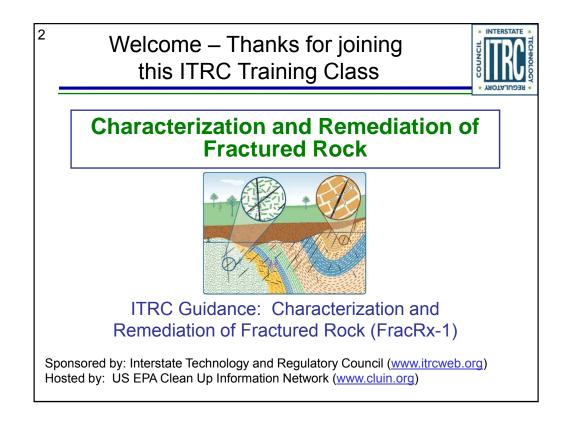


Associated Poll Questions:

Tell us about your site(s): [check all that apply]

Existing fractured rock site, meeting remedial objectives

Existing fractured rock site, prior characterization, struggling to meet remedial goals New fractured rock site, not yet characterized



## **Training Course Overview:**

Characterization and remediation of contaminated groundwater in fractured rock has not been conducted or studied as broadly as groundwater at unconsolidated porous media sites. This unfamiliarity and lack of experience can make fractured rock sites perplexing. This situation is especially true in portions of the U.S. where bedrock aquifers are a primary source of drinking and process water, and demands on water are increasing. As a result, remedial activities often default to containment of contaminant plumes, point of use treatment and long-term monitoring rather than active reduction of risk. However, this attitude does not incorporate recent advances in the science and technology of fractured rock site characterization and remediation.

The basis for this training course is the ITRC guidance: <u>Characterization and Remediation of Fractured Rock</u>. The purpose of this guidance is to dispel the belief that fractured rock sites are too complex to characterize and remediate. The physical, chemical and contaminant transport concepts in fractured rock have similarities to unconsolidated porous media, yet there are important differences. These differences are the focus of this guidance.

By participating in this training class, you should learn to: Use ITRCs Fractured Rock Document to guide your decision making so you can: Develop quality Conceptual Site Models (CSMs) for fractured rock sites

Set realistic remedial objectives

Select the best remedial options

Monitor remedial progress and assess results

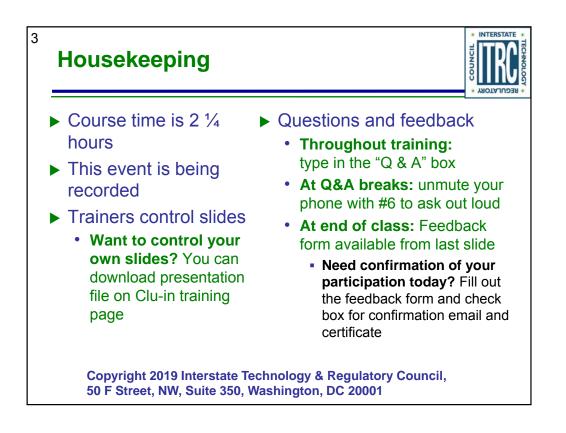
Value an interdisciplinary site team approach to bring collective expertise to improve decision making and to have confidence when going beyond containment and monitoring - - to actually remediating fractured rock sites.

Case studies of successful fractured rock remediation are presented to provide examples of how fractured rock sites can be evaluated and available tools applied to characterization and remediation.

Training participants are encouraged to view the associated ITRC guidance, <u>Characterization and Remediation of</u> <u>Fractured Rock</u> prior to attending the class.

ITRC (Interstate Technology and Regulatory Council) <u>www.itrcweb.org</u> Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (<u>www.clu-in.org</u>)

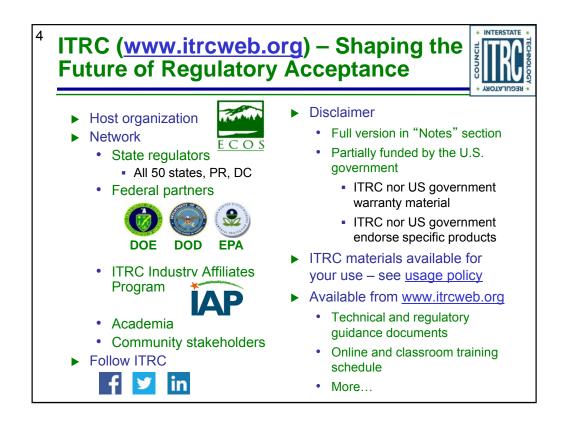
ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419



We have started the seminar with all phone lines muted to prevent background noise. Please keep your phone lines muted during the seminar to minimize disruption and background noise. During the question and answer break, press #6 to unmute your lines to ask a question (note: \*6 to mute again). Also, please do NOT put this call on hold as this may bring unwanted background music over the lines and interrupt the seminar.

Use the "Q&A" box to ask questions, make comments, or report technical problems any time. For questions and comments provided out loud, please hold until the designated Q&A breaks.

*Everyone* – please complete the feedback form before you leave the training website. Link to feedback form is available on last slide.



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 and innovative approaches. ITRC consists of all 50 states (and Puerto Rico 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 advance the regulatory acceptance 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 of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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Read trainer bios at <a href="https://clu-in.org/conf/itrc/FracRx/">https://clu-in.org/conf/itrc/FracRx/</a>

**Kristopher (Kris) McCandless** has worked for the Virginia Department of Environmental Quality (DEQ) in Woodbridge, Virginia since 2015. As an Environmental Geologist in the petroleum storage tank remediation division, he manages the characterization and remediation of numerous leaking petroleum storage tank sites, as well as assists the Land Protection Program with chlorinated solvent sites. Kris has spent most of his career as a project manager and hydrogeologist in the environmental consulting field. In the past two decades, his projects were focused on investigating and managing petroleum and chlorinated solvent sites in the Mid-Atlantic Piedmont states. Kris spearheaded investigations for Alternate Water Supplies for the DEQ Petroleum Program for State Lead sites as a contractor for DEQ, including locating new supply well locations, tracking groundwater flow through fractured media, performing packer testing to sample and isolate impacted zones within a supply well, performing pump tests in fractured rock, and assessing bedrock sites for remediation of chlorinated solvents. While reaping the benefits of many ITRC webinars during his consulting career, Kris joined the Fractured Bedrock team soon after employment with DEQ. Kris is actively engaged as a chapter lead for the ITRC Optimization of In situ Remediation team beginning in 2018. Kris earned his Bachelor of Science degree in Geology from George Mason University in 1988 in Fairfax, Virginia and is a Certified Professional Geologist (CPG) in Virginia.

Jeffrey Hale is a Senior Technical Consultant with Parsons, located in Pittsburgh, PA. He provides consultation for challenging environmental and natural resources issues internationally with emphasis on fractured rock & complex sites, emerging issues, remediation, liability management, and environmental forensics. Jeff has presented at many conferences on the topic of fractured rock characterization and remediation and served as an invited panelist at the NGWA Focus Conference on Fractured Rock and Eastern Groundwater Regional Issues. He has been involved with ITRC since 2014 as a principal contributor to the Characterization and Remediation in Fractured Rock document, and he serves as a section leader for the ITRC PFAS team. Jeff received a B.S. in Earth Sciences from Penn State in 1993, an M.S. in Geology from the University of Akron in 1995, and an M.S. in Engineering Management from Point Park University in 2008. He is licensed as a Professional Geologist in Pennsylvania.

**Melissa Boysun** is a Project Geologist for Environmental Resources Management in Zurich Switzerland. Melissa has worked as a geologist and consultant for ERM since 2012, and prior to that with Tetra Tech and AECOM from 2005 to 2012. Her work currently involves site investigation and remediation at midstream and downstream oil and gas facilities, wood preserving sites, and landfills. Prior to 2012, Melissa worked as a consultant on Department of Defense facilities, which included multiple investigations and pilot studies at fractured rock sites. She presented results from site investigations at fractured rock sites at the Battelle Conference in California and at AquaconSoil in Belgium. Melissa has contributed to ITRC as a team member for the Remediation of Fractured Bedrock Team and the LNAPL Update Team. She earned a bachelor's degree in Geology from Montana State University in 1999 and a master's degree in Geology from the University of Southern California in 2004. Melissa is also a certified PG with the California Board for Professional Engineers, Land Surveyors.

**Ted Tyler** is a Principal Engineer with Kleinfelder located in Phoenix, Arizona. Since 2002; Ted has worked at Kleinfelder as a project manager and environmental remediation design engineer specializing in biological and chemical treatment technologies, holding a patent on an innovative in-situ bioremediation process. Ted has provided engineering design bringing solutions to treat federal, industrial and commercial sites impacted by a wide array of contaminants (e.g.; chlorinated solvents; heavy metals; perchlorate; 1,4-dioxane; fuel hydrocarbons; etc.), and has provided solutions at sites with widely varying often challenging site geology such as sites underlain by deep vadose zones, heterogeneous soils, and fractured bedrock. He has contributed to ITRC as a team member on multiple ITRC teams including the most recent Fractured Bedrock Characterization and Remediation team. Prior to Kleinfelder he worked for 10 years at Groundwater Technology. Ted received his Bachelors and Masters and degree in Civil/Environmental Engineering from University of California in Los Angeles in 1990 and 1992, respectively, and is a registered professional engineer.

## INTERSTATE 6 Meet the ITRC Trainers Ryan A. Wymore John Dougherty **CDM Smith CDM Smith** Denver, CO Edison, NJ 303-550-2738 732-590-4652 wvmorera@cdmsmith.com Doughertyjn @cdmsmith.com Tamzen Macbeth **CDM Smith** Helena, Montana 802-249-5826 macbethtw@cdmsmith.com Read trainer bios at https://clu-in.org/conf/itrc/FracRx/

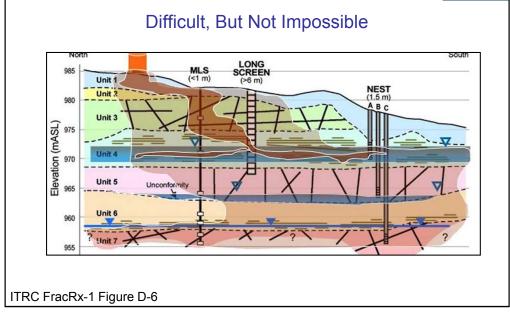
**Ryan A. Wymore, P.E.**, rejoined CDM Smith in Denver, CO in 2015. He serves as a national resource for evaluation, selection, and implementation of remediation strategies and solutions. Ryan has specialized in innovative groundwater remediation technologies, particularly bioremediation, monitored natural attenuation and chemical oxidation. Previously, he work at Geosyntec Consultants in 2014-2015, CDM Smith from 2005-2013, at North Wind Inc. from 2001-2005, and at the Idaho National Laboratory from 1998-2001. He has given over eighty presentations at various local, regional, national, and international symposia and meetings. Since 2002, he has worked with various ITRC teams that addressed DNAPLs, bioremediation, enhanced attenuation, and Environmental Molecular Diagnostics. He was an instructor on the ITRC Internet-based training courses: DNAPL Performance Assessment, Bioremediation of DNAPLs, and Integrated DNAPL Site Strategy. Ryan earned a bachelor's degree in Biological Systems Engineering from the University of Nebraska-Lincoln in 1997 and a master's degree in Civil/Environmental Engineering from the University of Idaho in Moscow, Idaho in 2003. He is a registered Professional Engineer in the state of Idaho and Colorado in the environmental discipline.

