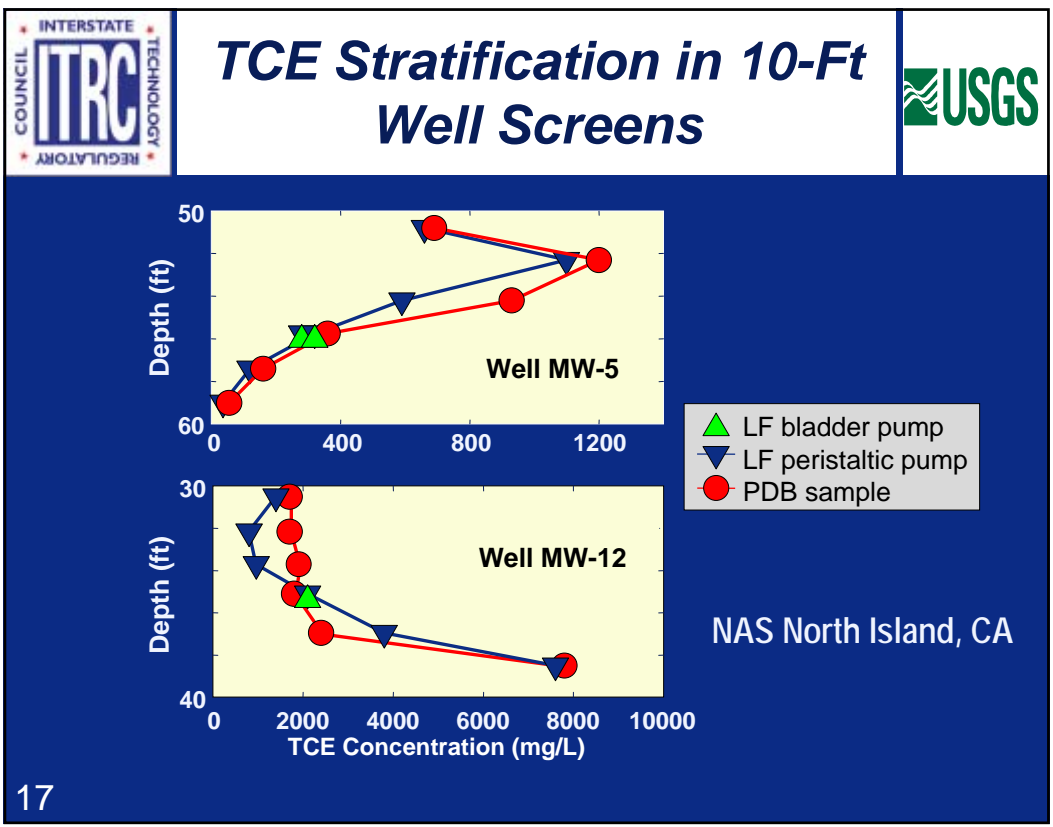
PDB vs. Purge-and-Sample under Field Conditions




Davis, CA (Jan. 1999)


Concentration Using Purge-and-Sample Method (µg/L)







Comparison of PDB and Purge Sampling Methods at Well 18S
(deployment of single PDB sampler in approximate center of screened interval)




	PDB Sampler Method (µg/L)	Purge-and-Sample Method (µg/L)
Total 1,2-DCE	130	650
TCE	570	2,300


4-casing-volume purge

Fridley, MN (Nov. 1999)

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Switched to Multiple PDB samplers and Low-Flow Sampling at Well 18S







★ These data imply that the low-flow sampling results can be a mixture of waters within the screened interval


Depth (TOC), in feet	Low-flow sample (µg/L)	PDB sample - Total 1,2-Dichloroethene (µg/L)	PDB sample - Trichloroethene (µg/L)
31.5	-	~200	~450
32.5	-	~200	~450
33.5	-	~200	~950
34.5	-	~450	~1300
35.5	-	~500	~1600
37.0	~400	-	-
37.5	-	~450	~1000
38.0	-	~500	~1650

Fridley, MN (May 2000)


