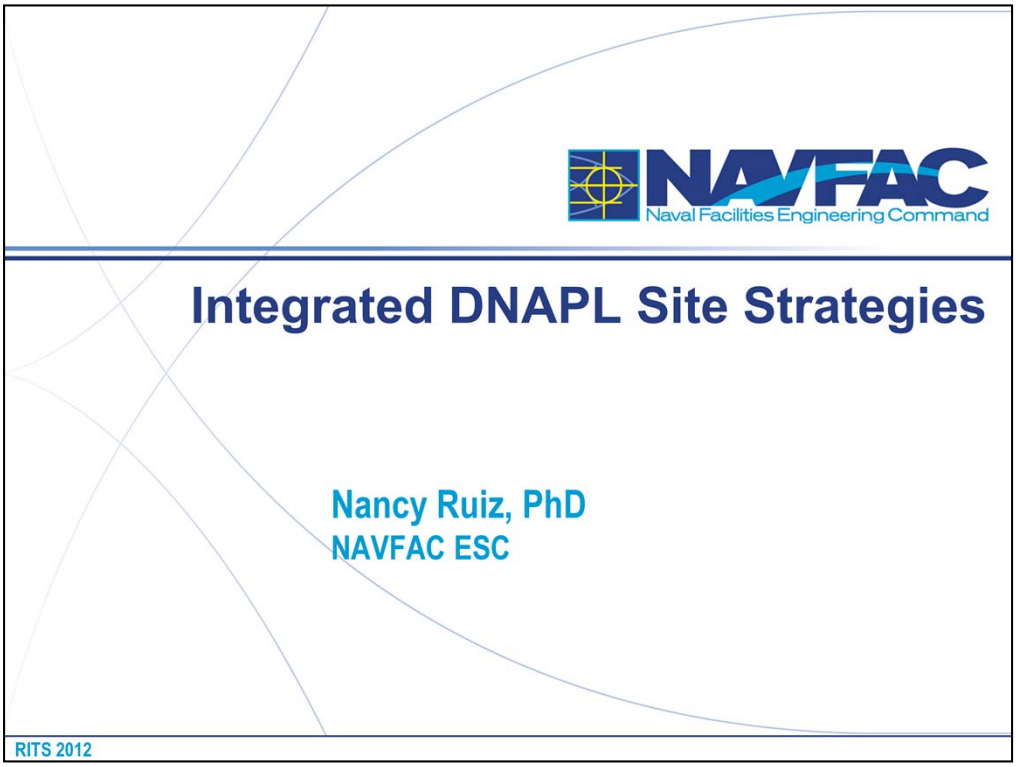
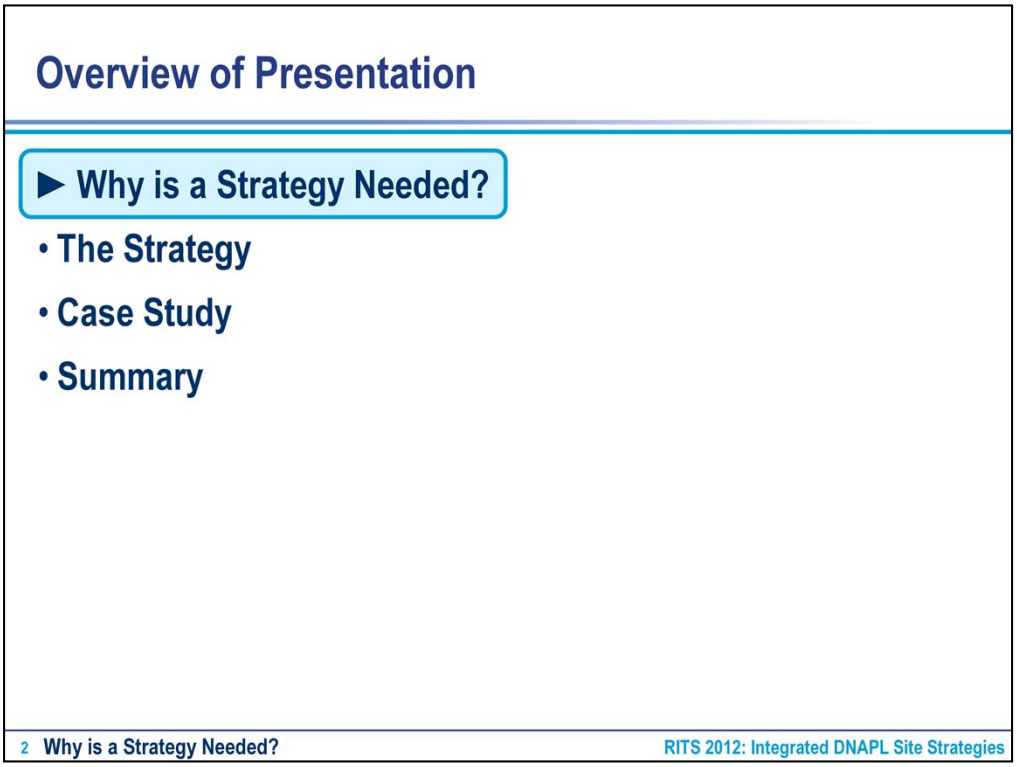


- Nancy was a member of the Interstate Technology & Regulatory Council (ITRC) team that developed the Integrated DNAPL Site Strategy (IDSS) guidance document.

- From the ITRC website, www.itrcweb.org:

  "ITRC consists of 50 states, the District of Columbia, multiple federal partners, industry participants, and other stakeholders, cooperating 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 new environmental technologies. ITRC accomplishes its mission in two ways: it develops guidance documents and training courses to meet the needs of both regulators and environmental consultants, and it works with state representatives to ensure that ITRC products and services have maximum impact among state environmental agencies and technology users."

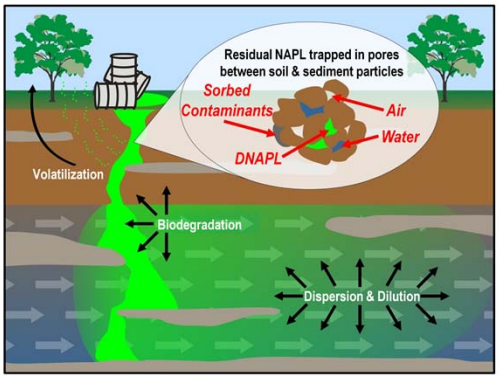


Context for the presentation:

- Why is a strategy needed and how does this strategy fit into the Navy's approach to chlorinated solvent sites?
- Then, the strategy will be discussed with references to Navy guidance and policy.
- After that, all the concepts will be brought together with a case study.
- Finally, the presentation will be wrapped up with the summary.

Key Terminology

- **Chlorinated Solvents vs. DNAPL**
  - **Define DNAPL**
    - Dense Non-Aqueous Phase Liquid
  - **DNAPL releases lead to chlorinated solvent plumes**
- **Why are chlorinated solvent sites difficult to remediate?**
  - **Source zone architecture**
  - **Density, solubility, and sorption**



Guidance document focus is on chlorinated solvent sites, not just sites with DNAPL

3 Why is a Strategy Needed? RITS 2012: Integrated DNAPL Site Strategies

- Note how interconnected DNAPL and chlorinated solvent sites are - DNAPL releases lead to chlorinated solvent plumes
- It's this history, starting with DNAPL that make chlorinated solvent sites difficult to remediate
  - Is there DNAPL still remaining: the infamous "source zone"
  - Also, physical properties of the contaminants make site remediation a challenge.
- Guidance does NOT require a site to have DNAPL present in order for the guidance to be applicable.

The Challenges…

- Incomplete understanding of chlorinated solvent sites
- Complex matrix – manmade and natural
- Unrealistic remedial objectives
- Selected remedy is not satisfactory

MDL = Method Detection Limit

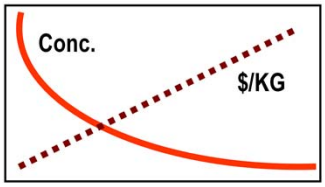
4 Why is a Strategy Needed? RITS 2012: Integrated DNAPL Site Strategies

The common challenges at chlorinated solvent sites include…

- Phase distribution of the contaminant (sorbed, dissolved, vapor, and DNAPL) confounds the understanding at a site.
- Complex hydrogeology (complex matrix) adds another challenge to the site.
- Historic remedial objectives may not have taken the site's complexity into account and promised quick fixes at sites.
- Finally, the remedy selected often does not perform as expected – so the remedy is deemed unsatisfactory. Is that due to an incomplete understanding of the site? And/or unrealistic expectations for a technology's performance?

The Questions…

- Are you not achieving your cleanup goals and/or objectives?
- Is it time to change your remedial approach?
- Are you tired of throwing money and time at your chlorinated solvent sites with little improvement in return?



5 Why is a Strategy Needed? RITS 2012: Integrated DNAPL Site Strategies

Knowing the challenges..the questions proposed to you today are…

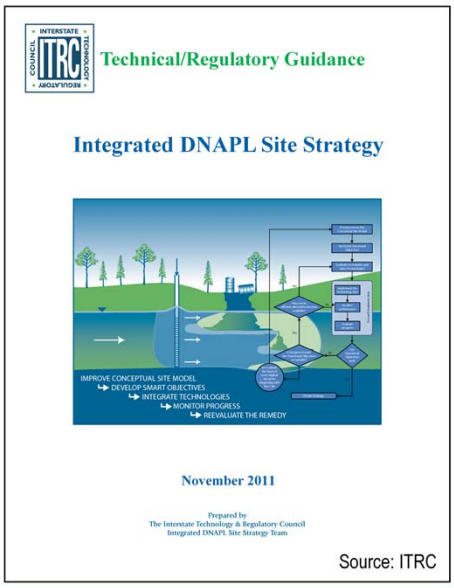
If you answered "yes" to the previous questions,

Do I have a strategy for you!

Guidance is available from the ITRC web site – www.itrcweb.org.