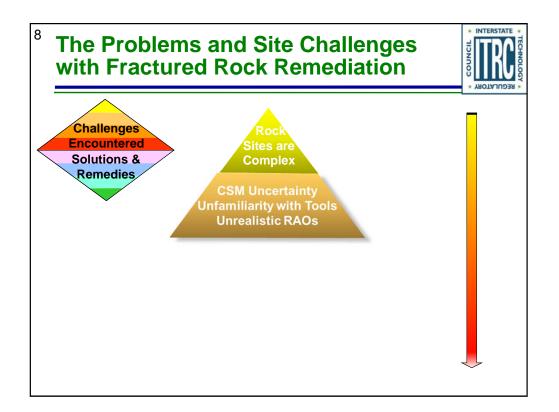
**Tamzen Macbeth** is a Vice President at CDM Smith out of Helena, Montana. She has worked for CDM since 2009. Previously, she worked for 7 years at North Wind Inc. Tamzen is an environmental engineer with an interdisciplinary academic and research background in microbiology and engineering. She specializes in the development, demonstration and application of innovative, cost-effective technologies for contaminated groundwater. Specifically, she is experienced in all aspects of remedies from characterization to remediation for DNAPLs, dissolved organic, inorganic, and radioactive contaminants under CERCLA and RCRA regulatory processes. She has expertise in a variety of chemical, biological, thermal, extraction and solidification/stabilization remediation techniques as well as natural attenuation. Her current work focuses developing combined technology approaches, and innovative characterization techniques such as mass flux and mass discharge metrics. Since 2004, Tamzen has contributed to the ITRC as a team member and instructor for the ITRC's Bioremediation of DNAPLs, Integrated DNAPL Site Strategy, Molecular Diagnostics and DNAPL Characterization teams. Tamzen earned a bachelor's degree in Microbiology in 2000 and a master's degree in Environmental Engineering in 2002 both from Idaho State University in Pocatello, Idaho, and a doctoral degree from in Civil and Environmental Engineering in 2008 from the University of Idaho in Moscow, Idaho.

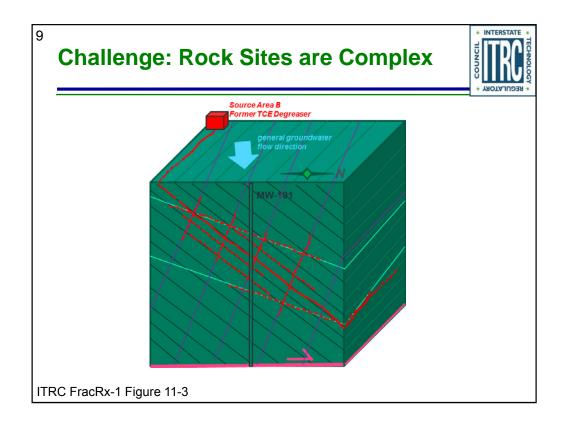
John N. Dougherty is a senior hydrogeologist at CDM Smith in Edison, New Jersey. Since joining CDM Smith in 1999, John has developed extensive experience applying a range of site characterization tools and drilling methods to the hydrogeologic characterization of groundwater contamination at fractured bedrock sites in New York, New Jersey, Kansas, Puerto Rico, and Massachusetts. At these sites, John applies site characterization tools including borehole geophysical logs (e.g. caliper, natural gamma, formation resistivity, fluid temperature and conductivity, and heat pulse flow meter), FLUTe transmissivity profiling, matrix diffusion sampling, and passive flux meters. John uses software to analyze geophysical logs, develop cross sections, and prepare stereo nets, to develop a conceptual groundwater flow model and design monitoring wells. In 2015 John worked with the US EPA Office of Research and Development and the University of Florida to test the Fractured Rock Passive Flux Meter (FRPFM), which is a new tool for characterizing mass flux/mass discharge in fractured rock, and was the principal author of the project report. John has also worked on water supply projects in Tanzania and Saudi Arabia which also utilized borehole geophysical tools. Since 2014 John has been a member of the Interstate Technology and Regulatory Council "Characterization and Remediation in Fractured Rock" team currently developing guidance and training for fractured rock site characterization and remediation. John earned a bachelor's degree in geosciences from The Pennsylvania State University in State College, PA in 1983. John is a Professional Geologist in Arkansas, Florida, and Pennsylvania.

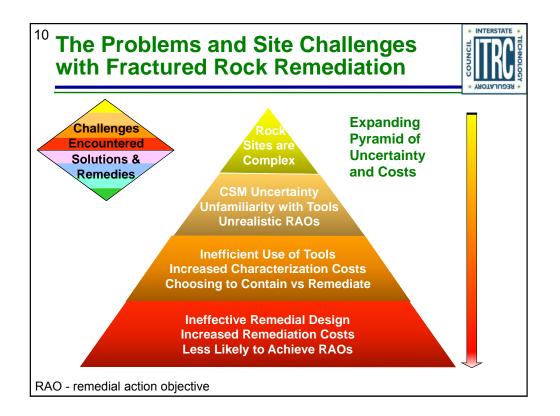


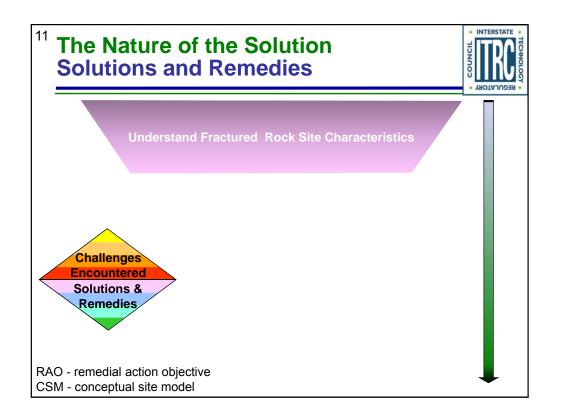




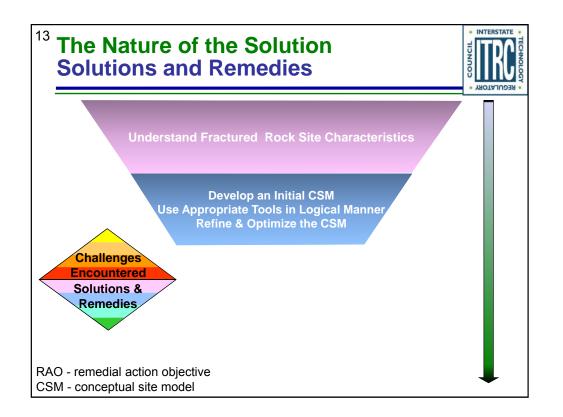


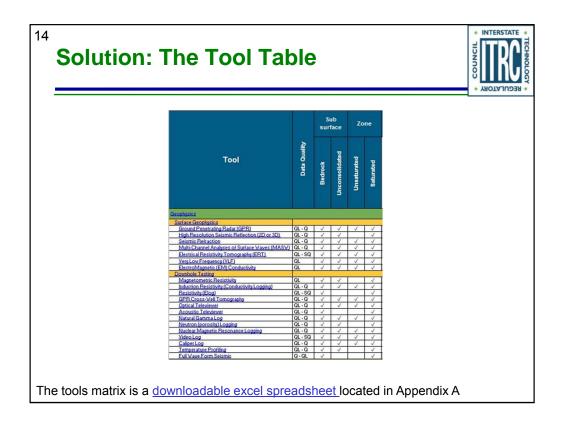


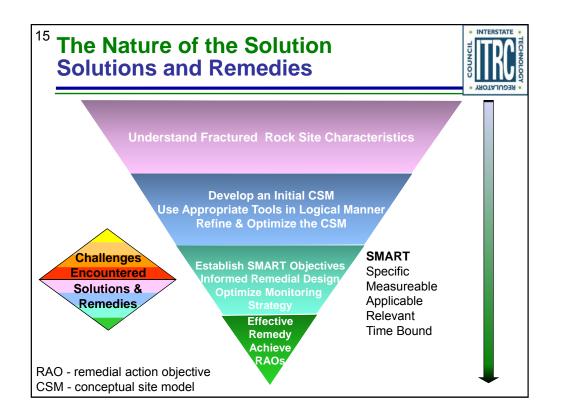


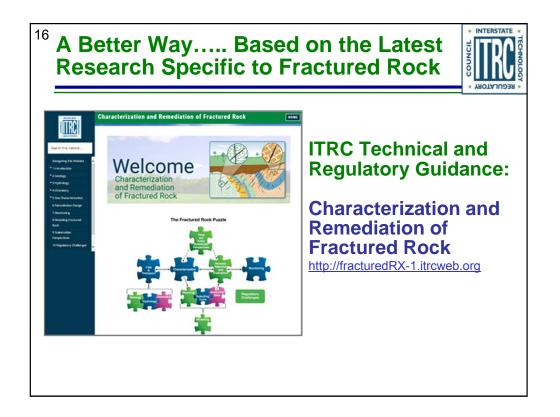


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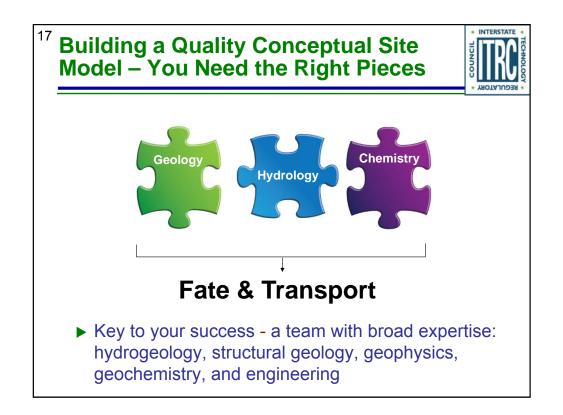


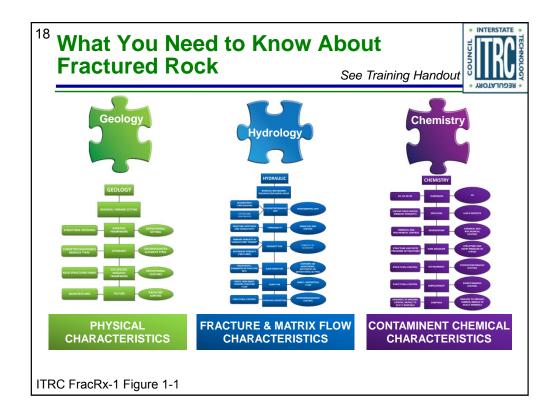


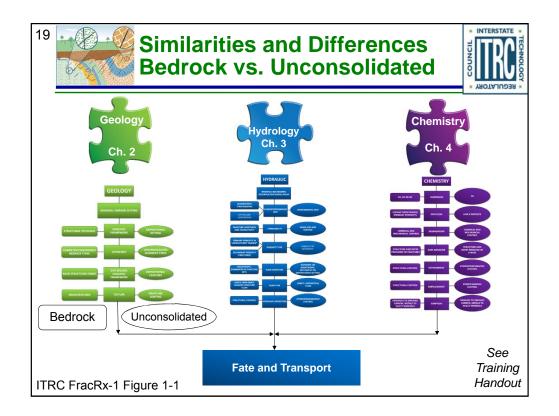


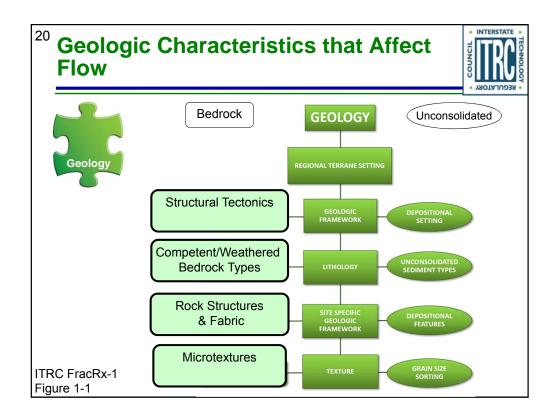


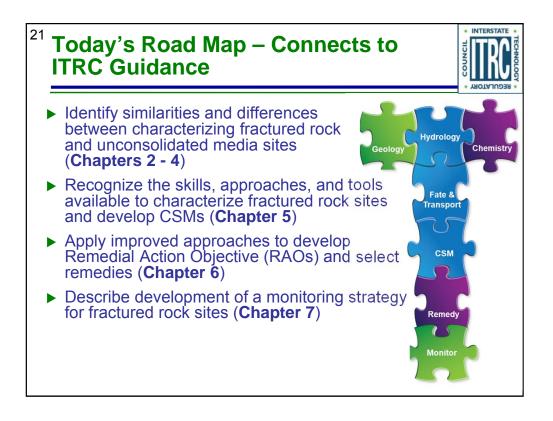
This guidance completes a succession of ITRC documents produced in the last 10 years that builds on ITRC's 2010 <u>Mass Flux and Mass Discharge</u> document, their 2011 <u>Integrated</u> <u>DNAPL Site Strategy</u> and their 2015 <u>Integrated Site Characterization</u> document