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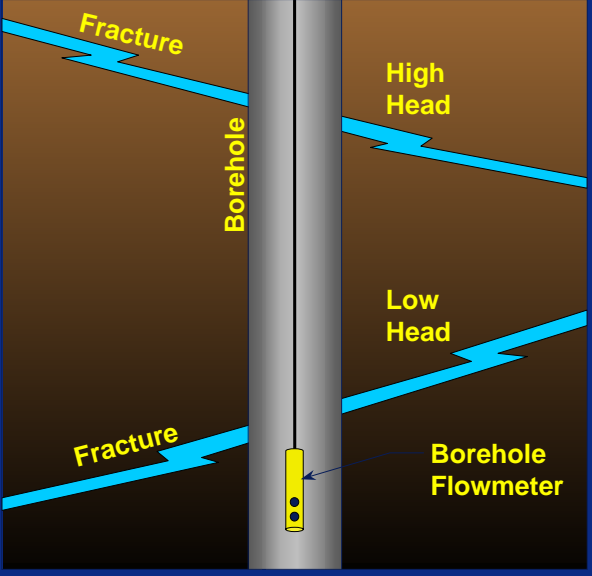
	<h2><i>Varying degrees of mixing during sampling</i></h2>	
<ul style="list-style-type: none"> ★ Thus, diffusion samplers typically constitute a point sample. Useful for targeting the high concentrations. Avg. concentrations for a screened interval are obtained by multiple samplers. ★ Low-flow samples sometimes constitute an approximate point sample (selected horizons at NAS North Island) providing no information on average concentrations in a well screen. In other wells, LF samples constitute a mixed sample over varying intervals. ★ 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>21</p>		

	<h2><i>Relation between well sampling and well construction</i></h2>	
<ul style="list-style-type: none"> ★ In some cases, VOC stratification in a well and disagreement between sampling methods can result from inadequate wells. ★ Examples include wells that connect zones of significantly different hydraulic head or contaminant concentration. ★ CONSIDER THE FOLLOWING EXAMPLES: 		
<p>22</p>		




Heat-Pulse Flowmeter




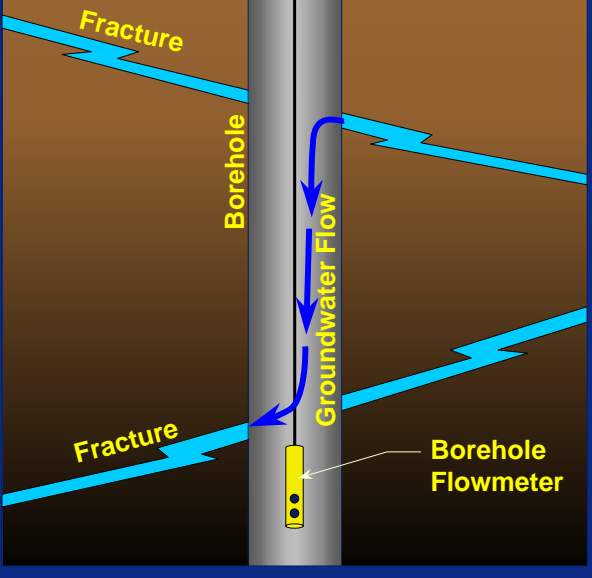


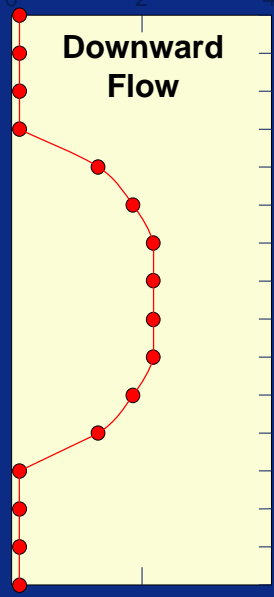
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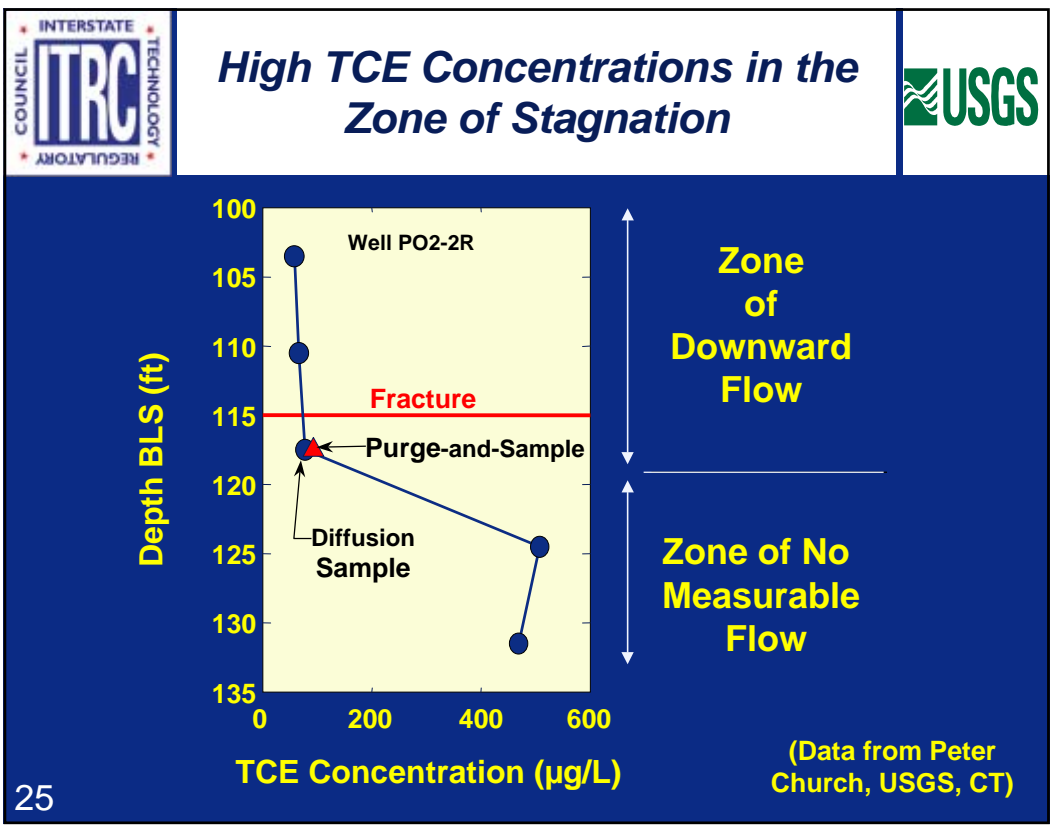
Heat-Pulse Flowmeter