The Solution…

- An Integrated DNAPL Site Strategy (IDSS)
- Provides comprehensive site management
- Develop an IDSS anytime
- Use for any recalcitrant contaminant



Source: ITRC

7 Why is a Strategy Needed? RITS 2012: Integrated DNAPL Site Strategies

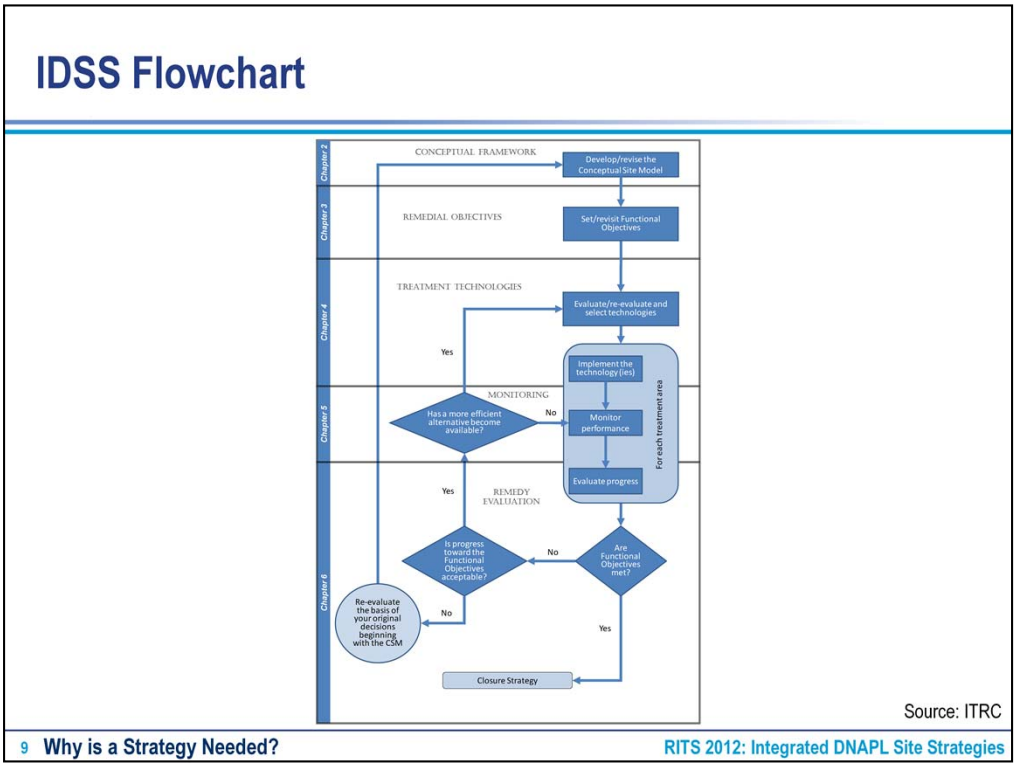
- Holistic approach to comprehensive site management
- You can develop an IDSS anytime:
  - At the beginning of the environmental restoration process, in fact, the guidance document is organized to take a site from beginning to closeout.
  - In the middle of the environmental restoration process. That's where most sites are today!
  - The IDSS has a section specifically dedicated to reviewing the current status of a site

The IDSS can be tied together with the Navy's approach to DNAPL site management.

- Today's presentation will introduce you to the IDSS. As mentioned previously, the guidance is available for download at the ITRC web page. In addition to this training, the ITRC offers training through EPA's Clu-In web site 3 to 4 times each year.

- ITRC IDSS training covers the guidance. This presentation goes one step further and ties the guidance into how the Navy approaches sites. Specifically, you'll see reference to the optional guidance discussed in earlier presentations from today as well as general plume management strategies.

- You'll see white text boxes showcasing Navy products throughout the presentation.



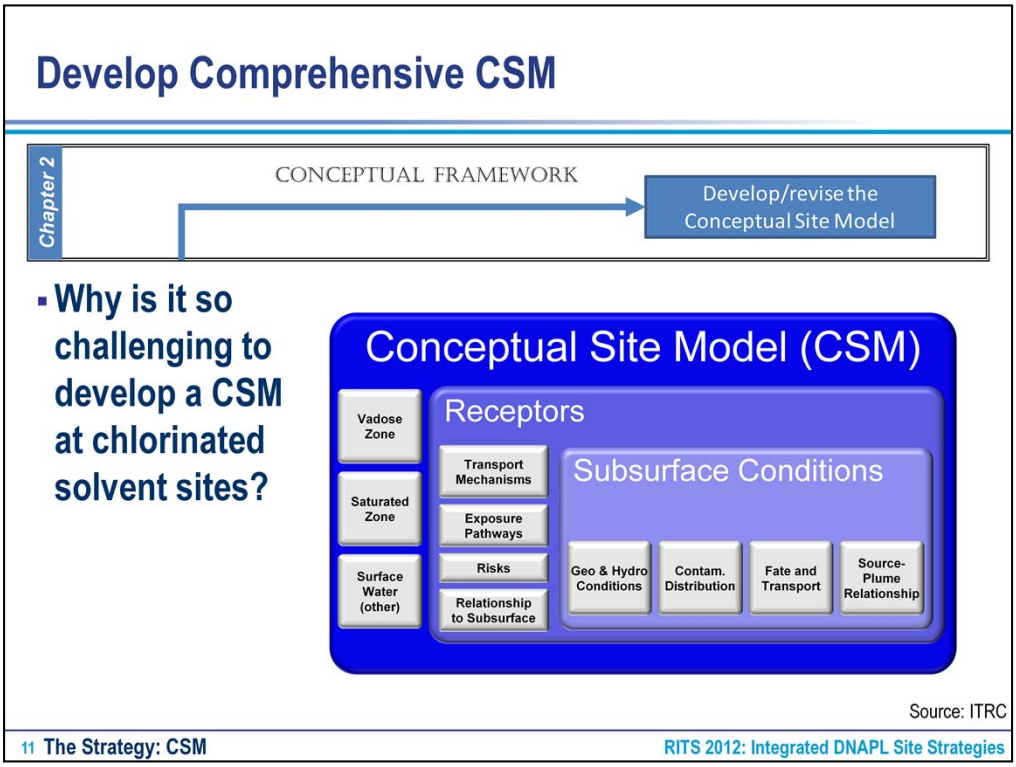
To wrap up the presentation introduction, here is the IDSS flowchart. This flowchart will be used to walk through each step.

Overview of Presentation

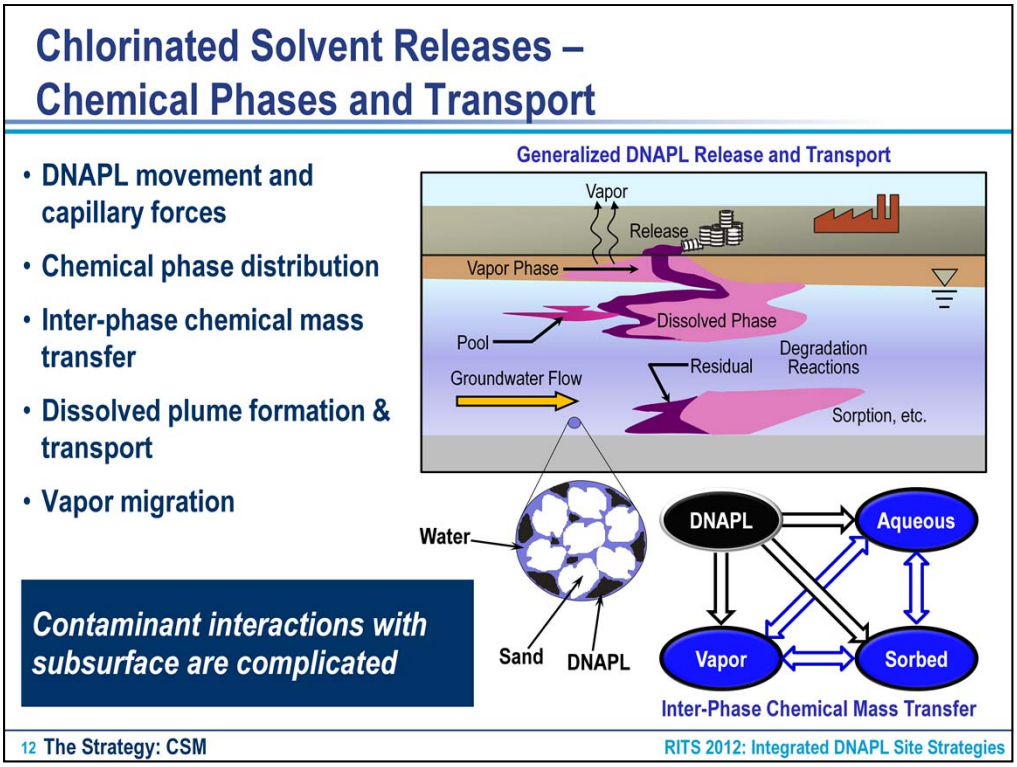
- Why is a Strategy Needed?
- ► The Strategy
  - ► Develop Comprehensive CSM
  - – Establish Remedial Objectives
  - – Select Treatment Technologies
  - – Develop Monitoring Approach
  - – Re-evaluate the Remedy
- Case Study
- Summary

10 RITS 2012: Integrated DNAPL Site Strategies

Note the subsections here directly correlate with the IDSS flowchart on the previous slides.



- Develop a CSM is at the top of the strategy. Key topics to consider during CSM development or updating are:
  - Transport and reaction processes
  - Key geologic conditions
  - Source and plume dynamics
  - Source and plume response to treatment
- The graphic is a CSM in itself. The layers of subsurface conditions feed into the mechanisms that can bring contamination to a receptor for each portion of a site.

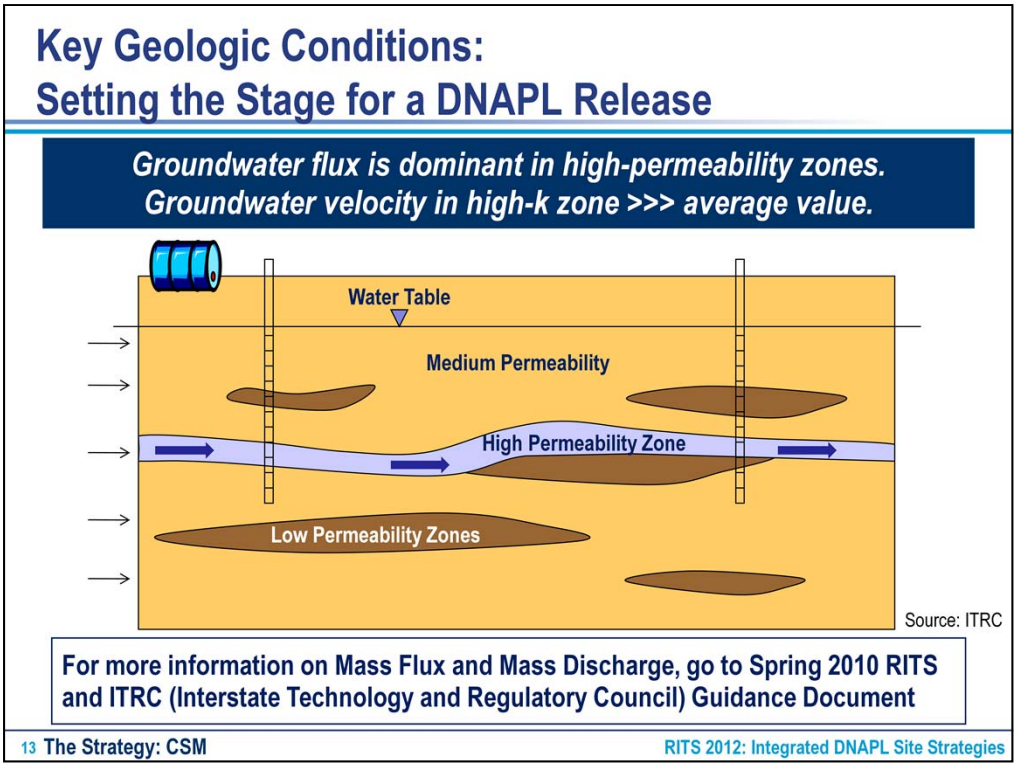


- A CSM can be challenging at a DNAPL site in that all chemical phases as well as transport should be accounted for within the CSM.

  - DNAPL moves down through system. Remember that DNAPL is a non-wetting solution so capillary force of water controls DNAPL movement into the pore space.

  - Mass transfer – Remember where your mass is. Note direction of movement out of DNAPL phase into aqueous, sorbed, and vapor phases.

  - Vapor phase can be very important because the vapor intrusion pathway can be a predominant risk driver at sites and should not be overlooked.



- The figure is a simplified illustration of heterogeneous geology, yet it alludes to the key geologic conditions to be considered at chlorinated solvent sites.