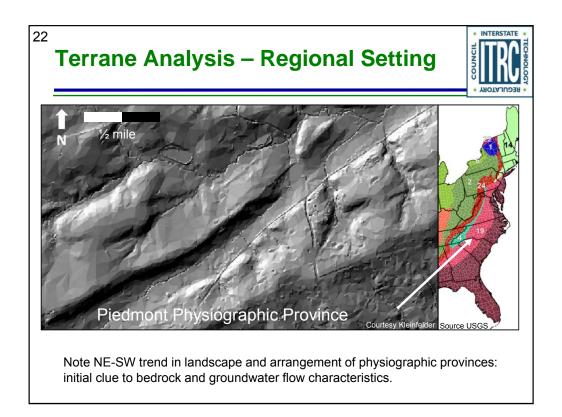


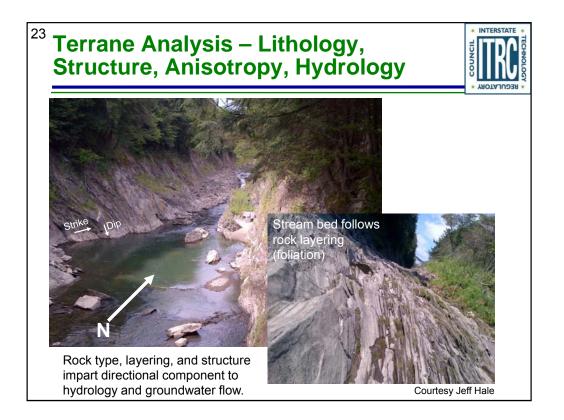


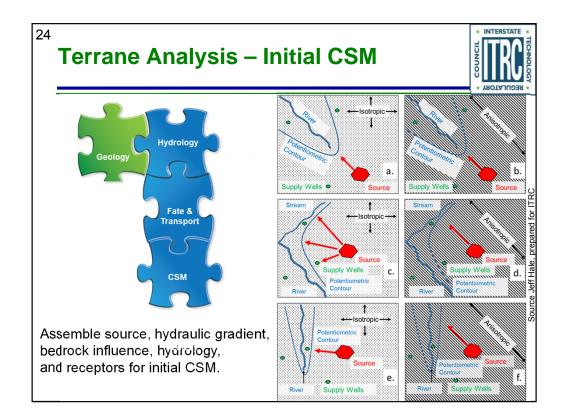


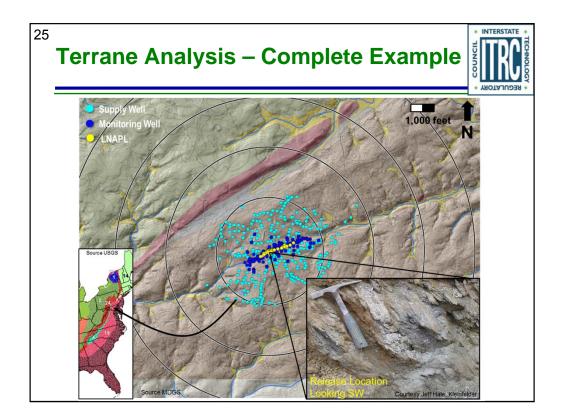


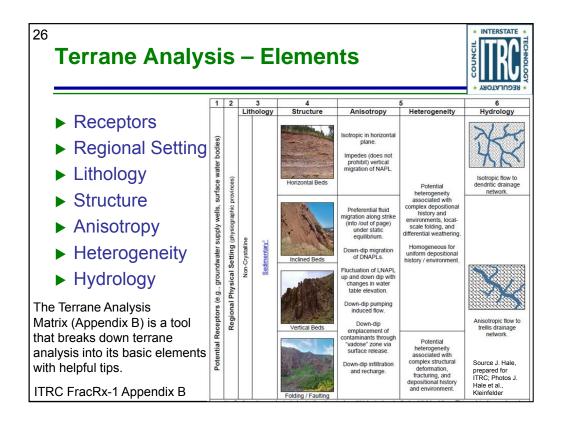


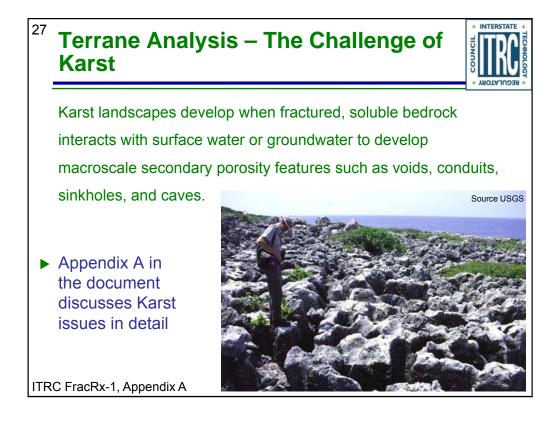


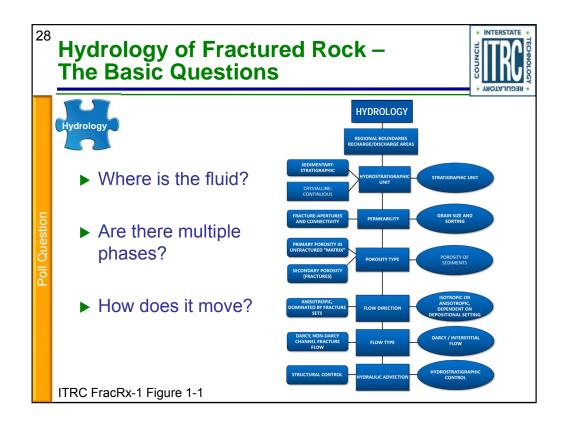










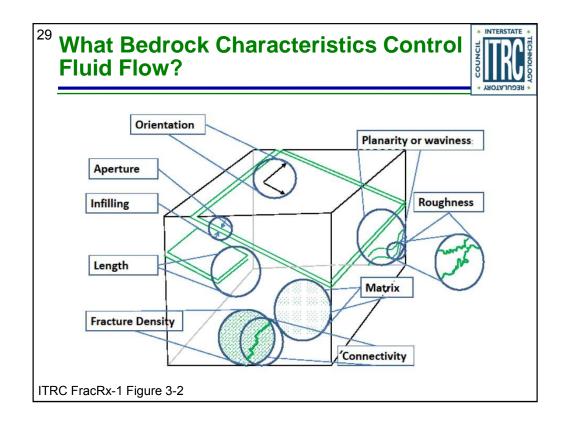


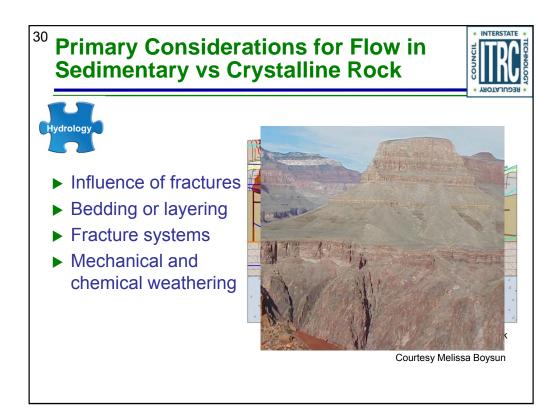
Poll Question: Which of these is the most important for determining flow in a fractured rock setting?

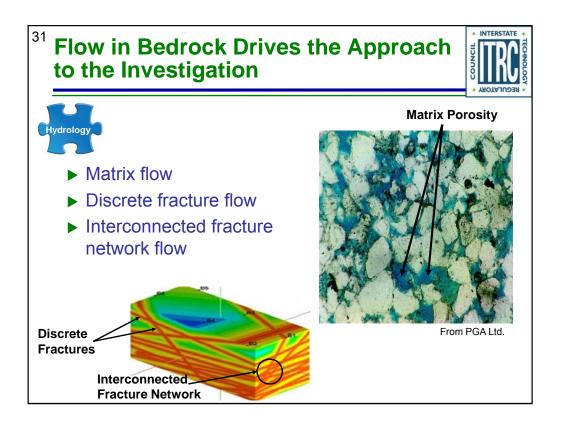
1.Where is the fluid?

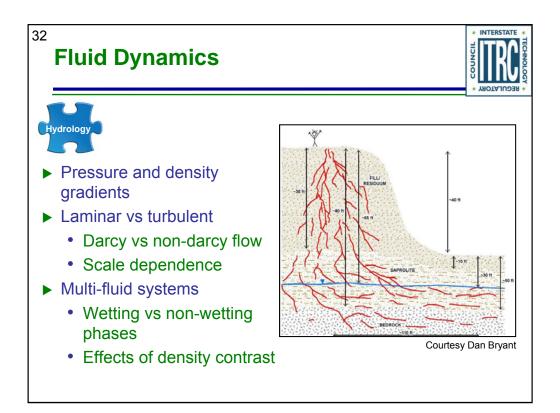
2.Are there multiple phases?

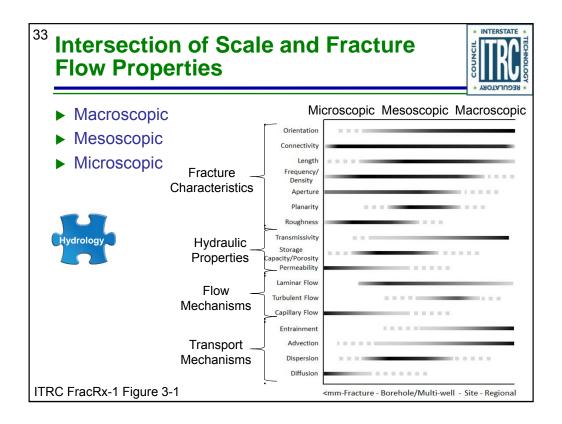
3.How does it move?

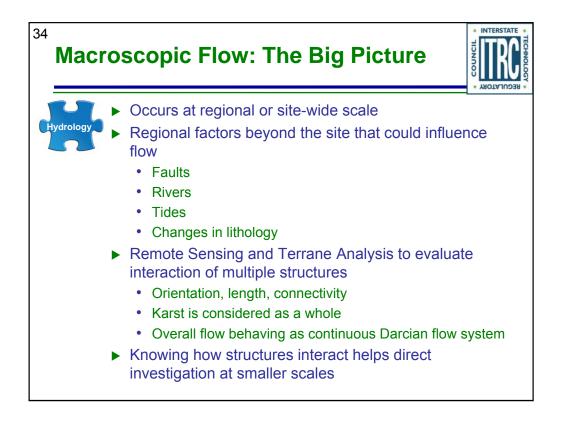


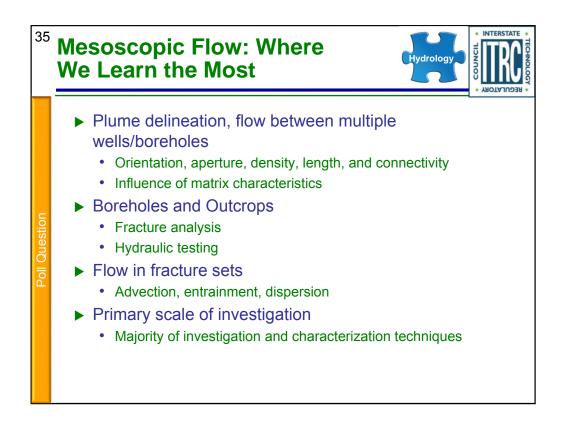






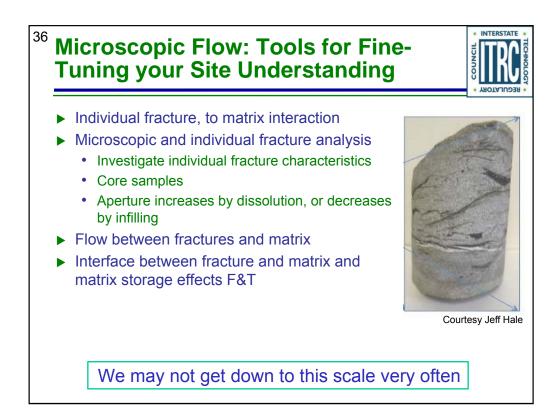


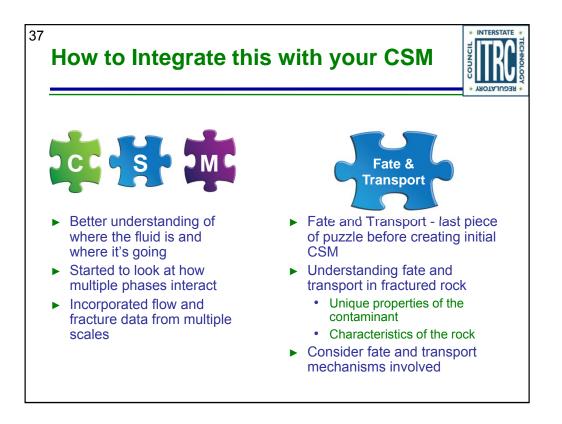


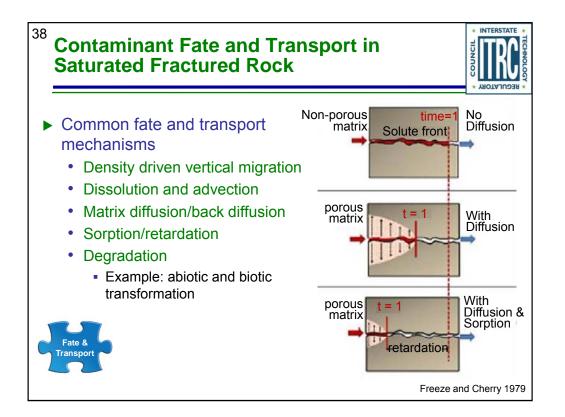


Poll question: Which of these is a general representative range of in-situ fracture apertures in the upper few hundred feet of rock (mm)?"