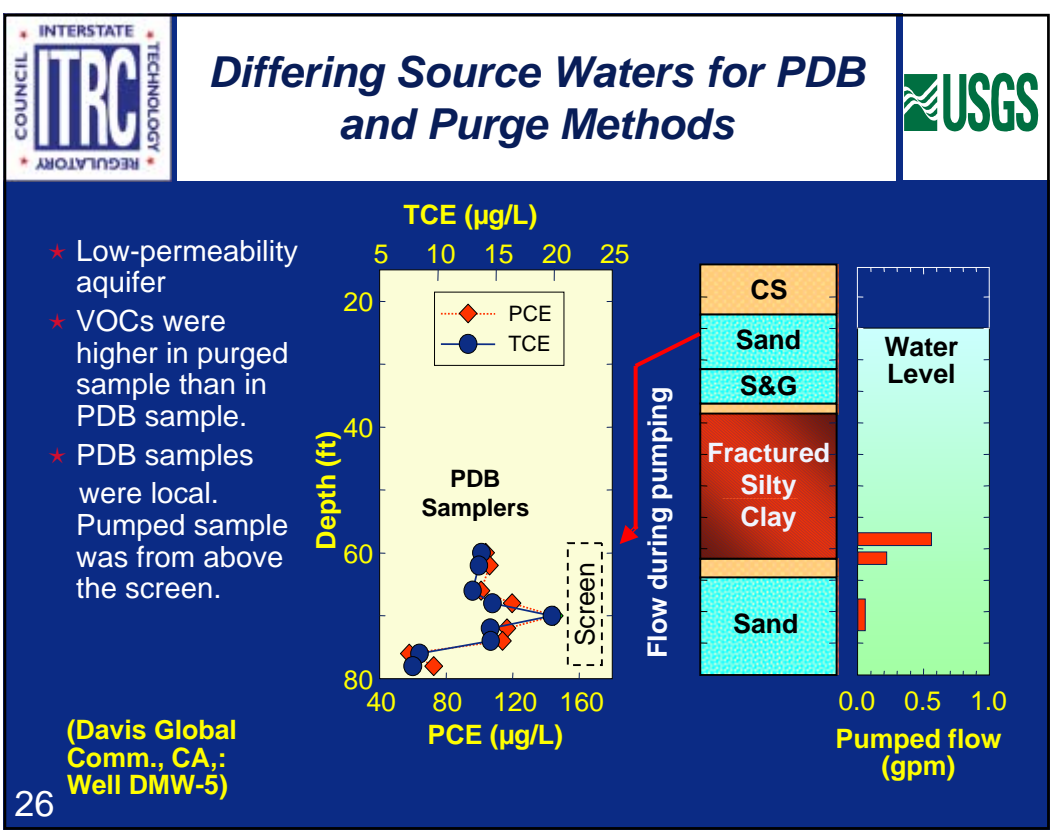




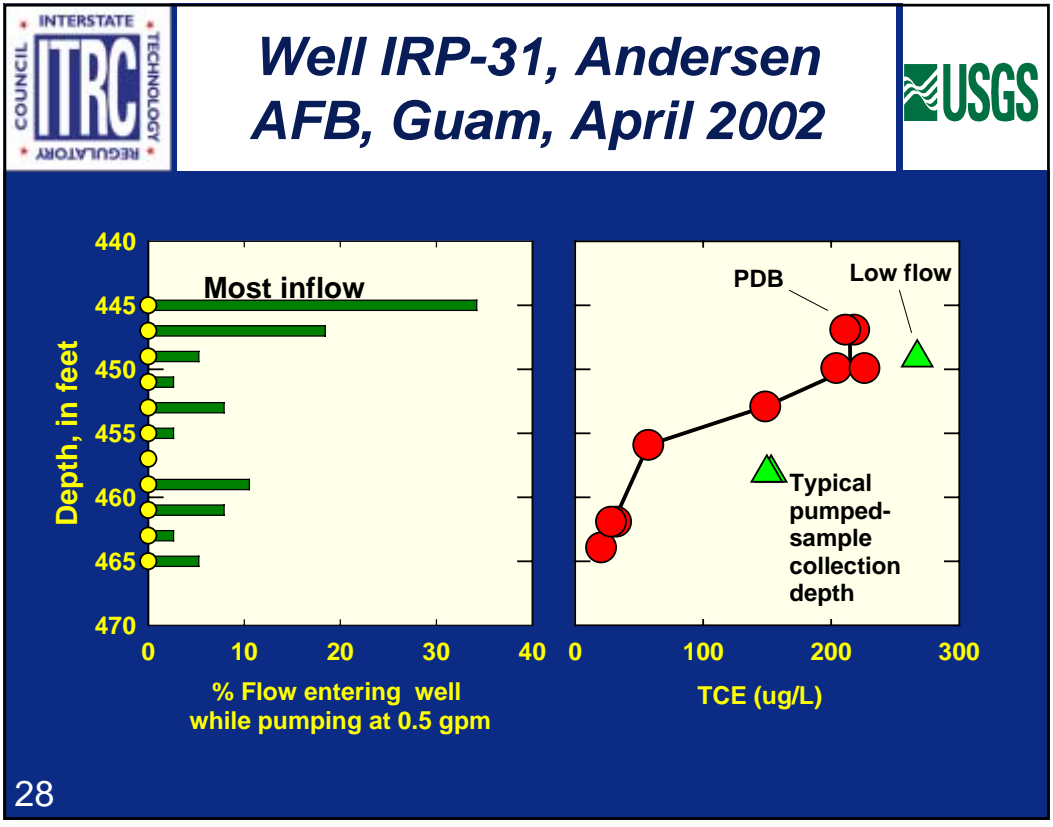
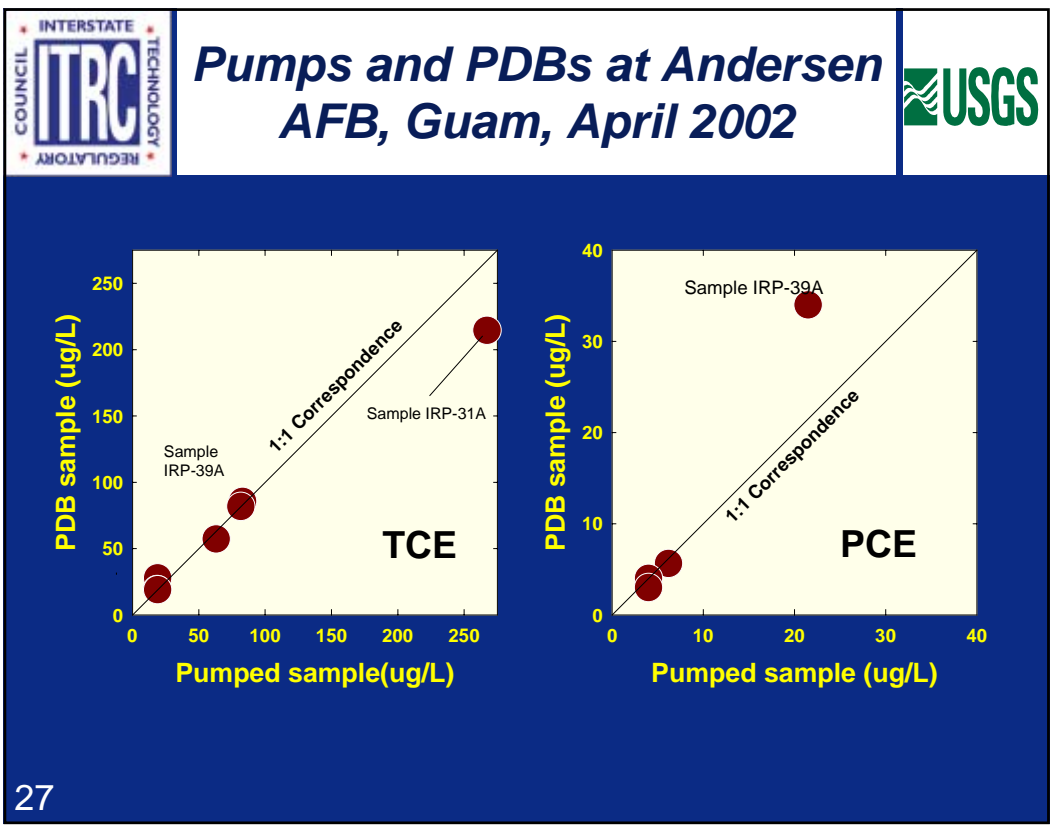