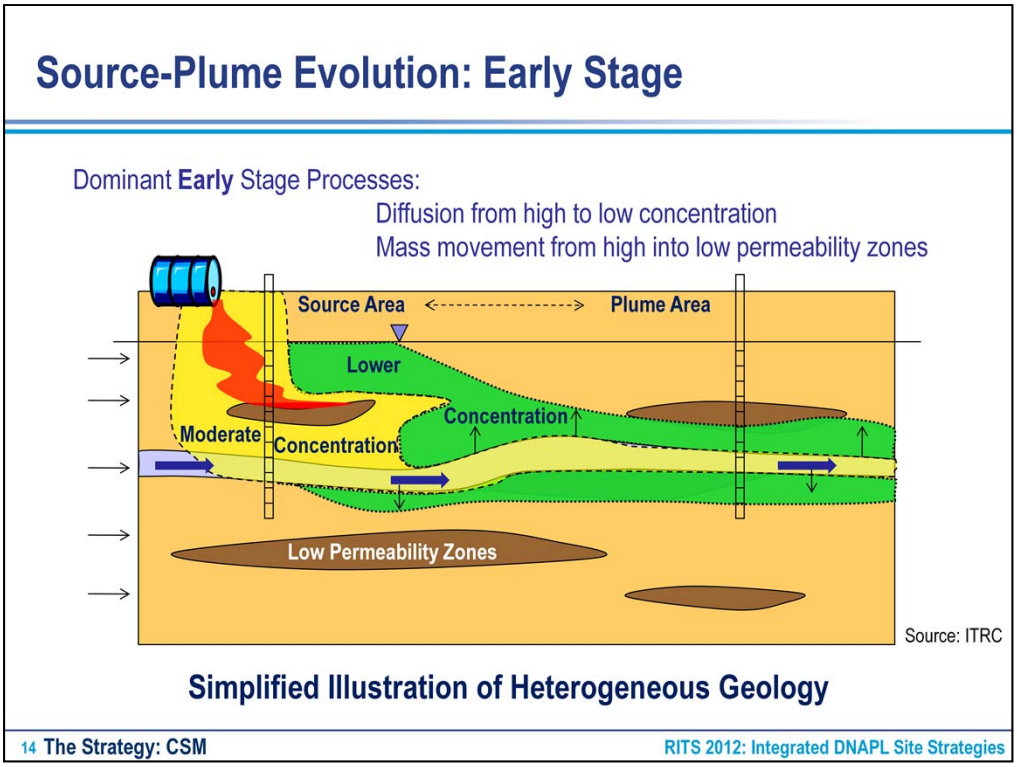
- Per Darcy's Law:

  - Groundwater velocity is high in areas with higher hydraulic conductivities.

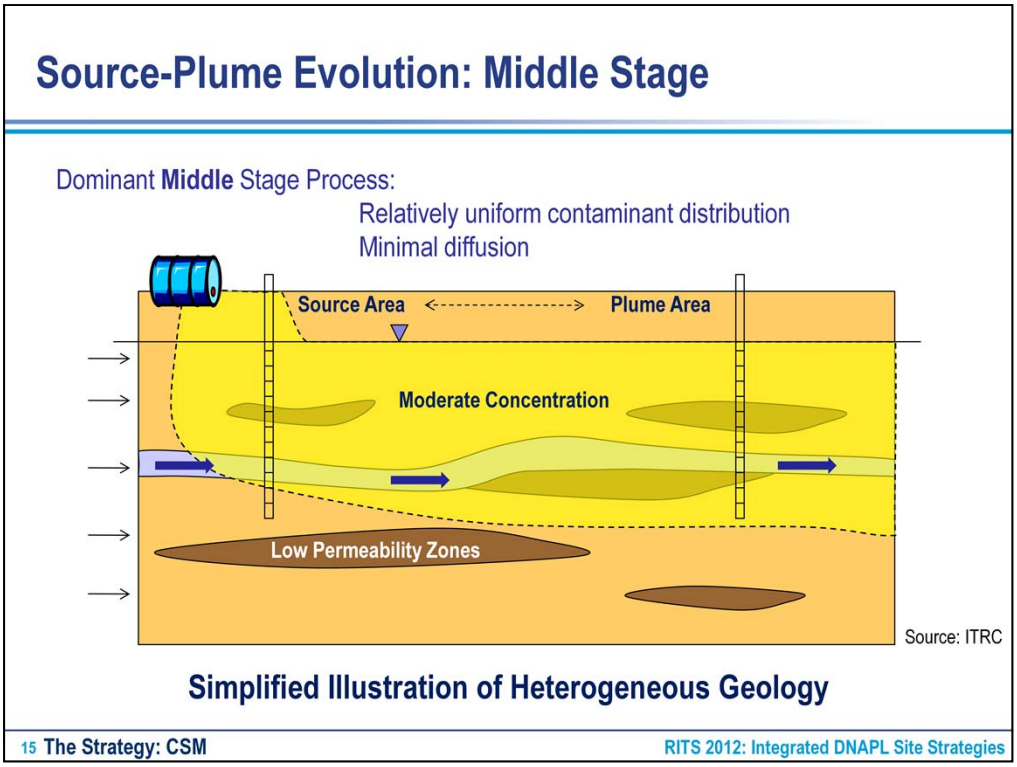
  - Thus, the majority of groundwater flux is through high-permeability zones.

  - Remember that flux is defined as contaminant flow per unit area.

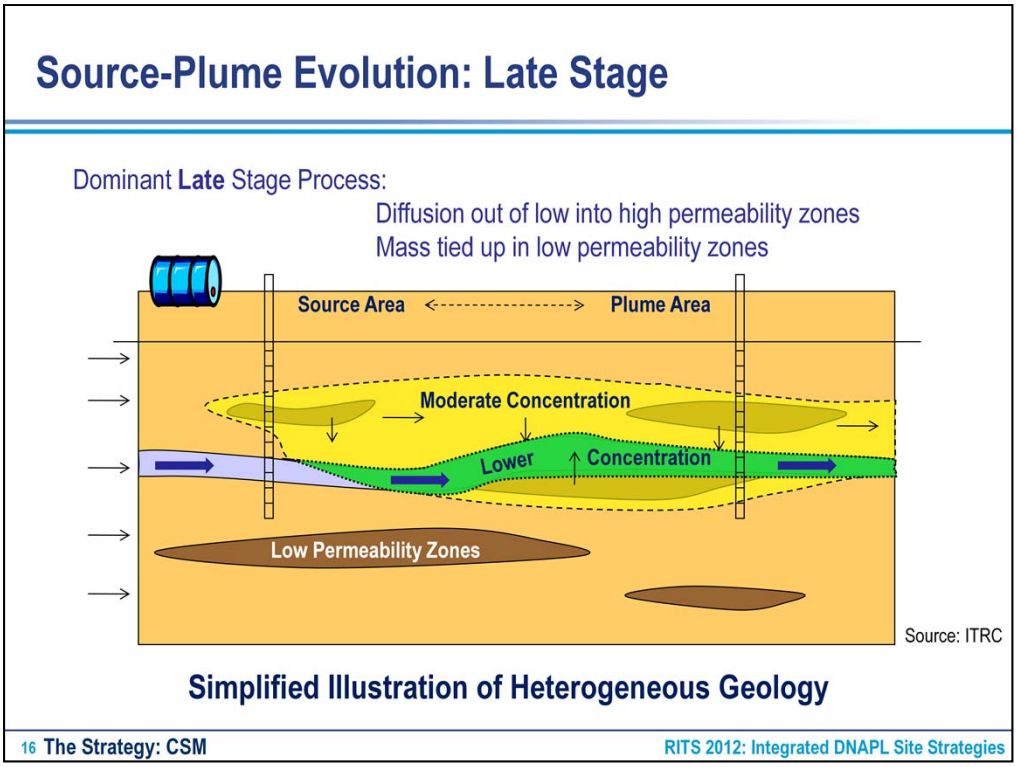
  - The flux is illustrated here as a flow tube.



- There aren't many DNAPL releases in "early stage".
- Usually after 10-20 years , the site has moved into middle or late stage, but early stage is important to understand as the starting point.



System is in equilibrium (sorbed phase and aqueous phase).



- Late stage is where diffusion out the low permeability zones sustains the dissolved phase plumes.

- How could you determine if your site is in this stage?

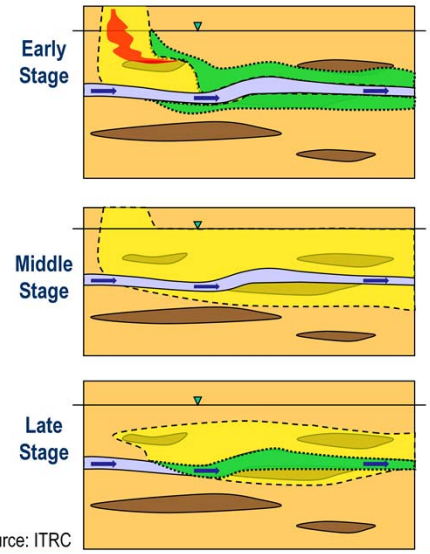
  - Use MIP (Membrane Interface Probe) through low permeability zones.

  - If in the late stage, results will show that the silt/clay layers have substantially more contaminant than transmissive zones.

Plume Response to In Situ Source Treatment

- Response dependant on stage of plume evolution
- Is contaminant mass accessible to treatment?

- In situ treatment often preferentially treats high permeability zones
- "Back-diffusion" can control plume response



Source: ITRC

17 The Strategy: CSM RITS 2012: Integrated DNAPL Site Strategies

- Importance of understanding a source-plume evolution is to better understand the impact the stage has on treatment efficacy.

- Early Stage – Biggest bang for the buck on improvement in plume condition because diffusion out of transmissive zones has been minimal at this stage.

- Middle Stage – Worst scenario for potential back-diffusion because a large reservoir of moderate concentrations exists over a large volume that may not be accessible to treatment.

- Late Stage – Still potential for back diffusion but less so than middle stage because contaminant mass reservoir in the inaccessible zones has been somewhat depleted.

CSM Summary

- Are the following understood at the site?
  - Transport processes and exposure pathways
  - Stage of source/plume evolution
  - How exposure concentrations will respond to treatment
- If the problem isn't understood, then the problem probably can't be solved
- Next ITRC guidance (from IDSS team) will update 2003 DNAPL site characterization document

Update your CSM! It's Navy policy.

18 The Strategy: CSM RITS 2012: Integrated DNAPL Site Strategies

- The discussion at the ITRC meetings showed just how important updating a sites CSM is…

- The Navy also recognizes the importance of updating a CSM. Even with changes to a SAP, an updated CSM is required.