- A. 0.005-0.05
- B. 0.05-0.5
- C. 1.0-5
- D. 5-50
- E. Impossible to tell

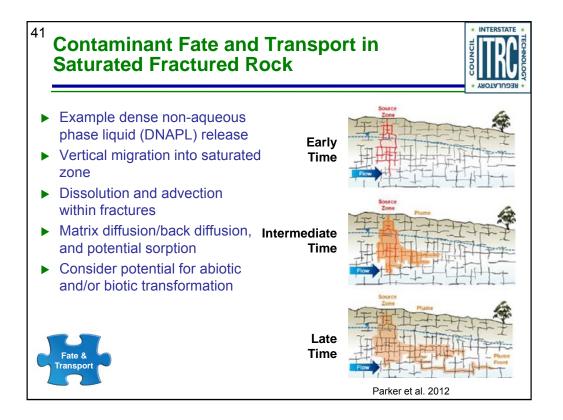


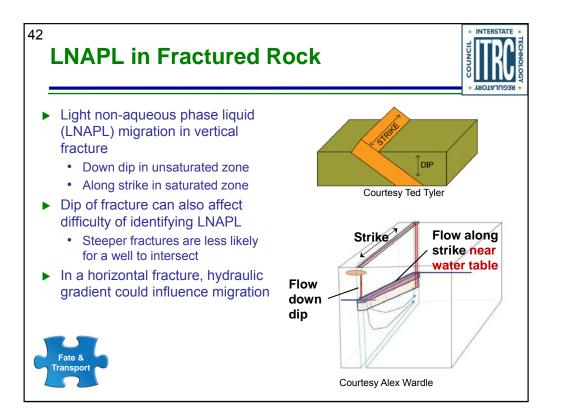


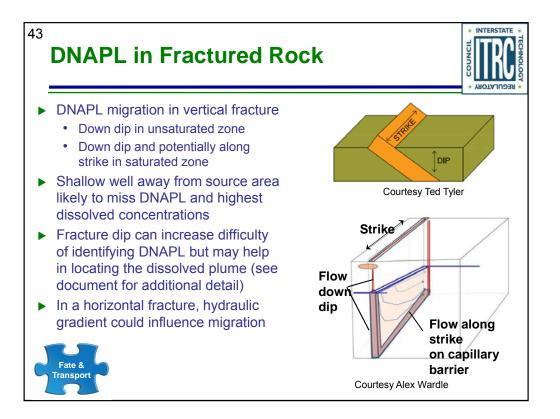


Identificatio	on of	Conta	imina	nt Prop	oerties	
Chemical	Liquid Density	Vapor Pressure	Solubility	Henry's Constant	Кос	
	g/cm^3 (water = 1 g/cm^3)	mm HG (volatile >= 1 mm HG)	mg/L	atm- m^3/mole	L/kg	Reactivity
trichloroethene (TCE)	1.46	58 @ 20 C	1100	0.0103 (EPA)	166	abiotic biogeochemical transformation
<ul> <li>Flow th</li> </ul>	how th rough l rough <sup>y</sup>	nese pro bedding vertical f	pperties planes ractures	s affect f	low in be	/
RC FracRx-1Table 4	<b>⊦</b> -1					

	Identifica Transpo				ate and		
	Chemical	Liquid Density	Vapor Pressure	Solubility	Henry's Constant	Кос	
		g/cm^3 (water = 1 g/cm^3)	mm HG (volatile >= 1 mm HG)	mg/L	atm-m^3/mole	L/kg	Reactivity
tr	ichloroethene (TCE)	1.46	58 @ 20 C	1100	0.0103 (EPA)	166	abiotic biogeochemical transformation
Fa	Potential fo Potential fo Potential re	density, likely or partitioning or dissolved	y to sink in s g to vapor pl plume and r ong fracture	aturated z hase natrix diffu		matrix	Fate & Transport
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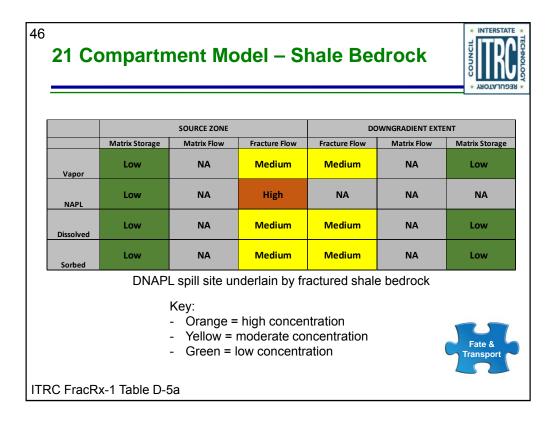




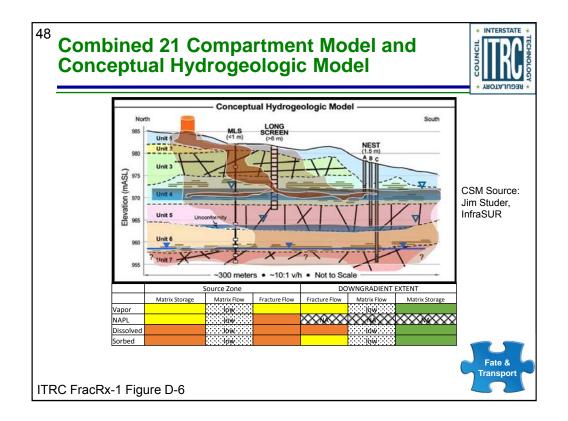


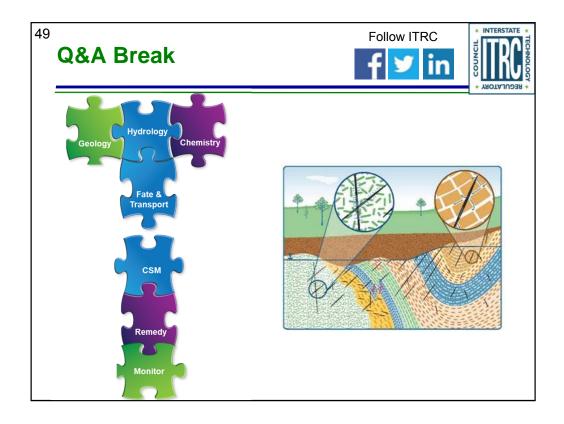
	SOURCE ZONE			DOWNGRADIENT EXTENT		
	Matrix Storage	Matrix Flow	Fracture Flow	Fracture Flow	Matrix Flow	Matrix Storag
Vapor*			,a		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	
NAPL*				NA	NA	NA
Dissolved						
Sorbed						

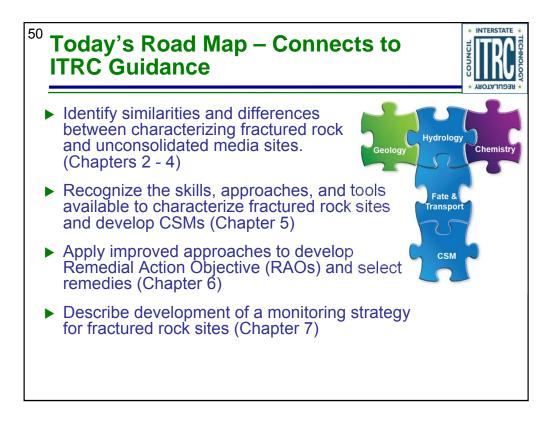
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		SOURCE ZONE		DOWNGRADIENT EXTENT			
	Matrix Storage	Matrix Flow	Fracture Flow	Fracture Flow	Matrix Flow	Matrix Storage	
Vapor	Low	Medium	Medium	Medium	Medium	Low	
NAPL	Low	Low	High	NA	NA	NA	
Dissolved	Low	Medium	Medium	Medium	Medium	Low	
Sorbed	Low	Low	Medium	Medium	Medium	Low	
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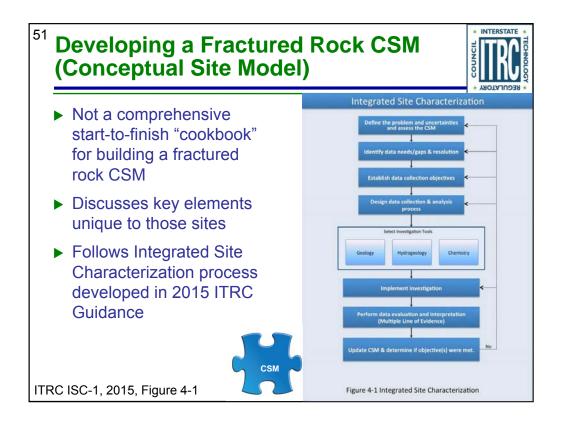


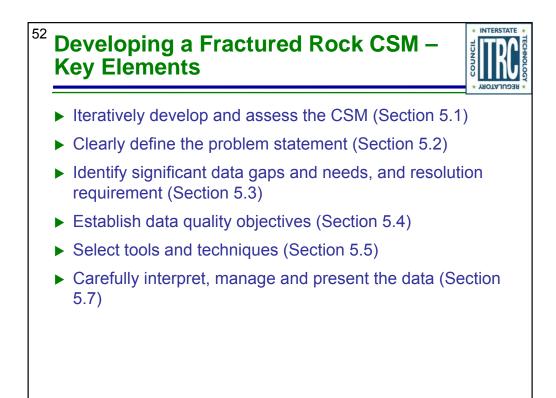
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		SOURCE ZONE		DOWNGRADIENT EXTENT		
	Matrix Storage	Matrix Flow	Fracture Flow	Fracture Flow	Matrix Flow	Matrix Storage
Vapor	Negligible	NA	Medium	Medium	NA	Negligible
NAPL	Negligible	NA	High	NA	NA	NA
Dissolved	Negligible	NA	Medium	Medium	NA	Negligible
Sorbed	Negligible	NA	Medium	Medium	NA	Negligible
	DNAPL s	pill site und Key:	erlain by <b>fra</b> e	ctured grani	ite bedrock	C
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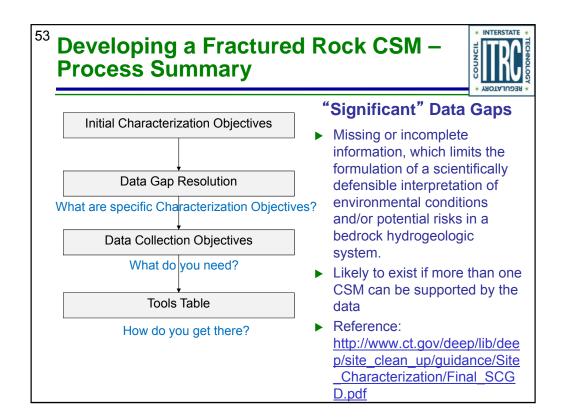