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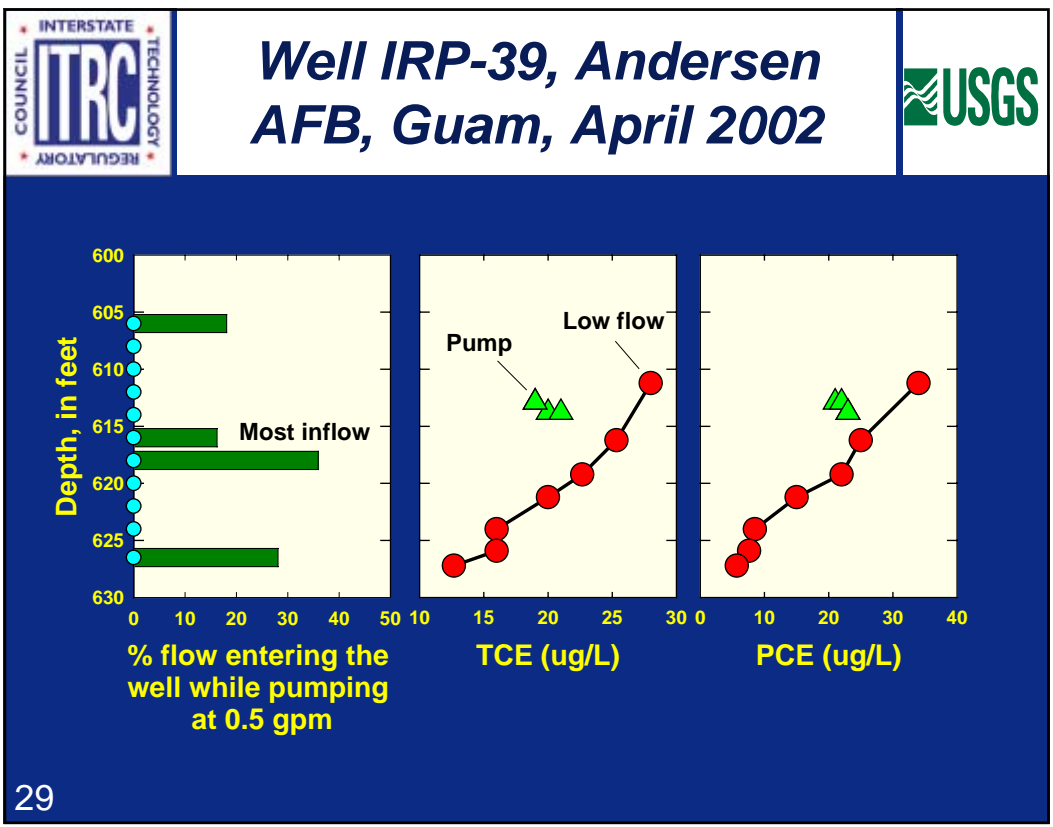