Overview of Presentation

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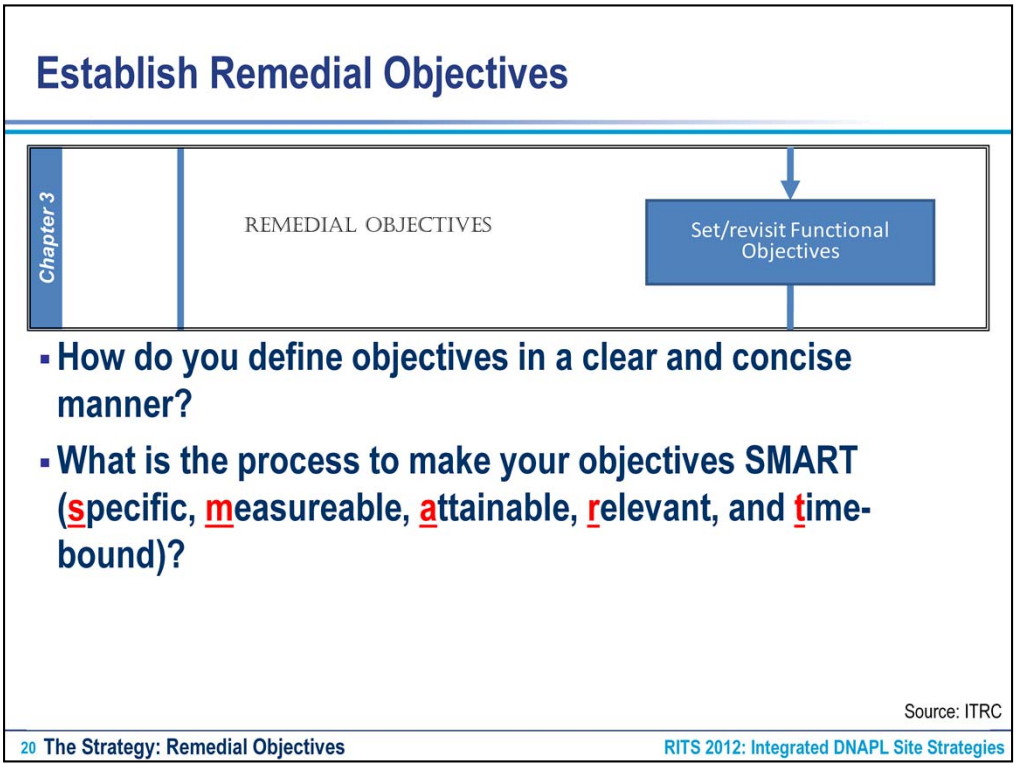

To help with establishing remedial objectives, the ITRC team looked to the National Research Council (NRC) and their 2005 report an Source Zone Assessment and Remediation. Their recommendation for objectives are on the next slide.

Types of Objectives

- **Absolute objectives**
  - **Based on broad social values**
    - Example: protection of public health and the environment
  - **Remedial Action Objectives (RAOs)**
- **Functional objectives**
  - **Steps taken to achieve absolute objectives**
    - Example: reduce loading to the aquifer by treating, containing, or reducing source
  - **Performance Objectives**
    - Navy Guidance for Optimizing Remedy Evaluation, Selection, and Design (2010)

For more information on objectives, see NAVFAC Plume Management Handbook (2008) and Alternative Endpoints RITS presentation (Fall 2010)

21 The Strategy: Remedial Objectives RITS 2012: Integrated DNAPL Site Strategies

- The NRC suggested absolute and functional objectives.
  - At most sites, the ultimate objective of site restoration is to achieve MCLs in all impacted media, but this objective is often technically and/or economically impracticable within "short" time frames, meaning <30 years. RAOs in the Navy are written as absolute objectives.
  - Functional objectives are steps towards achieving absolute objectives. Navy optimization guidance recommends performance objectives to measure progress towards RAOs in a similar manner to functional objectives moving towards absolute objectives.

Functional Objectives Should be SMART

SMART means:

- **Specific**
  - Objectives are detailed and well defined
- **Measureable**
  - Parameters are specified and quantifiable
- **Attainable**
  - Realistic within the proposed timeframe and availability of resources
- **Relevant**
  - Has value and represents realistic expectations
- **Time-bound**
  - Clearly defined and short enough to ensure accountability

22 The Strategy: Remedial Objectives RITS 2012: Integrated DNAPL Site Strategies

- SMART acronym was developed by the American Management Association (AMA) to recognize good objectives.

- SMART attributes are:

  - A means to devise clear and concise functional objectives

  - Community stakeholders have voiced concerns that “viable” approaches are rarely chosen. Using the SMART attributes may help communicate the overall strategy with long term (absolute) objectives and reasonable (functional) objectives.

Functional Objectives Time Frame

- Time frame should accommodate
  - Accountability
  - Natural variation of contaminant concentration and aquifer conditions
  - Reliable predictions
  - Scientific understanding and technical ability
- Team suggests 20 years or less for Functional Objectives

Site management and active remediation time frame may continue for much longer than 20 years

23 The Strategy: Remedial Objectives RITS 2012: Integrated DNAPL Site Strategies

Time frame aspect led to long discussions within ITRC. The team felt strongly regarding the time frame.

To give some perspective on time frames and what can happen in 20 years:

In 2012, we have lots of choices of remediation technologies: in situ chemical oxidation with a variety of oxidants; biostimulation and bioaugmentation for enhanced bioremediation; and thermal technologies; to name just a few. Zero-valent iron, long a choice to reductively degrade chlorinated solvents, is available in a wide range of particle size and final product configuration: macro, micro, and nano scale; bare metal, bimetallic, embedded with other materials such as a carbon source, and emulsified with biodegradable oil.

Today, if granular zero-valent iron is put into a trench, with or without sand, to create a permeable reactive barrier, it is sometimes referred to as a ”traditional” PRB.

Going back 20 years, to 1992, the first papers and presentations describing zero-valent metals-mediated degradation of chlorinated solvents were presented in 1992. So in 20 years, granular ZVI has gone from cutting edge to traditional technology.

Going back a further 20 years, to 1972, the EPA was just getting up on its feet, and remediation managers had very little choice beyond dig-and-haul and pump-and-treat.

So 20 years as an outside limit for functional objectives seems pretty generous.

General Example: How to make functional objectives SMART?

- **Define Site and Problem**
  - **Large industrial facility where 10,000-gallon PCE was released into a highly heterogeneous system**
  - **20 years later…**
    - 60% of DNAPL remains as residual
    - Plume has travelled off site

Source: ITRC

24 The Strategy: Remedial Objectives RITS 2012: Integrated DNAPL Site Strategies

Here's an example site to practice applying SMART function objectives.

General Example: Absolute and SMART Functional Objectives

- **Absolute Objective**: Prevent adverse human exposure via off-site groundwater given current and future reasonable use
- **Interim Functional Objectives**
  - Provide alternate water supply and institute Land Use Controls (LUCs) until concentrations are reduced to below the drinking water standard
  - Show a positive trend towards achieving the final functional objective within 2 years
- **Final Functional Objective**
  - Reduce PCE mass flux at the property boundary such that concentrations in off-site groundwater are reduced below the drinking water standard within 20 years

25 The Strategy: Remedial Objectives RITS 2012: Integrated DNAPL Site Strategies

- Absolute objective is expected. It's the standard protection of human health.
- Project team recognized the need for interim (short term functional objectives) and longer functional objectives.
- Interim functional objective examples. Note that these are only examples and not a complete list.
  - LUCs can be tracked in LUC Tracker – which is part of NIRIS now.
- Final functional objective
  - Example is three order of magnitude reduction in flux.
  - Note the timeframe.

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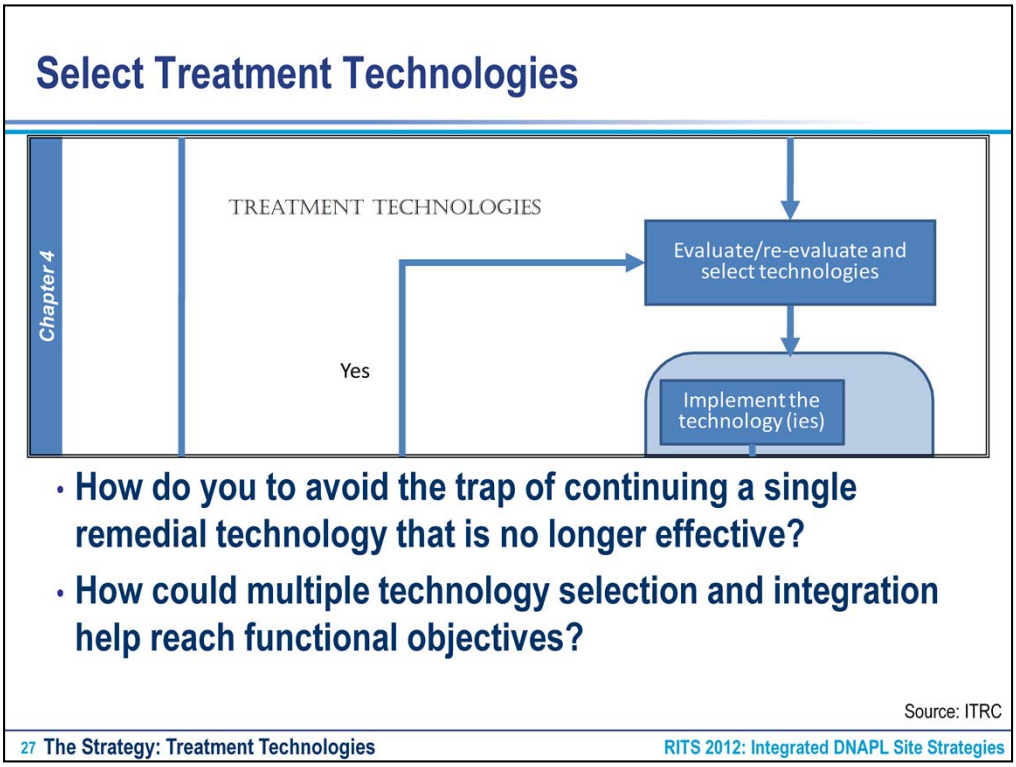


Technology performance and compatibility are the focus of this section.

Treatment Technology Selection

- Evaluate site based on…
  - Site considerations
    - e.g., geology, hydrogeology, and contaminants
  - Regulatory requirements
  - Sustainability
  - Community stakeholder interests
- Technology Categories
  - Physical removal
  - Chemical/biological treatment
  - Containment

28 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- Always remember the importance of site specific conditions. They can impact the solution of a technology tremendously .

- Technology categories are based on the primary mechanism by which they impact individual chlorinated solvent phases (e.g., DNAPL, sorbed, dissolved, and vapor phases).

Technology Assessment: Multiple-Site Performance Studies

- **Strong point about these studies…**
  - **Independent researchers, careful before/after evaluation**
  - **Repeatable, consistent comparison methodology**
  - **Describes spectrum of sites**
  - **Real data, not anecdotal**

Ground Water Monitoring&Remediation
Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent–Impacted Sites

Ground Water Monitoring&Remediation
ISCO for Groundwater Remediation: Analysis of Field Applications and Performance

Journal of Environmental Engineering
Multiyear Temporal Changes in Chlorinated Solvent Concentrations at 23 Monitored Natural Attenuation Sites

Ground Water Monitoring&Remediation
State–of–the–Practice Review of In Situ Thermal Technologies

29 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- The technology assessment was based on reviewing technology performance using multi-site studies.

- Full references of these and other studies are included at the back of the presentation.

Others Say Use Caution….

- Not site-specific
- Some lump pilot scale, full scale
- May not account for intentional shut downs (i.e., they stopped when they got 90% removal)
- Don't account for different levels of design/experience
- We are a lot better now….

- Multi-site studies also have important limitations to recognize
- Caution should be exercised when using performance data without considering the site-specific issues.