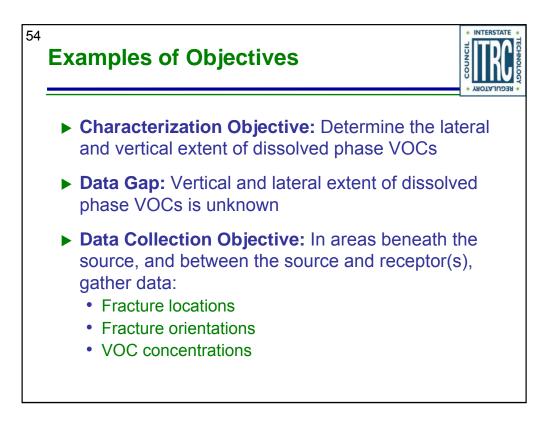


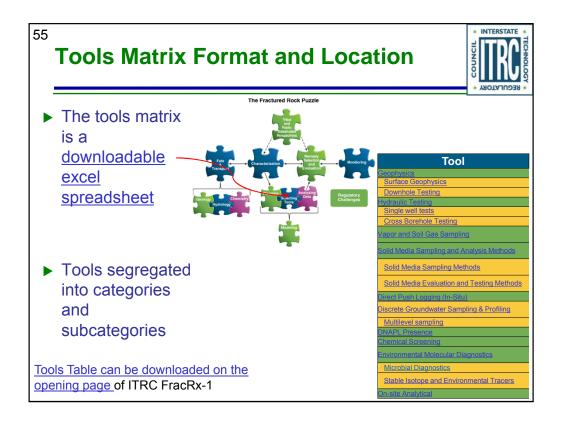




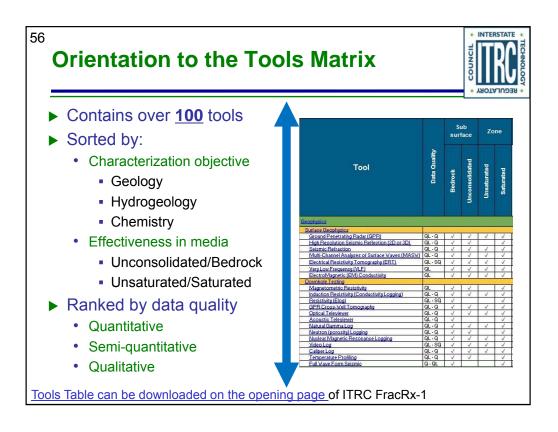


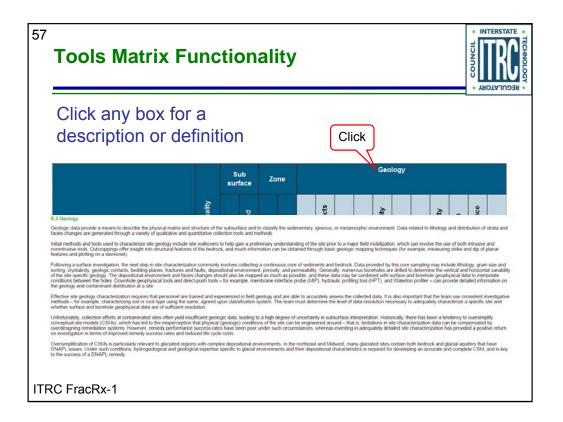


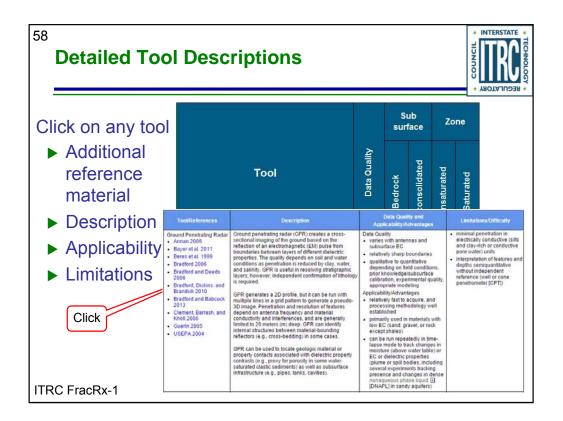


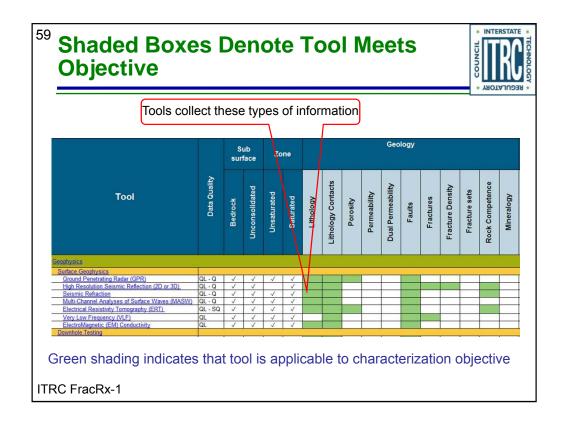


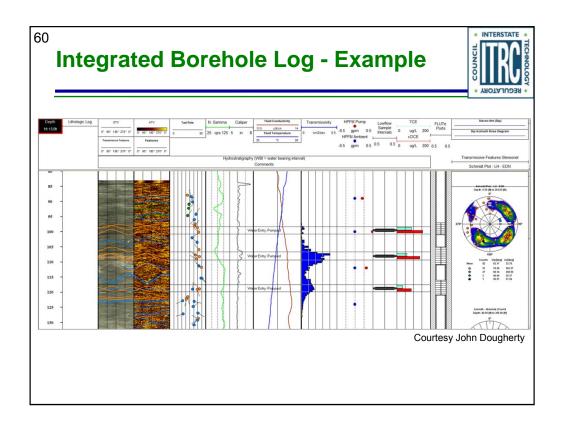
The tool is downloadable by click on the Select Tools on the opening page of the Web document. There are also a number of links to the tools throughout the Characterization section of the document.