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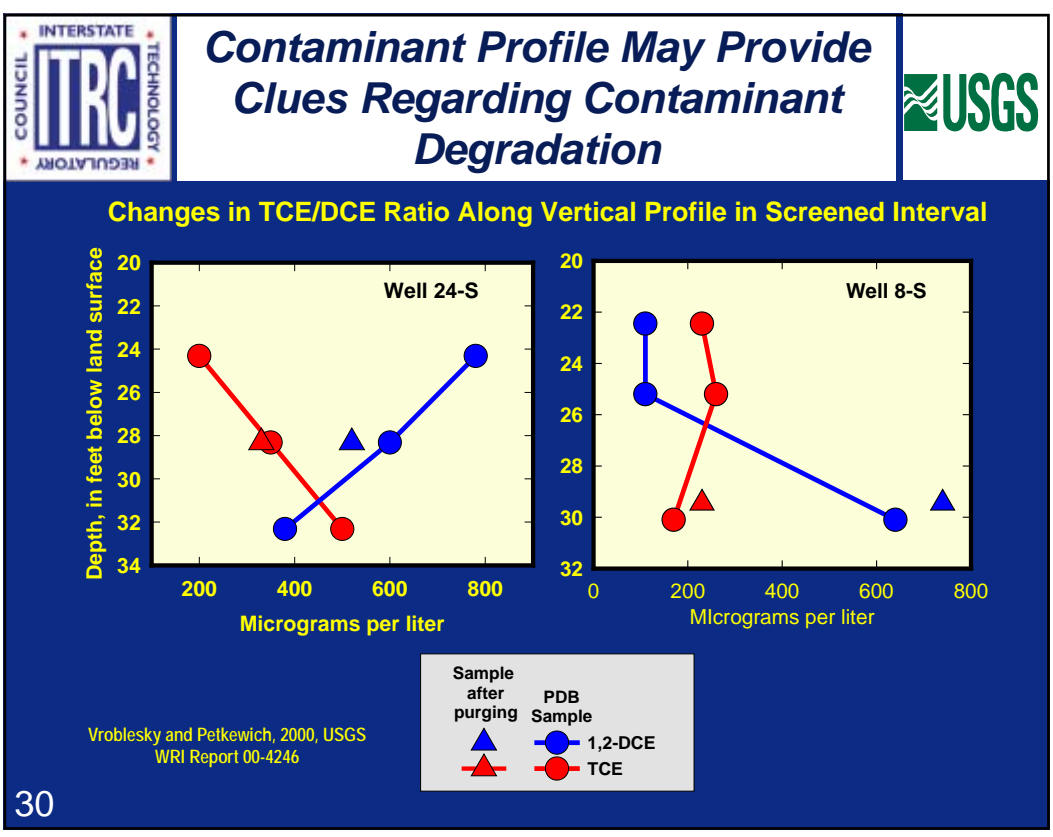