Technology Performance

Technology Category	Technology	Frequency	Performance (Contaminant Reduction)
Physical Removal	Excavation	11 of 118 sites (9%) [1] 104 of 230 sites (45%) [2]	80%-100% mass removal for 3 sites[1]
	Thermal	27 of 118 sites (23%) [1] 12 of 230 sites (5%) [2]	25%-100% mass removal[1] 90%-99% decrease in conc.[3]
Containment	Low-Permeability Barrier Walls	80 of 362 sites (22%) [2]	83% site met design objectives
	Pump and Treat	1 of 118 sites (1%) [1] 83 of 627 sites (13%) [2]	16% to 99% decrease in concentration[4]
	Permeable Reactive Barriers	8 of 627 sites (1%) [2] 157 ZVI sites world wide	22% to 99.9% decrease in concentration by ZVI[5]

Survey of technology used. Results vary on a site-by-site basis.

[1] 2004 [2] EPA no date. [3] 2010 [4] EPA 1999 [5] 2010
ZVI: Zero Valent Iron

31 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- Reference [1] is Carmen's 2004 survey of DNAPL sites.
- Excavation: 9% of DNAPL sites were addressed using excavation while 45% of source treatment decision documents at Superfund sites from 2005-2008 stated that excavation was part of the remedy.
- Thermal: 23% of DNAPL site used thermal. Thermal was a component in 5% sites noted in the EPA's source treatment decision documents (same reference as excavation). Reference [3] is a performance report specifically for thermal treatment.
- Reference [4] and [5] provide treatment technology specific performance results.

Technology Performance (cont.)

Technology Category	Technology	Frequency	Performance (Contaminant Reduction)
Chemical/ Biological Treatment	*In Situ* Chemical Oxidation	25 of 118 sites (21%) [1] 36 of 627 sites (6%) [2]	73% to 94% mass reduction[3]
	In Situ Chemical Reduction	6 of 118 sites (5%) [1]	25% to 50% mass reduction[1] 98% for soil mixing with ZVI [4]
	Enhanced Bioremediation	25 of 118 sites (21%) [1] 53 of 230 sites (23%) [2]	29% to 99.9% reduction in concentration[3]
	Monitored Natural Attenuation	116 of 627 sites (17%) [2]	74% reduction in concentration over 9 yrs [5]

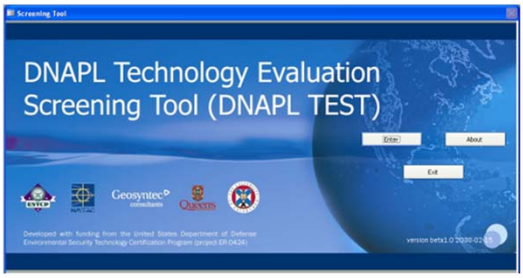
Treatment timeframe varies amongst* in situ *remedies and impacts performance assessment

[1] 2004 [2] EPA no date [3] 2008 [4] 2009 [5] 2006

32 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- In the references, the frequency for in situ treatment is based on source zone treatment.
- ARTT WG released a Fact Sheet on ISCO in 2010. A Fact Sheet on ISCR is under development at this time, but a final release date has not been set.

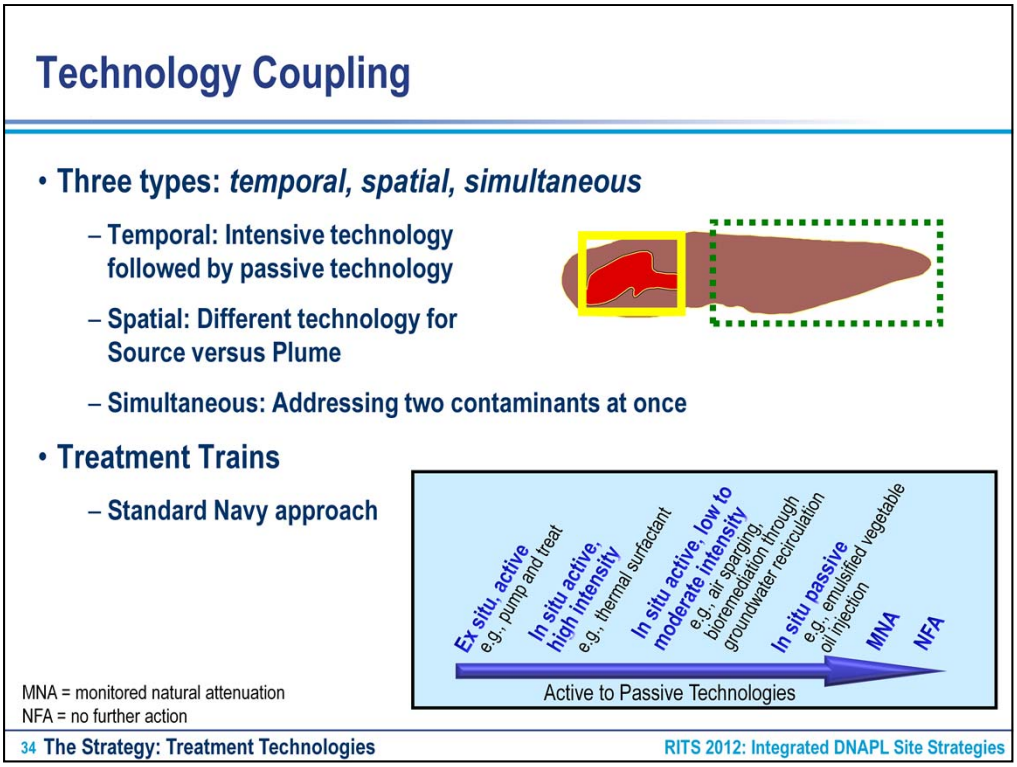
DNAPL Technology Evaluation Screening Tool (TEST)



- **Objectives**
  - **Aid in the selection of technologies based on desired performance metrics**
  - **Evaluate potential technology performance**
  - **Reduce the uncertainty of estimating and predicting remedial outcomes**
- **A database of information derived from case studies**
  - **Supported by numerical modeling to address data gaps**

33 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- Available through the ESTCP web site in a beta version.



- After reviewing some potential sources for technology performance, here is some summary info on how the technologies were applied:

  - Simultaneous: Addressing two contaminants at the same location with two technologies (guidance document uses P&T with air stripping for one contaminants and GAC for a different contaminant).

  - Treatment graph comes from Groundwater Plume Management Handbook (Navy 2008).

Technology Compatibility Matrix

- **Compatibility matrix of 9 technologies**
- **Examples:**
  - **"Generally Compatible"**
    - Thermal followed by *In Situ* Bio:
      - Potentially synergistic
      - Microbes population may be reduced
      - But then rapid recovery
  - **"Likely Incompatible"**
    - In Situ Reduction followed by *In Situ* Oxidation
      - Destruction of both reagents
  - **"Potentially Compatible but Not An Anticipated Couple"**
    - Bio followed by Surfactant Flushing
      - Would probably work, but unlikely to be coupled

Apply This Technology First or in Upgradient Area / Followed by This Technology or in Downgradient Area		Physical/Removal Technologies			Chemical/Biological Technologies				Containment Technologies	
		Surfactant/ Cosolvent Flushing	Thermal	Other Extractive Techno-logies	In Situ Chemical Oxidation	In Situ Chemical Reduction	Engineered Bioremed-iation	Monitored Natural Attenuation	Permeable Reactive Barriers	Other Containment Techno-logies
Physical/Removal Technologies	Surfactant/Cosolvent Flushing		Potentially compatible but not an anticipated couple				Generally compatible		Potentially compatible but not an anticipated couple	
	Thermal	Potentially compatible but not an anticipated couple		Potentially compatible but not an anticipated couple			Generally compatible		Potentially compatible but not an anticipated couple	
	Other Extractive Technologies	Potentially compatible but not an anticipated couple			Generally compatible				Potentially compatible but not an anticipated couple	
Chemical/Biological Technologies	In Situ Chemical Oxidation	Potentially compatible but not an anticipated couple				Potentially compatible but not an anticipated couple	Generally compatible but requires consideration of chemical reagents		Potentially compatible but not an anticipated couple	Generally compatible
	In Situ Chemical Reduction	Potentially compatible but not an anticipated couple			Likely incompatible		Potentially compatible			
	Engineered Bioremediation	Potentially compatible but not an anticipated couple			Compatibility varies	Potentially compatible but not an anticipated couple		Generally compatible	Potentially compatible but not an anticipated couple	
	Monitored Natural Attenuation	Potentially compatible but not an anticipated couple							Potentially compatible but not an anticipated couple	
Containment Technologies	Permeable Reactive Barriers	Potentially compatible but not an anticipated couple			Likely incompatible	Potentially compatible but not an anticipated couple				Potentially compatible but not an anticipated couple
	Other Containment Technologies	Potentially compatible but not an anticipated couple								

See full-page-sized matrix in book

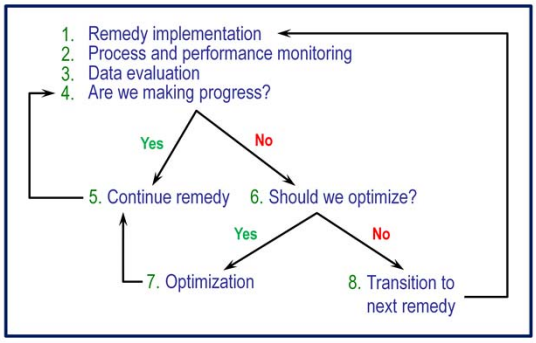
Source: ITRC

35 **The Strategy: Treatment Technologies** **RITS 2012: Integrated DNAPL Site Strategies**

- The IDSS team assessed each potential coupling for compatibility.
- The notes associated with the matrix provide details on the logic of how each couple was assessed for compatibility.
- Good reference for RPM.
- Under generally compatible note that "opposing" combinations (ISCO then bio) were thought to be permanent. Field results show otherwise (in fact the technologies work well with each other).

Transitioning Between Technologies

- ***Potential Transition Triggers:***
  - **Contaminant concentrations**
  - **Contaminant phase (particularly free phase)**
  - **Contaminant lineage, parent vs. daughters**
  - **Site conditions created during method execution**
  - **Cost per unit of contaminant destroyed**



Source: ITRC

Coordinate transition points with stakeholders early in the process

36 The Strategy: Treatment Technologies RITS 2012: Integrated DNAPL Site Strategies

- Another item to consider when coupling technologies-when to transition. This slide lists potential triggers.

- Contaminant concentrations as triggers include:

  - Contaminants of concern most likely to be contacted by the public or environment

  - Concentrations in a single <u>key</u> phase

- Don't wait until a P&T remedy is costing $500,000/year to remove 1 teaspoon of contaminant to <u>start</u> the transition discussion with stakeholders.