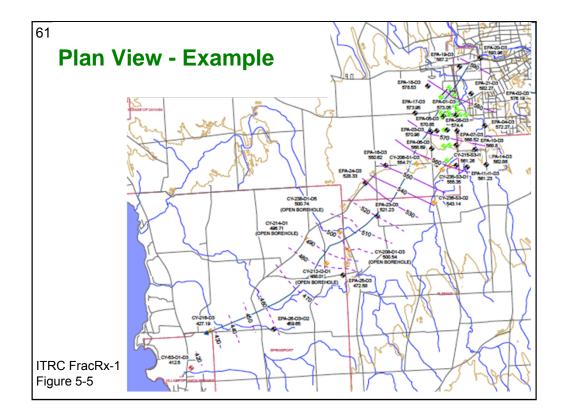


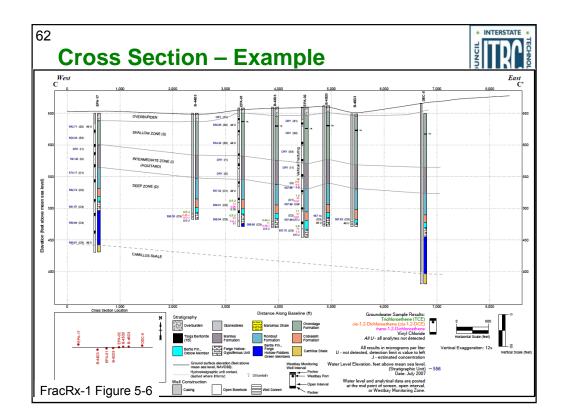


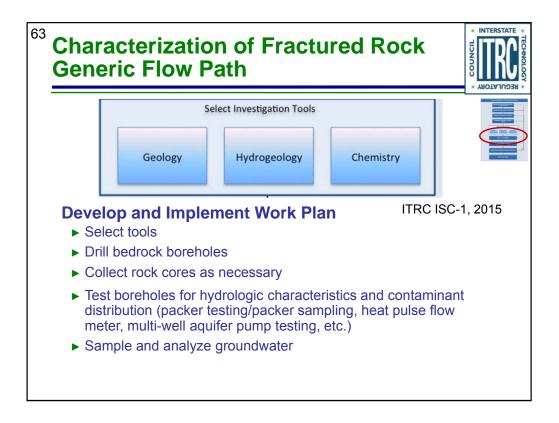


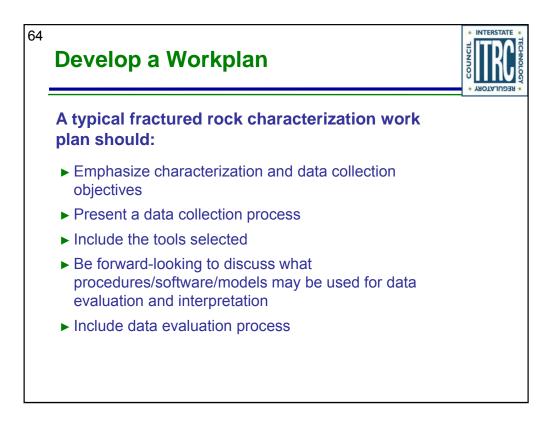


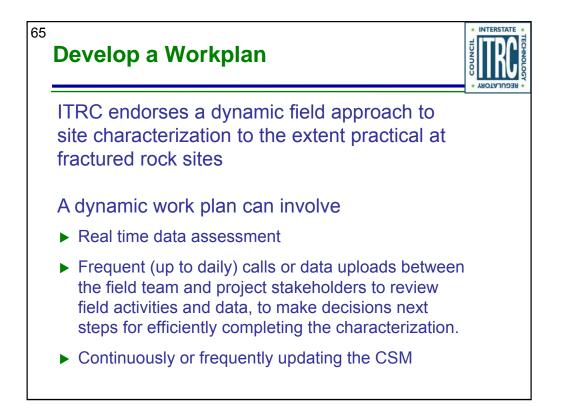


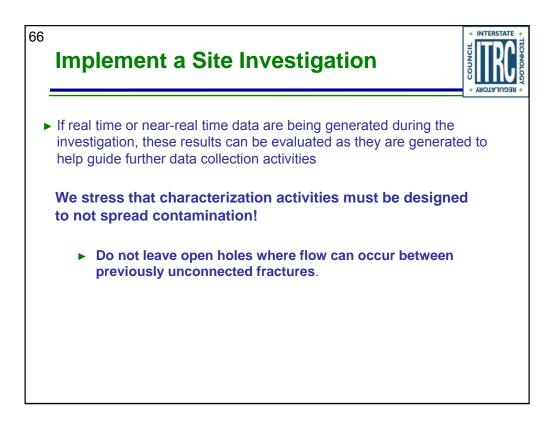


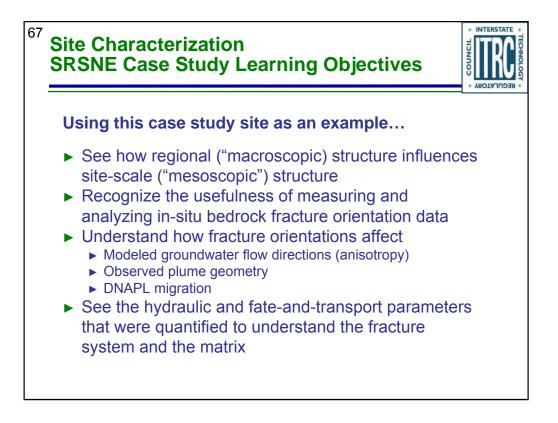


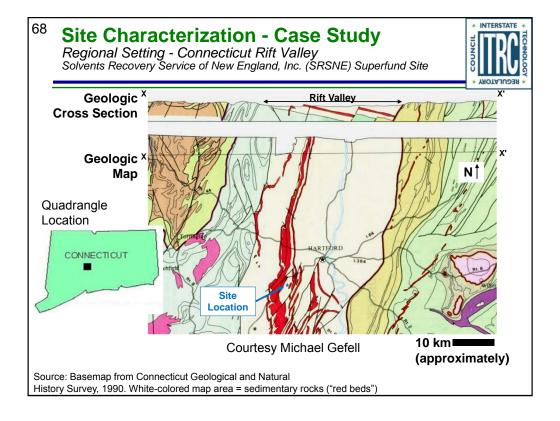


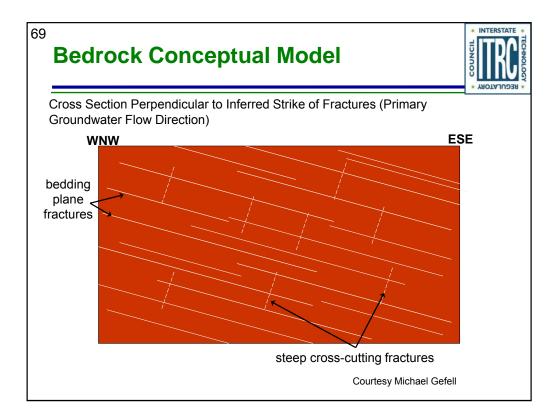


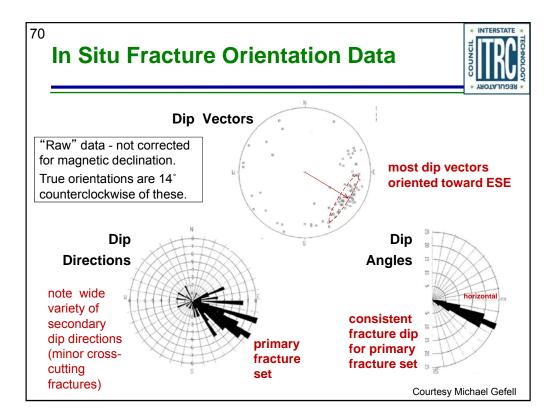


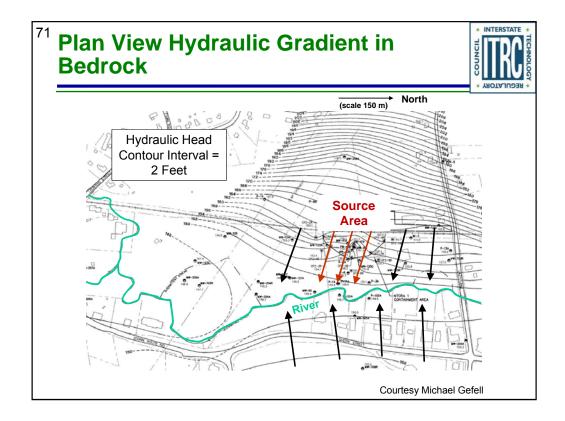


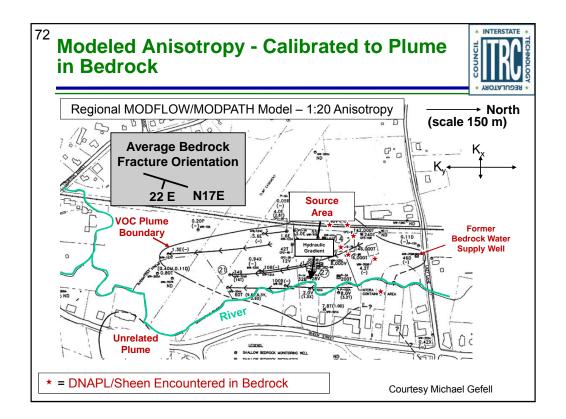


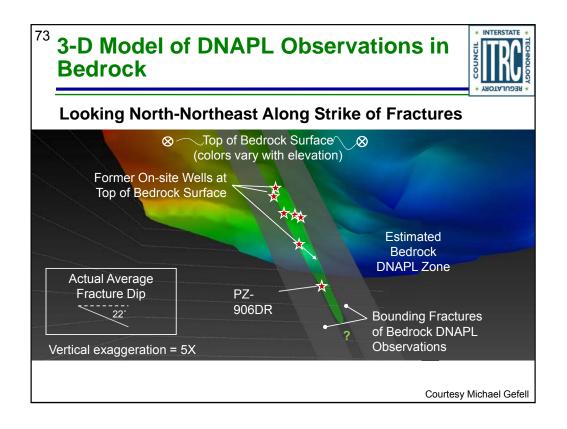


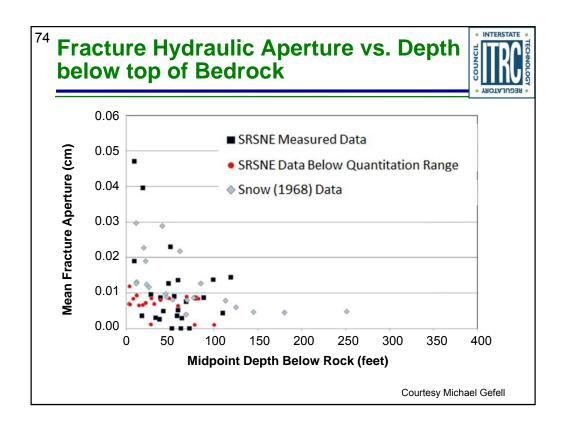


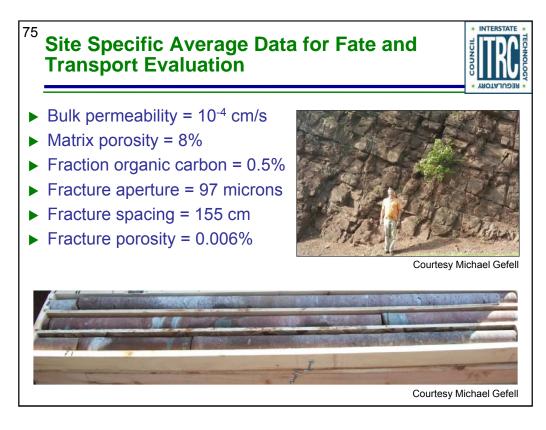


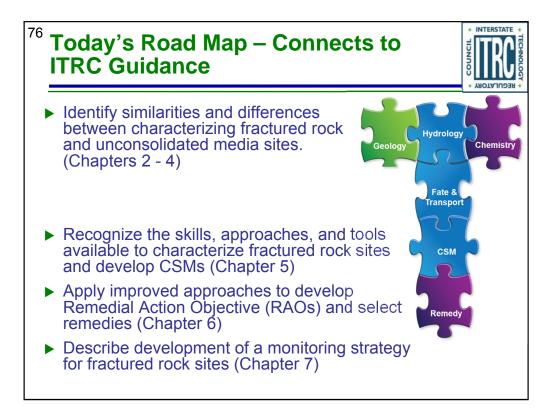


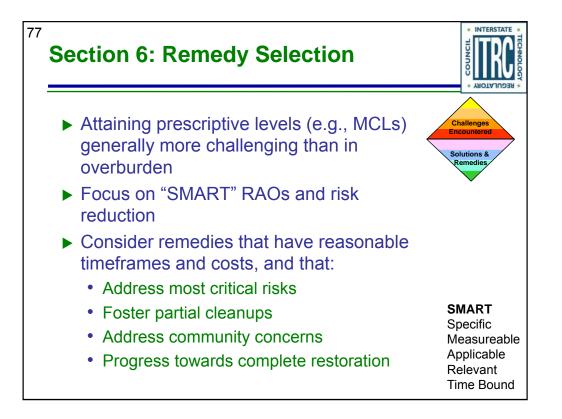


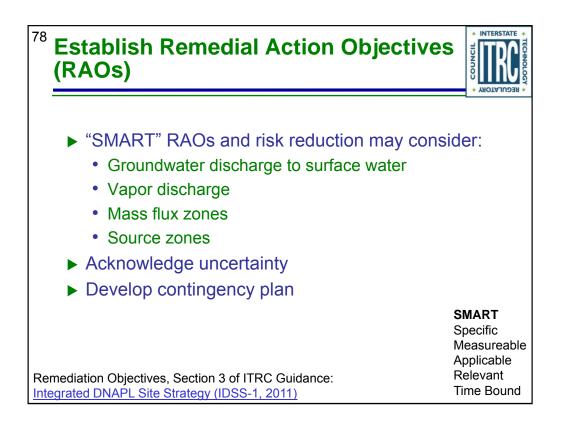












Remediation Objectives, Section 3 of ITRC Guidance: Integrated DNAPL Site Strategy (IDSS-1, 2011) at

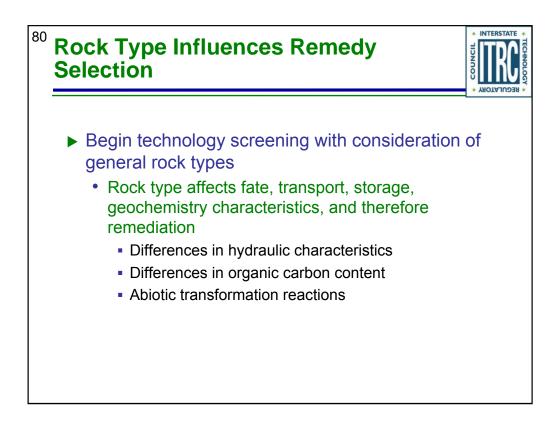
http://www.itrcweb.org/GuidanceDocuments/IntegratedDNAPLStrategy\_IDSSDoc/IDSS-1.pdf

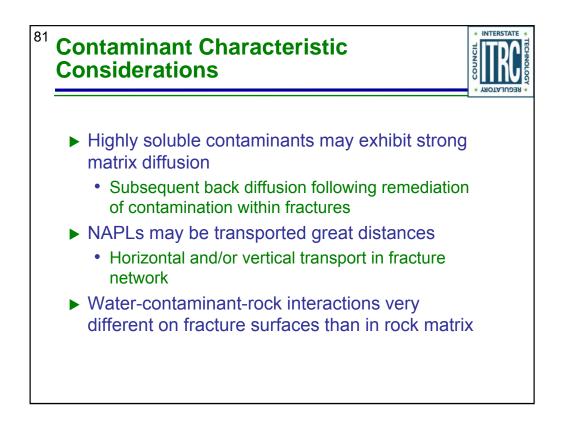
Online training at https://clu-in.org/conf/itrc/IDSS/

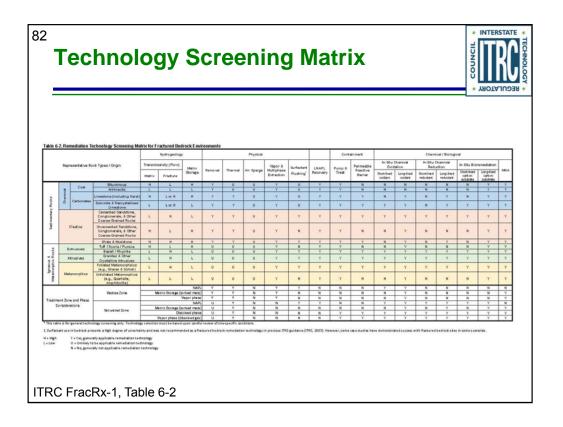
# <sup>79</sup> Special Considerations in Bedrock

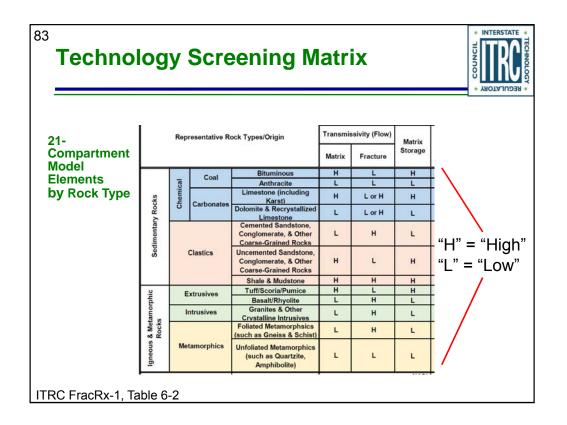


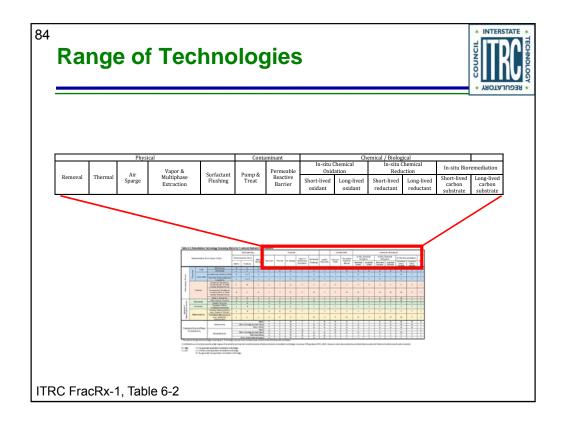
Properties	Difference at Fractured Rock sites	Impact
Hydraulic conductivity/ mass storage	Wider range of hydraulic conductivity and contaminant mass storage domains	Injection and extraction based remedies can be more difficult to implement successfully
NAPL	NAPL distribution may be even more complex than in porous media	NAPL more difficult to remove/contact
Groundwater flow direction/flux	Groundwater flow is more complex, especially on local scales	Preferential flow can complicate amendment distribution; passive remedies (e.g. barriers) can be more difficult to install
Abiotic/biotic reactions	Wide range of biotic and abiotic interaction with fracture surfaces and rock matrix	Need to understand rock types and whether matrix degrades or immobilizes contaminants; can enhance MNA at some sites
ITRC FracRx-1, Summary of Section 6.2		