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Questions and Answers








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



Available for download from:

In the links page at the end of this presentation

OR

<http://www.itrcweb.org>



<http://www.frtr.gov>



<http://www.sc.er.usgs.gov/publications>



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)

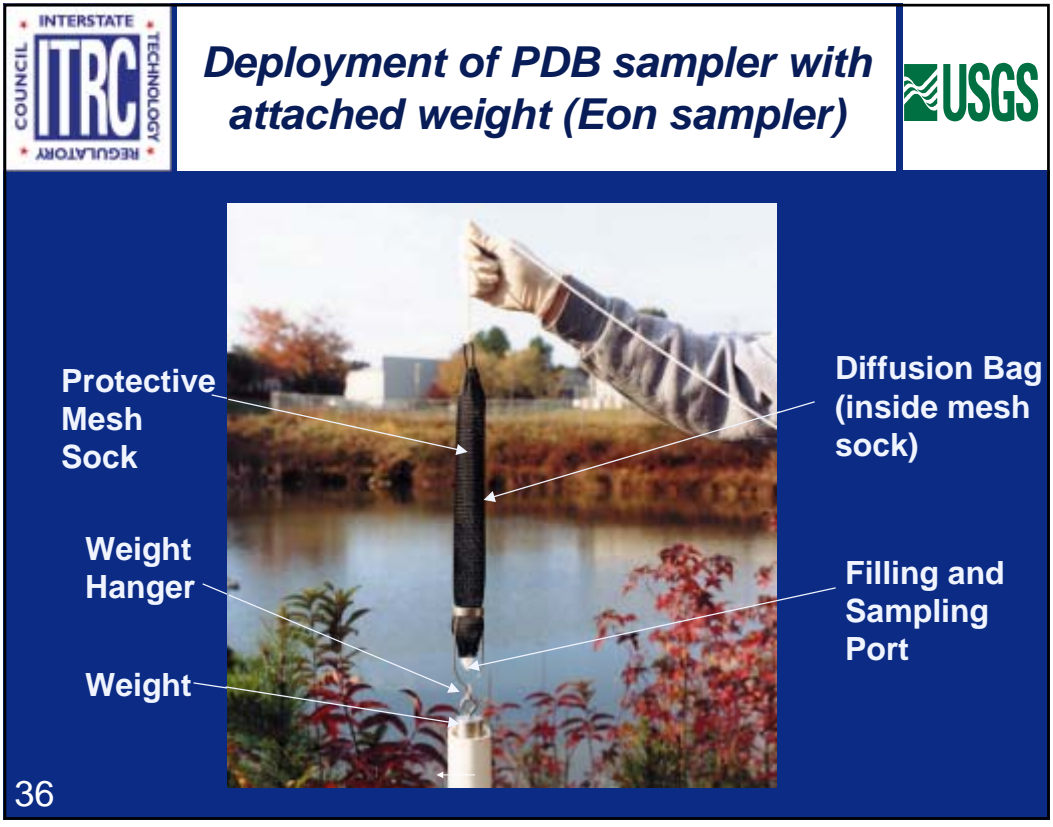
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	<h2 style="text-align: center;"><i>PDB Sampler User's Guide. Part 1</i></h2>	
<ul style="list-style-type: none"> ★ Executive summary ★ Introduction <ul style="list-style-type: none"> ● Summary of limitations and advantages ★ PDB sampler deployment ★ 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 style="margin-top: 20px;">33</p>		