Overview of Presentation

- Why is a Strategy Needed?
- ► The Strategy
  - Develop Comprehensive CSM
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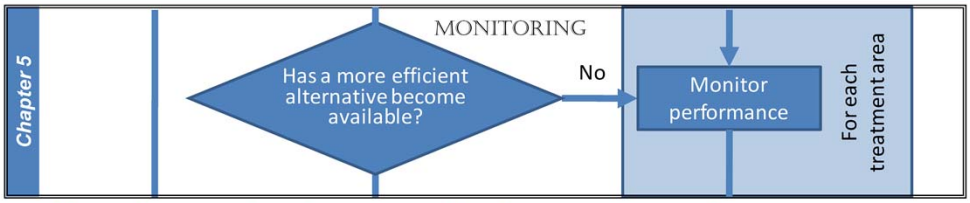
Chapter 5: Monitoring

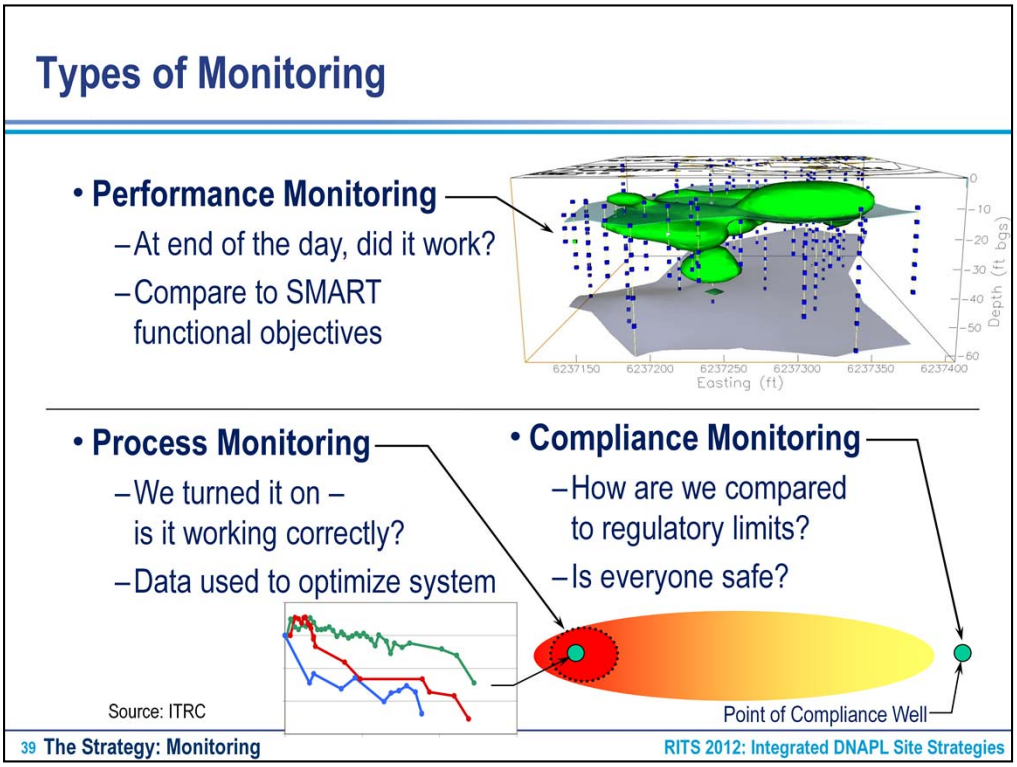


- How do you design a monitoring program that assesses your progress towards reaching your functional objectives?
- What data should you collect to evaluate remedy performance?

Source: ITRC

38 The Strategy: Monitoring RITS 2012: Integrated DNAPL Site Strategies

This chapter talks about the factors that go into a monitoring approach.



- Performance monitoring assesses the effectiveness of the remedy in meeting the SMART objectives. Is the remedy reducing contaminant concentrations?

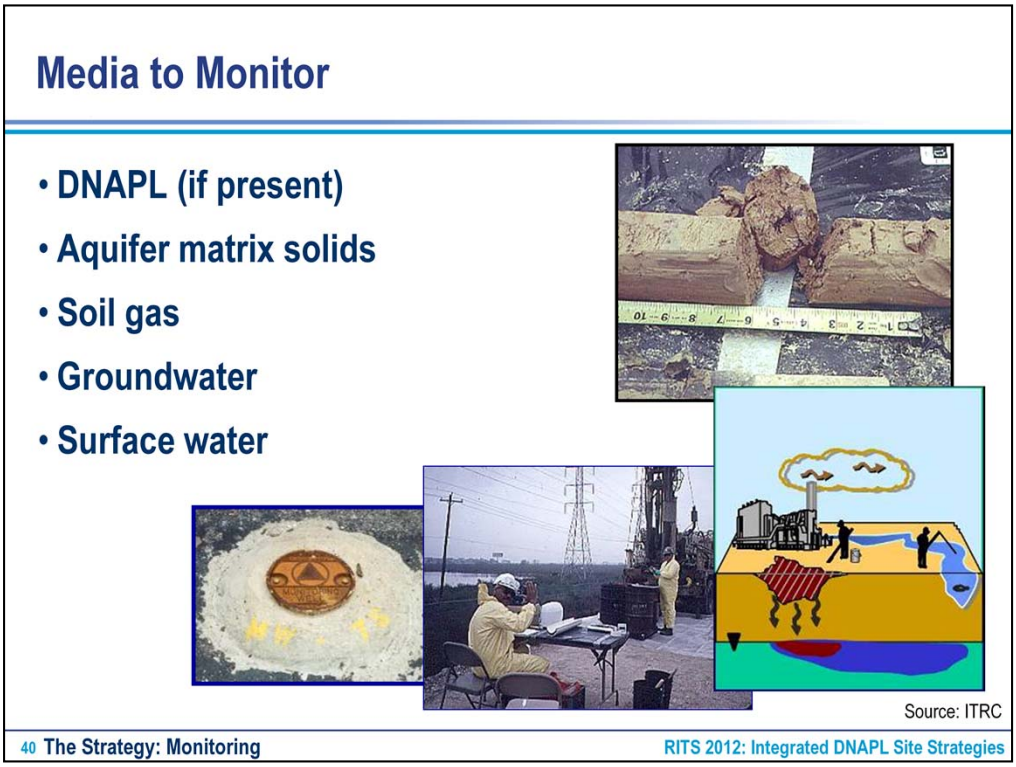
- Process monitoring evaluates whether the system is meeting its functional objectives (during active remediation).

    - For example during an ISCO injection, lots of system parameters are measured – pressures in the lines going into the aquifer with oxidant, flow rates, etc.

    - These types of system parameters need to be monitored to make sure that the remedial system is operating properly or to determine if system performance could be improved.

- Compliance monitoring assesses where the contaminant levels are in comparison to regulatory limits and helps document the extent of the impact and status of exposure (if that is occurring at the site).

    - These locations are often selected through dialogue with stakeholders.



- DNAPL is often not seen at sites, although groundwater concentrations can be quite high and indicative of DNAPL.

- Aquifer matrix solids can help in establishing baseline contamination levels. During and after remedial efforts, additional samples can be collected to monitor progress. It should be noted that sample representativeness is a limitation. Often small samples are collected and within these small samples there can be significant heterogeneity.

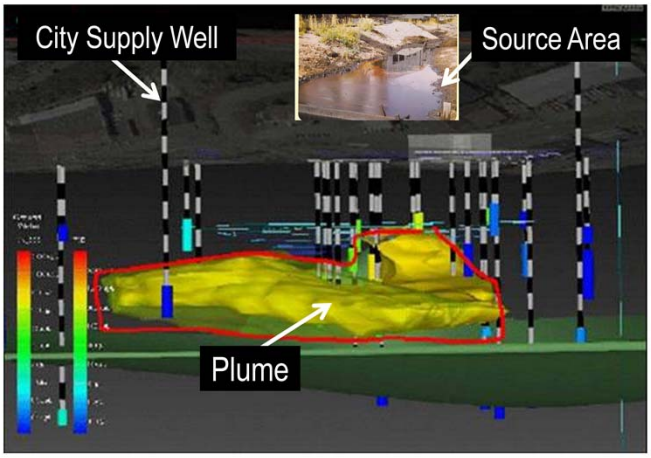
- Soil gas samples are collected if vapor intrusion is pathway of concern and could also be used as a qualitative screening tool to detect DNAPL source areas in the unsaturated zone.

- Groundwater is the ubiquitous media to monitor. Regulations are based on the media and mass flux/mass discharge are measured in this media.

- Surface water can be media to monitor depending on site conditions. For example, when contaminated ground water is discharging to a surface water body.

Data Evaluation

- **Key concept: *Maintaining* and *Improving* the Conceptual Site Model**
  - **Visualization tools can help**



Source: ITRC

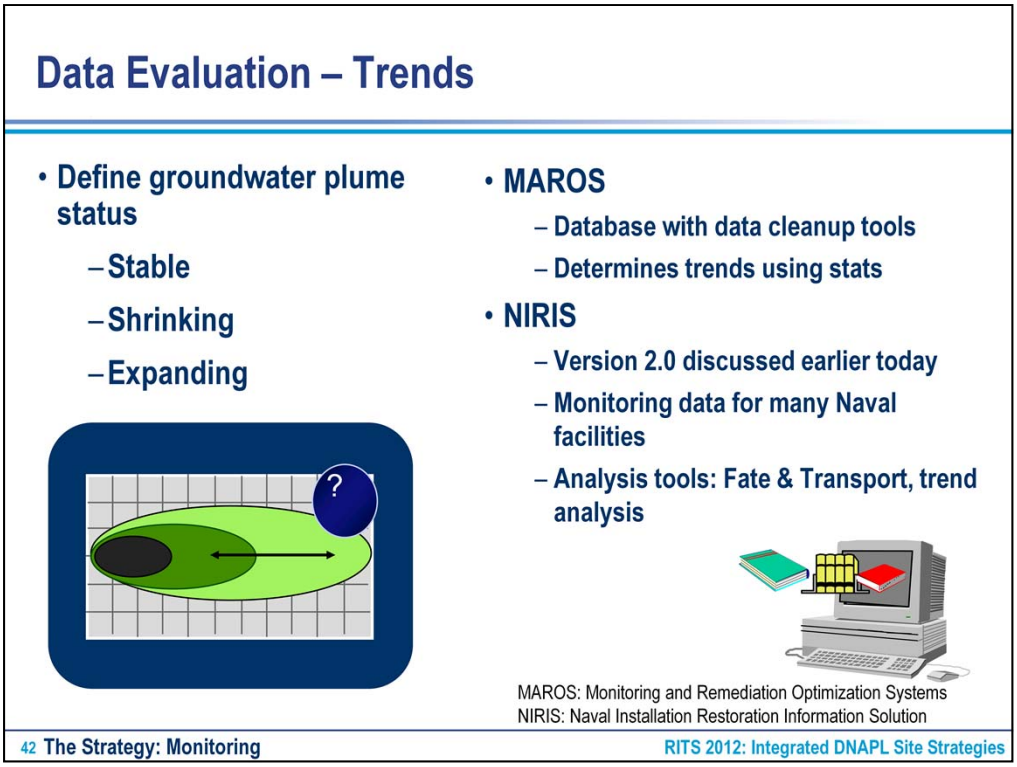
41 **The Strategy: Monitoring** RITS 2012: Integrated DNAPL Site Strategies

- After determining what data are relevant to your site, what options are available for data evaluation?

  - As noted in Chapter 2, the conceptual site model (CSM) must be maintained and viewed as a living document. As data are collected during remedy implementation, these data should be incorporated in the CSM. This will help improve understand of the site as well as evaluate remedy performance.

  - Visualization tools (as shown here) can help the project team as well as stakeholders better understand the site and its progress over time.

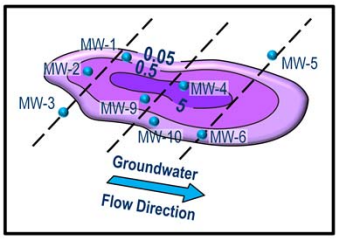
  - Additionally, statistics can help identify and determine trends (next slide).