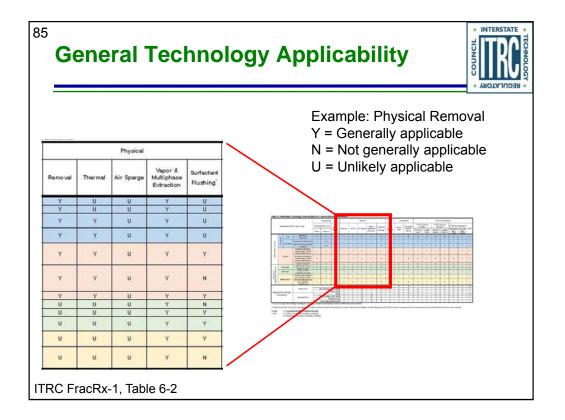


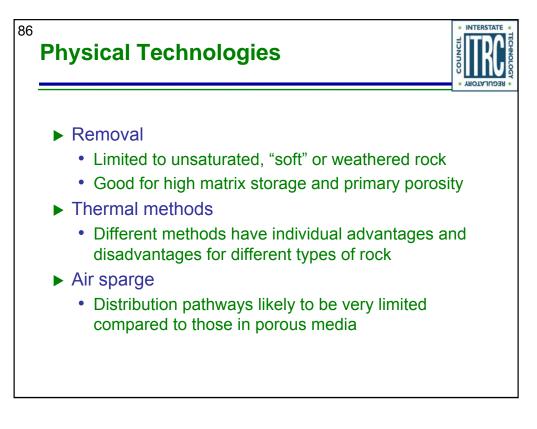


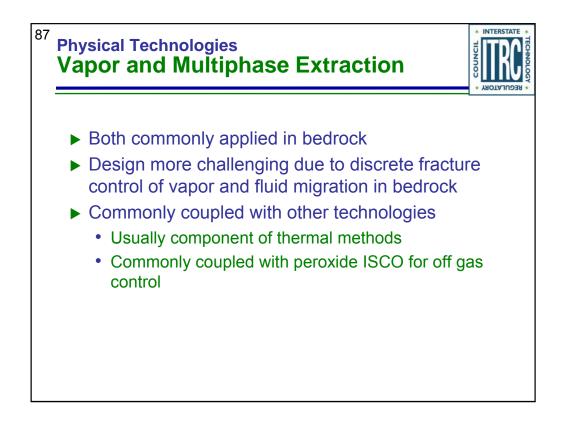


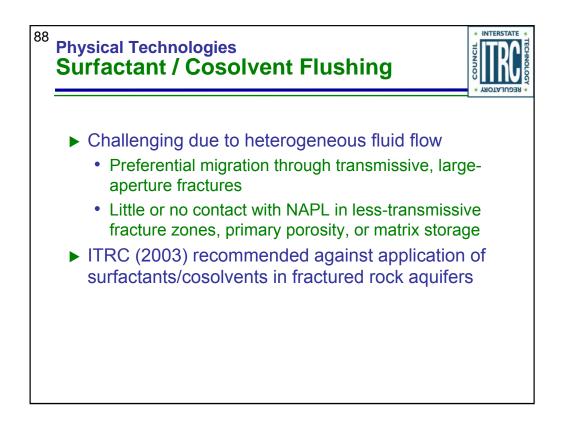


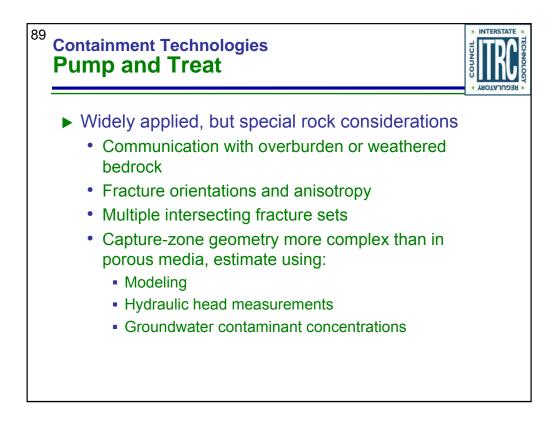


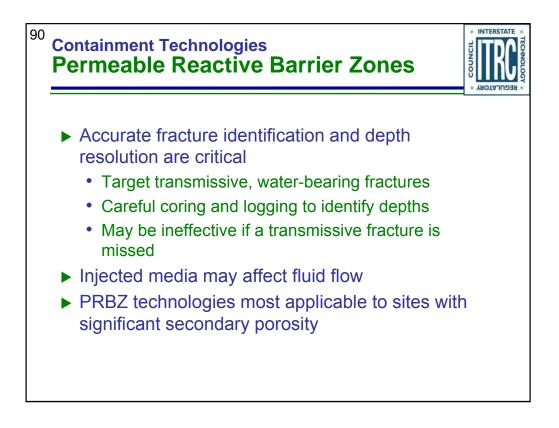


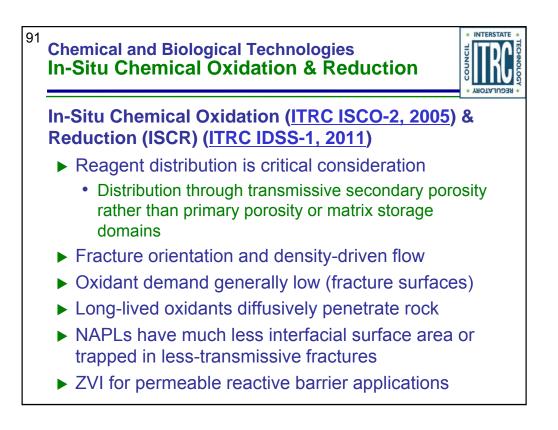


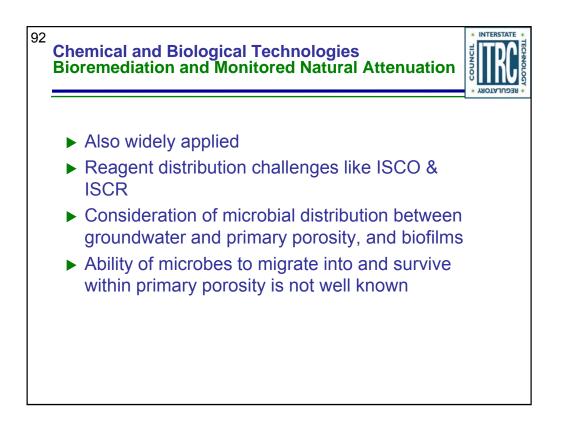


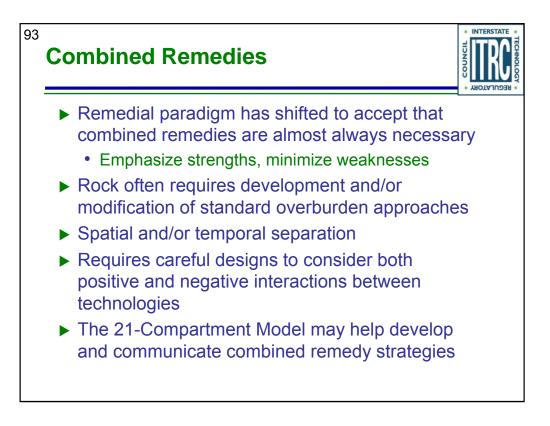


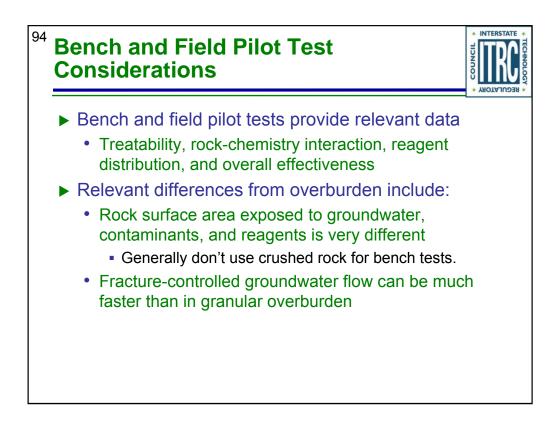


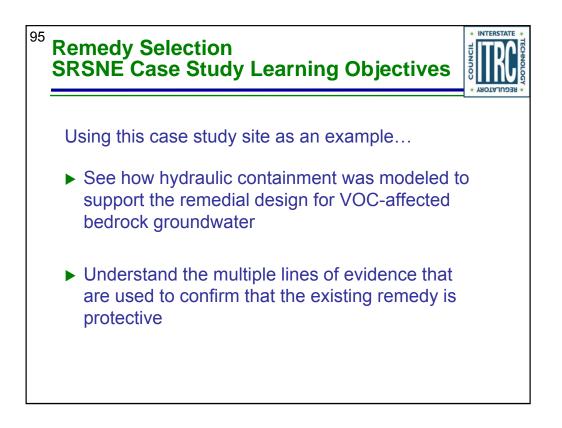


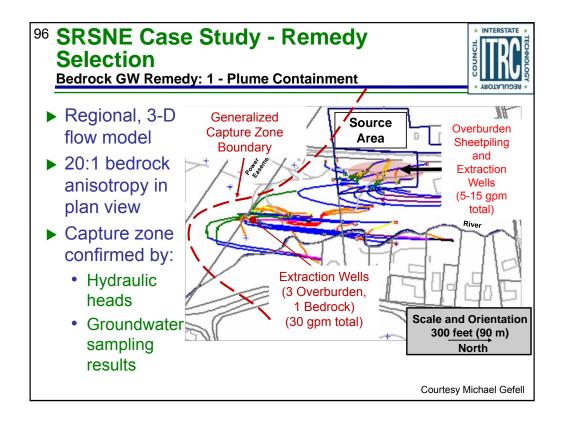


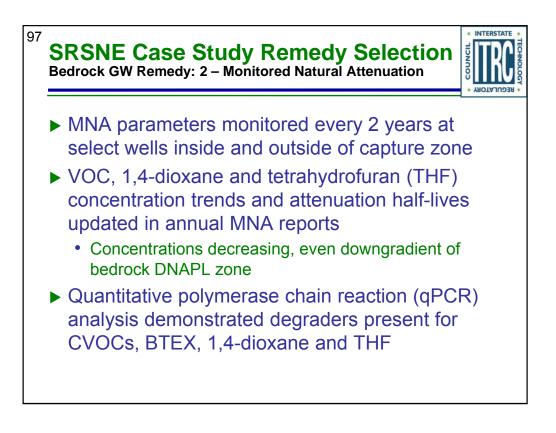


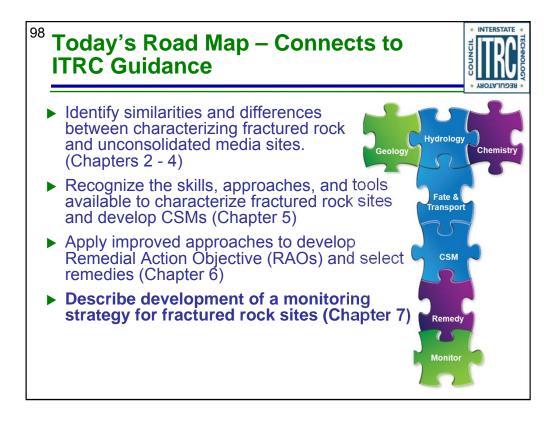


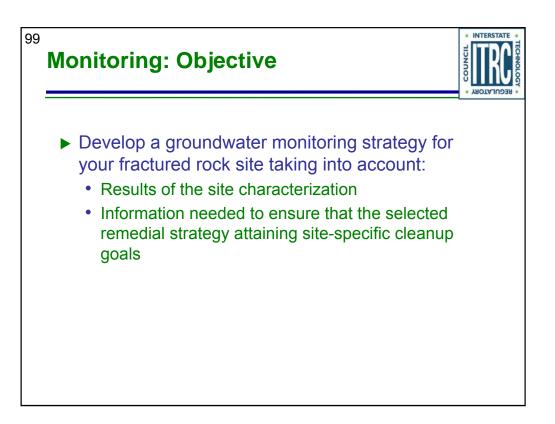


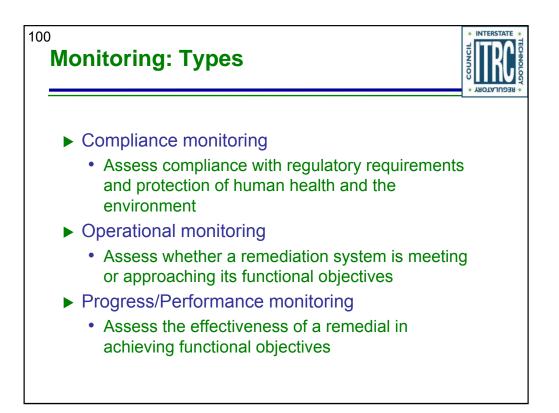


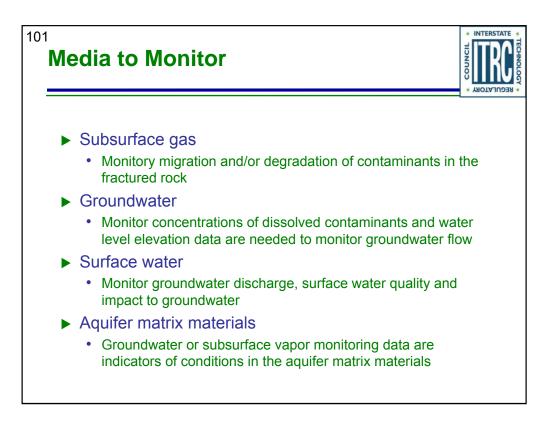


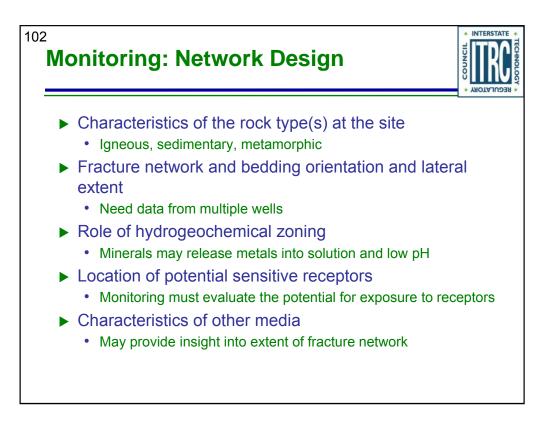


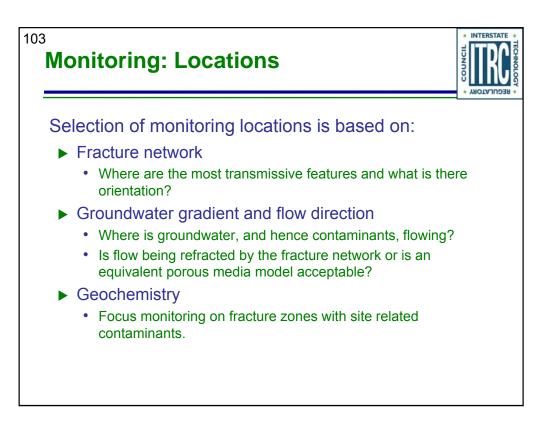


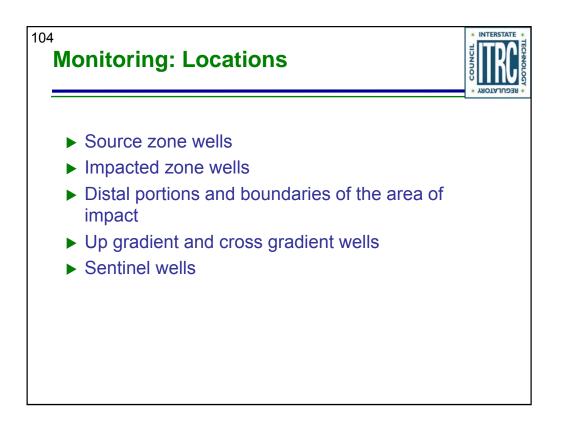


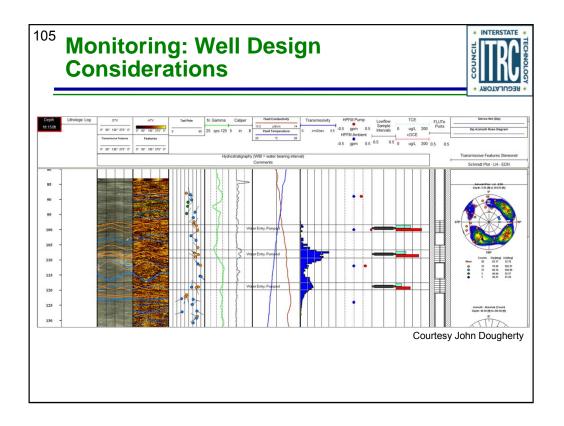


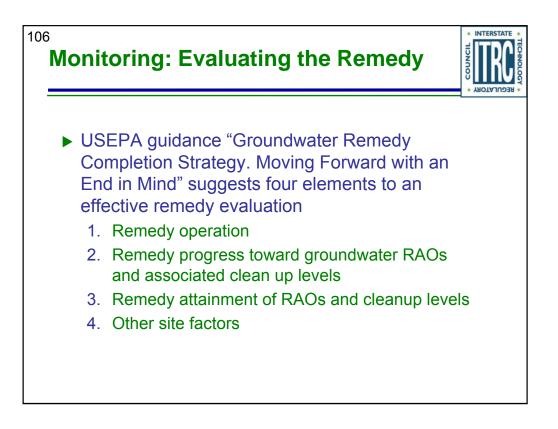












#### <sup>107</sup> Monitoring Strategy: Greenville Case Study

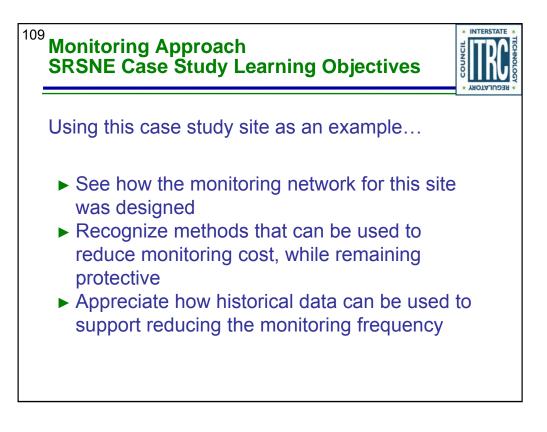


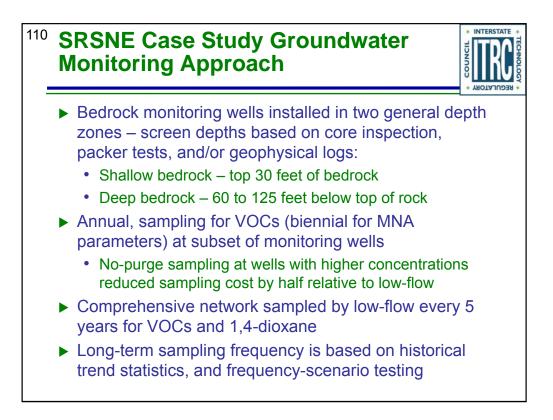
- Former Industrial Site in Greenville, South Carolina illustrates development of a remediation monitoring strategy
- Media to monitor
  - · Groundwater and surface water
- Monitoring network design
  - Weathered rock zone grades into competent bedrock consisting of metamorphic gneiss with little matrix porosity
  - Fractures in the bedrock were predominantly subhorizontal