	<h2 style="text-align: center;"><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 style="margin-top: 20px;">34</p>		

		<h2 style="margin: 0;">Comparison of Methods (AFCEE/Parsons Eng.)</h2>			
CRITERIA	USGS PDB	DMLS	MICROPURGE	CONVENTIONAL	
Ease of use	Excellent	Fair	Poor	Fair	
Labor hours per sample	0.66	1	2.75	3.66	
IDW Generation (liters)	<1	<1	100	500	
Costs for dedicated equip.	Low	High	Low	High	
Between-well decon.	Minimal	High	Moderate	Moderate	
Immediacy of results	Slow	Slow	Rapid	Rapid	
Analytes other than VOCs?	No	Yes	Yes	Yes	
Evaluation of VOC stratification?	Possible	Possible	Partial	No	
OK MNA sampling?	No	No	Yes	Partial	
Cost per Sample	\$65	\$555	\$308	\$444	

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Field Filling PDB Sampler






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Commercially Available Prefilled PDB Sampler








Sampler




Weight



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Methods of Attaching PDB Samplers to the Line or Weight




- ★ The PDB sampler can be attached to the weighted line by a variety of methods.
 - 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

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Two Approaches to Measuring the Line to Determine the PDB Attachment Point





- ★ Weight suspended above the well bottom
 - 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
 - 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.

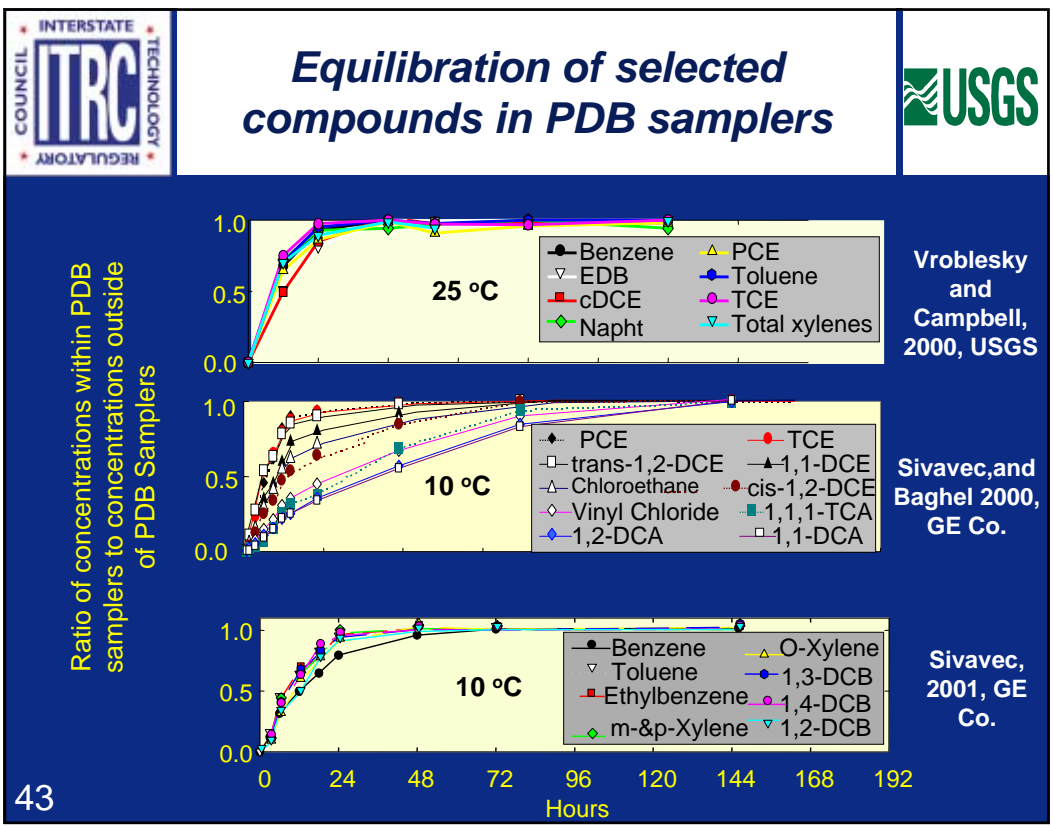
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	<h2 style="text-align: center;"><i>Things to Consider When Measuring From the Bottom Upward</i></h2>	
<ul style="list-style-type: none">★ Measure the well depth<ul style="list-style-type: none">● Compare measured and reported (from well logs) depths 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.		