- Functional objectives could be based in plume status:
  - Is the plume stable?
- Statistics programs are available to help evaluate the data:
  - MAROS is available, developed with EPA funds
  - NIRIS offers tools on the Citrix server side:
    - GMS, for example, not only has fate & transport modeling in the manner of MODFLOW, MODPATH, MTSD, SEAM3D, but also spatial analysis tools

Optimizing Monitoring

- **Monitoring network**
  - Any redundant wells or data gap area?
- **Frequency and duration**
  - Do I need to sample quarterly? Lots of research.
- **Contaminant and constituent**
  - Can 1 or 2 COCs (chemicals of concern) explain the big picture?
- **Key tools:**
  - *MAROS, GTS Algorithm, and Summit Monitoring Tools*



Source: ITRC

For more information, see the Long Term Monitoring Optimization Software RITS (Fall 2009) and DON Guidance for Planning and Optimizing Monitoring Strategies (2010)

43 The Strategy: Monitoring — RITS 2012: Integrated DNAPL Site Strategies

- Note ESTCP project & RITS (Fall 2009) in the key tool bullet.

- Over the timeframe of remedial action operation and into long term monitoring, the monitoring plan should be evaluated.

  - Is the monitoring network still applicable? Are some wells already clean? Do they still need to be monitored?

  - What about the frequency of monitoring? Maybe quarterly sampling isn't required once the plume is decreasing in size.

  - Have the contaminants shifted? Are all analytes required?

  - These are questions that should be asked when compiling monitoring reports and recommendations for changes in the monitoring strategy should be routine.

Overview of Presentation

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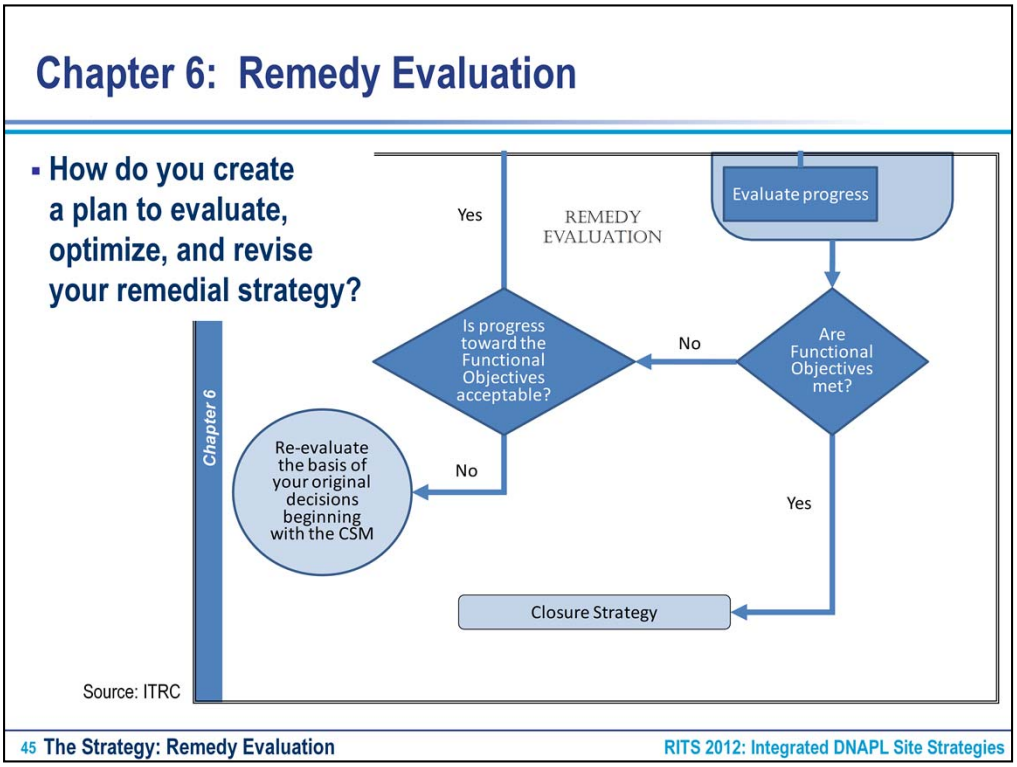
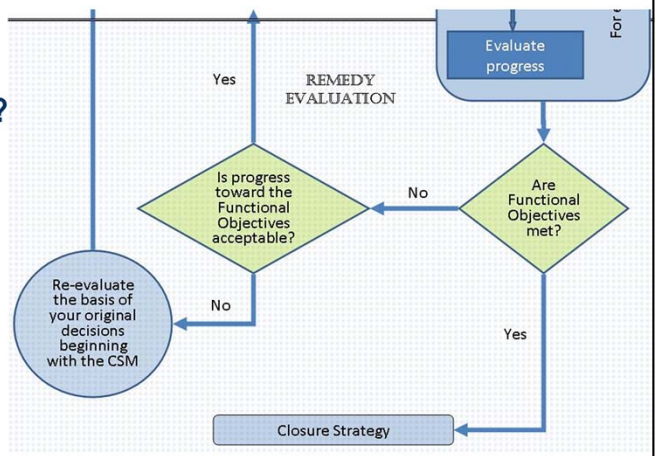
- Summary



Chapter 6 is where most sites are.

Key Questions to Consider

- **Are Functional Objectives being met – is progress acceptable?**
- **Can you be more efficient?**
- **How do you trouble-shoot if you are not?**



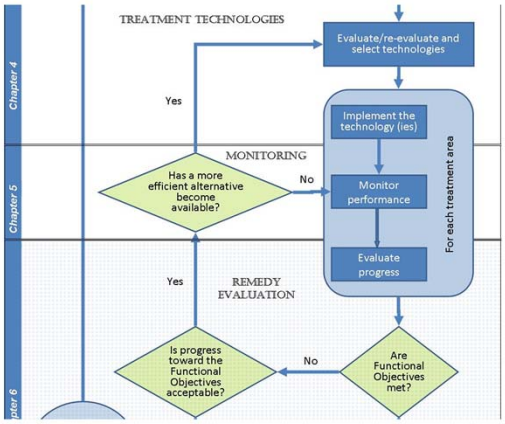
Source: ITRC

46 The Strategy: Remedy Evaluation RITS 2012: Integrated DNAPL Site Strategies

- Currently, re-evaluation of sites that are not meeting objectives often focuses on technology application without also re-evaluating whether the CSM or the absolute and functional objectives are impeding measureable progress.
- Also, when are key times to review progress at a site?
- Some sites rely on Five-Year Reviews for LTM/MNA, but if the site has active systems, the project team should build review into functional objectives on a more frequent basis to assure adequate progress in a reasonable timeframe.

Is progress towards the Functional Objective acceptable?

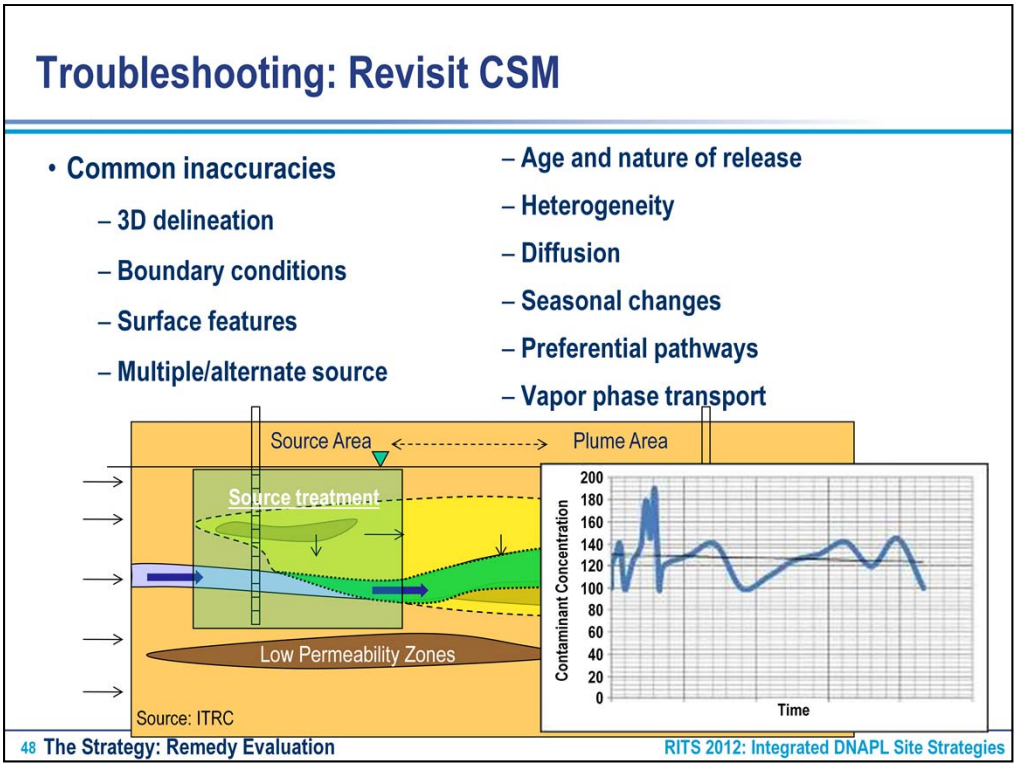
- Why optimize?
  - Enhanced operation of remedy
  - Cost reduction
  - Change in resource use
- Advances in long-term site management due to
  - Dynamic nature of environmental law
  - Improved understanding of impacts of remedial actions
- Technology optimization
  - New/better practices
  - Technology advancement
  - Transition technology



Source: ITRC

47 The Strategy: Remedy Evaluation RITS 2012: Integrated DNAPL Site Strategies

- If yes, then…
  - Note that Remedy Optimization is not just technology optimization. But rather, it's optimization of the entire integrated site strategy.
  - Remedy Optimization is important for determining whether best practices have been implemented at the site.



- As CSMs at chlorinated solvent site are complex, minor inaccuracies in one or more elements can be multiplicative and compound the error in understanding the site.

  - Typical components of the CSM related to the source zone and plume structure are listed here.

  - You can see how these items are interdependent.

  - Remember the CSM is a living document.

Troubleshooting: Revisit Objectives

- Reasons objectives don't work
  - Metrics not aligned with objectives
  - Unrealistic expectations of technology performance
  - Data does not support objectives
  - Regulatory goals not achievable in predicted time
  - Lack of interim objectives

Need to be SMART

49 The Strategy: Remedy Evaluation RITS 2012: Integrated DNAPL Site Strategies

After addressing concerns in Section 2, let's move to Section 3 and revisit the objectives.

- Metrics – these may not mesh with functional objectives or could be miss-applied metrics.

- Unrealistic expectation of technology performance – remedies for DNAPL were often developed assuming that ONE technology would achieve closure requirements, but these expectations are often not realistic.

- Data do no support objectives – meaning the data do not help evaluate the objectives or determine if the remedy is approaching the functional objectives.

- Regulatory goals and lack of interim objectives go together in that if goals go beyond a generation (as noted previously in this training), then interim goals should be developed to help track process.

- Remember that SMART means specific, measureable, attainable, relevant, and time-bound.