  - Water-bearing fracture zones could be readily identified

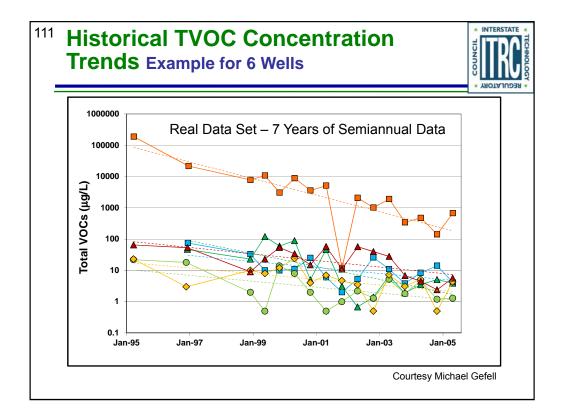


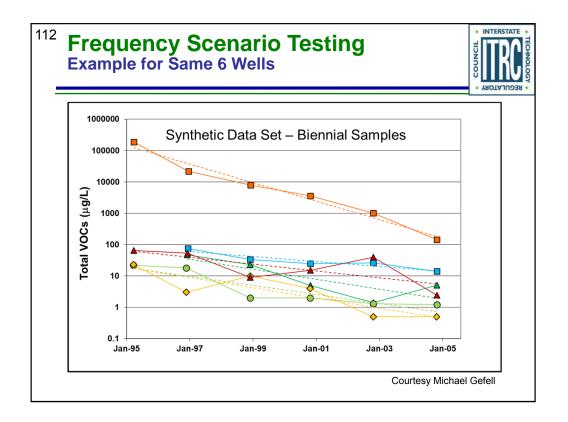


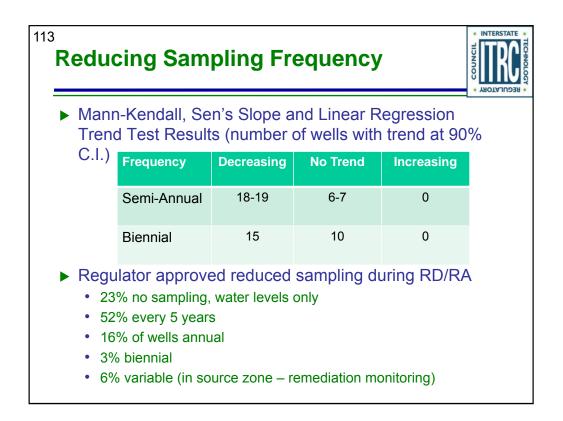
- Monitoring network design (cont'd)
  - 15 monitoring wells in the source area and 37 monitoring wells in the impacted zone and adjacent areas in saprolite and bedrock
  - Included upgradient, cross gradient, and sentinel wells
  - Wells installed upgradient and down gradient of ZVI barriers to monitor remedy progress
  - Additional cross gradient wells were installed to confirm the treatment area boundaries
  - Periodic surface water sampling is conducted down gradient \ of the impacted zone



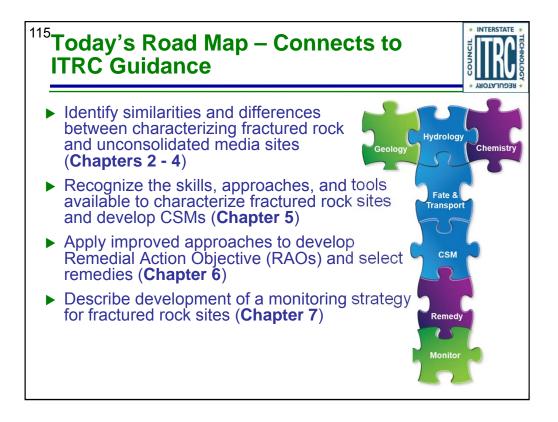


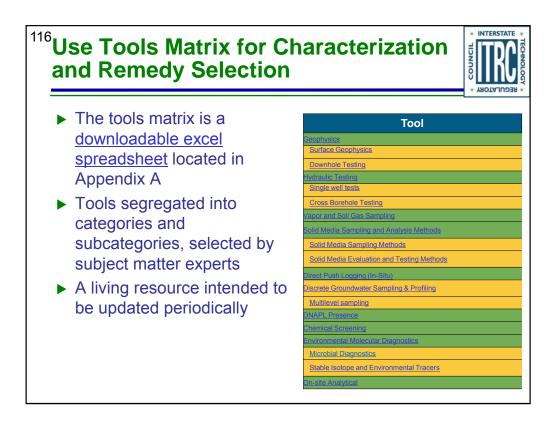


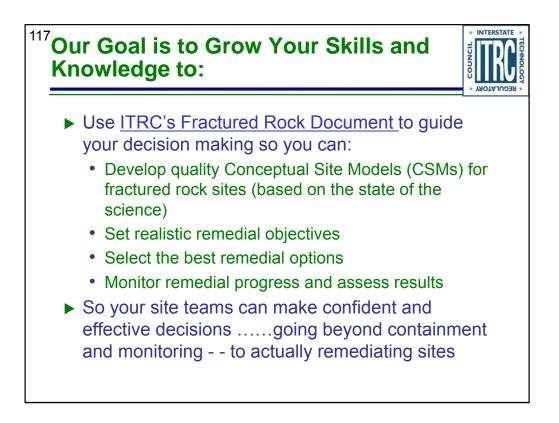














Links to additional resources: https://clu-in.org/conf/itrc/FracRx/resource.cfm

Your feedback is important – please fill out the form at: https://clu-in.org/conf/itrc/FracRx/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

 $\checkmark$  Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

 $\checkmark$  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 with ITRC:

 $\checkmark$  Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

- $\checkmark$  Sponsor ITRC's technical team and other activities
- ✓Use ITRC products and attend training courses
- ✓ Submit proposals for new technical teams and projects