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	<h2 style="text-align: center;"><i>Consider the Screen Length Deploying PDB Samplers</i></h2>	
<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		

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PDB Sampler Equilibration in Lab Studies




USGS



- ★ 48 hours for TCE and several tested compounds at 25 C (Vroblecky, 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)**



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	<p><i>One water-transfer method is to insert a discharge tube through the polyethylene</i></p>	
		
<p>45</p> <p>Inserting the tube through the polyethylene into the PDB sampler</p>	<p>Transferring water to a VOA vial</p>	



	<p><i>Attaching a Bottom-Discharge Device</i></p>	
		
<p>46</p>		



	<p><i>Water Also can be Removed Simply by Cutting the Sampler Open and Gently Pouring into VOA Vials</i></p>	
 <p>47</p>		

	<p><i>Determining applicability of PDB Samplers</i></p>	
<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>48</p>		

	<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>49</p>		

	<h3><i>If PDB-sampler VOC concentrations are higher than VOC concentrations from the conventional method</i></h3>	
<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>50</p>		

	<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 		
<p>51</p>		

	<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. - A pumped sample may produce an average concentration across the screened interval, but several field tests suggest that low-flow samples sometimes constitute approximate point samples and sometimes constitute an average concentration over intervals that may vary from well to well 		
<p>52</p>		



Vertical stratification of VOCs



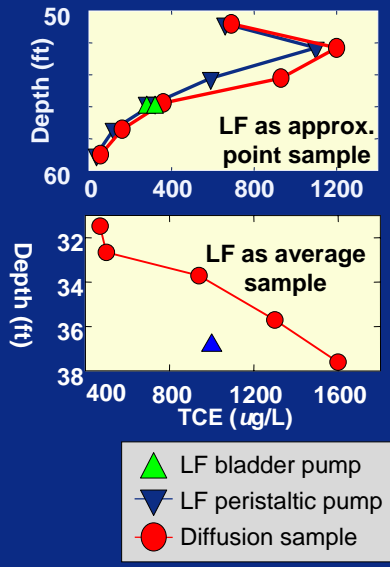
- In areas where vertical stratification of VOCs is anticipated, using multiple PDB samplers may more fully characterize the contaminated horizon than using a single PDB sampler.
 - Particularly true in well screens 10 ft or longer, but significant VOC stratification has been observed in intervals less 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.





Comparisons of PDB samplers to conventional methodologies



- Resulting concentrations may differ because each methodology is sometimes influenced in different ways by aquifer hydraulic and chemical heterogeneity
 - PDB sampler: typically an approximate point sample
 - 3-Casing-volume purge-and-sample: integrates water over a relatively large area
 - Low-flow sampling: Sometimes an approximate point sample and other times an average concentration over a larger area.



	<h2>Quality control and assurance</h2>	
<p><u>Replicate samples</u></p> <p>At least 10 percent are recommended.</p> <p><u>Fill water blank</u></p> <p>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></p> <p>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></p> <p>Required for field-filled PDBS.</p> <div style="border: 1px solid white; padding: 5px; margin-top: 10px; text-align: center;"> <p>Note: Blanks are taken at the time of sampler deployment and sent immediately for analysis</p> </div>		

	<h2>Question & Answers</h2>	
<div style="display: flex; justify-content: space-between;"> <div data-bbox="225 1199 782 1688" style="width: 40%;">  </div> <div data-bbox="882 1263 1125 1412" style="width: 55%; text-align: center;"> <p>Helpful Hint: Securely Attach the Line at the Well Head</p> </div> </div> <div style="text-align: center; margin-top: 20px;"> <p>Thank you for attending this ITRC training course.</p> </div>		