Troubleshooting: Revisit Technology

- Technology Performance
  - Is evaluation valid after revisiting the CSM and Objectives?
  - Does the current technology meet expectations?
- Technology Decisions
  - Continue with existing technology
  - Optimize existing technology
  - Cease operation
  - Transition to another approach
- Revisit Monitoring Approach for appropriateness

50 The Strategy: Remedy Evaluation RITS 2012: Integrated DNAPL Site Strategies

- The information from the three categories on the previous slide come together to make decision regarding whether to:
  - Continue with existing technology
  - Optimize existing technology
  - Cease operation
  - Transition to another approach

Overview of Presentation

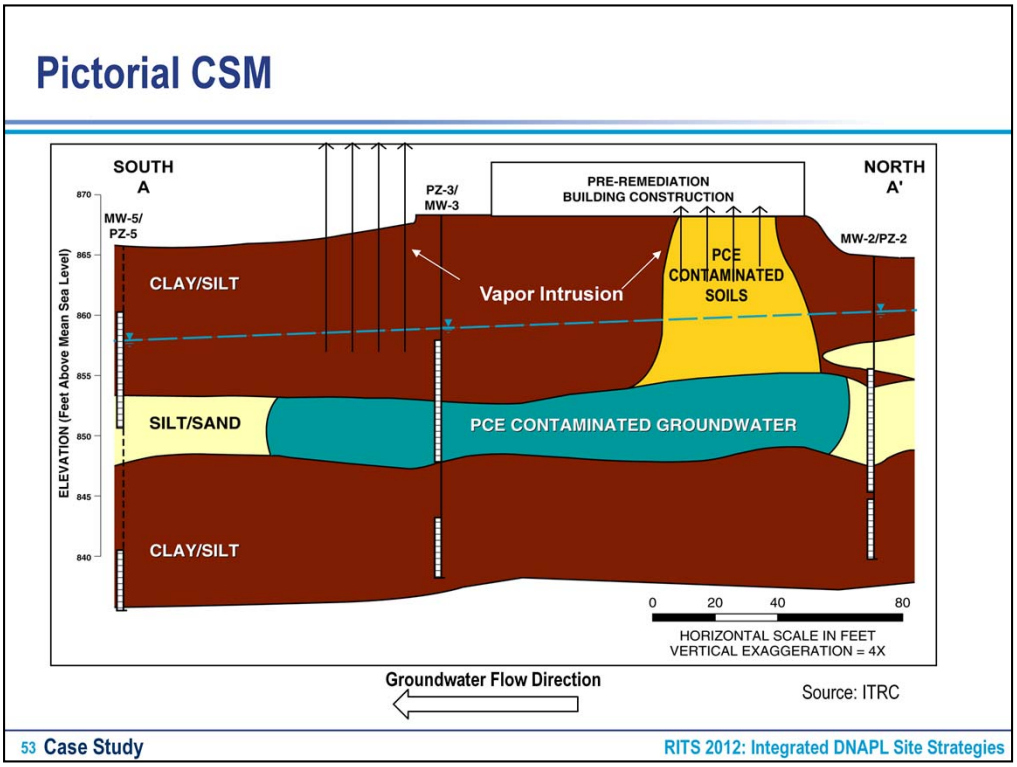
- Why is a Strategy Needed?
- The Strategy
- ► Case Study
- Summary

Site Scenario

- Prior excavation removed approximately 130 tons of soil containing DNAPL
- Residual PCE contamination
  - 4,000 µg/kg in soil
  - 180 µg/L in groundwater
- PCE has migrated ~200 feet downgradient
- No commercial buildings or residential homes downgradient and no potential adverse impacts to nearby drinking water wells

52 Case Study RITS 2012: Integrated DNAPL Site Strategies

- Example provided by ITRC team member.
- Site is located in Wisconsin.



- Note the location of the pre-remediation building construction.
    - This location is directly above the residual contamination.

Site Risk and Goal

- Risk Assessment
  - Indoor air vapor intrusion (VI) risk
- Negotiated Cleanup Levels to mitigate VI risk
  - 40 µg/kg PCE in soil
  - 8 µg/L PCE in groundwater
- Overall Goal:
  - Redevelop the property for shopping mall

54 Case Study RITS 2012: Integrated DNAPL Site Strategies

- Main concern is vapor intrusion at this site. 2-pronged approach to achieve 2 orders of magnitude reduction in soil and groundwater concentrations.
- Clean up levels were negotiated with the agencies.
- 2-pronged approach to achieve 2 orders of magnitude reduction in soil and groundwater concentrations to reduce VI risk.

Consider Objectives

- Stakeholders include:
  - Local community members
  - Redeveloper
  - Regulators
- Absolute objectives
  - Protect human health and the environment
  - Address adverse community impacts
  - Apply resources effectively and efficiently
  - Redevelop the property for shopping mall

Remember SMART Functional Objectives

- **S**pecific
  - 40 µg/kg
- **M**easureable
  - Confirmation samples
- **A**chievable
  - Excavation, SVE, or ISCO
- **R**elevant
  - Intended use of property
- **T**ime-bound
  - 6 months

- SMART Functional Objective

  Reduce concentrations of volatile organics in the vadose zone to less than 40 µg/kg within 6 months that will allow a "No Further Action" for unrestricted use, with no engineering or administrative controls required

SVE: Soil Vapor Extraction
ISCO: In Situ Chemical Oxidation

56 Case Study RITS 2012: Integrated DNAPL Site Strategies

- To address the VI risk, a functional objective was developed.
- SMART criteria from site specific information are listed above.

Technology Selection

- **Source Zone**
  - Excavation selected
  - Dewatered to 13 feet below ground surface (bgs)

Before Excavation

ZONE	SOURCE		PLUME	
	Low Perm	High Perm	High Perm	Low Perm
Vapor	2	3	Not Applicable	
DNAPL				
Aqueous	1	2		
Sorbed	3	3		

3 depicts >1000 µg/Kg	2 depicts >100 µg/Kg	1 depicts >10 µg/Kg	0 depicts >1 µg/Kg

57 Case Study RITS 2012: Integrated DNAPL Site Strategies

The figure maps the contamination level before excavation.

Technology Selection (cont.)

- **Source Zone**
  - Excavation removed residual source
  - Met functional objective in vadose zone for VI

After Excavation

ZONE	SOURCE		PLUME	
	Low Perm	High Perm	High Perm	Low Perm
Vapor	0	0	Not Applicable	
DNAPL				
Aqueous	0	0		
Sorbed	0	0		

3 depicts >1000 µg/Kg	2 depicts >100 µg/Kg	1 depicts >10 µg/Kg	0 depicts >1 µg/Kg

58 Case Study RITS 2012: Integrated DNAPL Site Strategies

- This figure maps the expected outcome of the excavation.

Technology Selection (cont.)

- **Plume**
  - Potassium permanganate (ISCO)
  - Focused treatment of high permeability plume

Before ISCO

ZONE	SOURCE		PLUME	
	Low Perm	High Perm	High Perm	Low Perm
Vapor	Not applicable		1	1
DNAPL				
Aqueous			2	1
Sorbed			2	1

3 depicts >1000 µg/L	2 depicts >100 µg/L	1 depicts >10 µg/L	0 depicts >1 µg/L

59 Case Study RITS 2012: Integrated DNAPL Site Strategies

- This figure illustrates the groundwater contamination in the different phases.

Technology Selection (cont.)

- **Plume**
  - ISCO reduced aqueous concentrations
  - Removed vapor intrusion risk due to plume

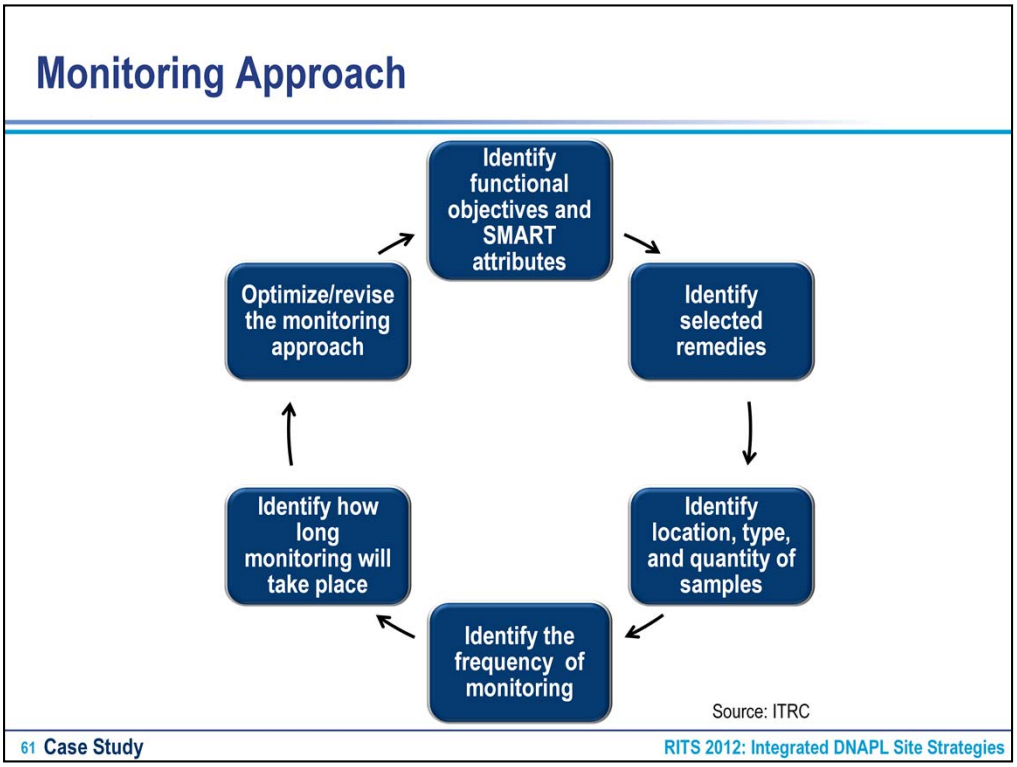
After ISCO

ZONE	SOURCE		PLUME	
	Low Perm	High Perm	High Perm	Low Perm
Vapor	Not applicable		0	0
DNAPL				
Aqueous			0	0
Sorbed			0	1

3 depicts >1000 µg/L	2 depicts >100 µg/L	1 depicts >10 µg/L	0 depicts >1 µg/L

60 Case Study RITS 2012: Integrated DNAPL Site Strategies

- This figure describes the expected outcome for ISCO treatment to the plume.
  - Note, contamination remains sorbed in the low-permeability zone.
  - It is hoped that the remaining contamination will not back diffuse at levels greater than the negotiated groundwater concentration level



This figure shows how the SMART attributes can help in developing a monitoring framework.

Monitoring Approach (cont.)

Functional Objective	Media	Method	Location	Period	Metric
VI (soils)	Soil	Grab samples	Under proposed construction site	Post excavation	40 µg/kg PCE
VI (groundwater)	Groundwater	Monitoring well	Under proposed construction site	Post ISCO 18 months	8 µg/L PCE

SMART functional objectives help define monitoring approach

For the example, the SMART attributes were used in defining the monitoring approach.

Overview of Presentation

- Why is a Strategy Needed?
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Take-Home Points

- Update the CSM!
  - It's a living document
- Develop SMART functional objectives that direct progress towards absolute objectives
  - Recognize that these sites will not achieve absolute objectives quickly and plan accordingly
- Select technology(ies) based on SMART objectives and realistic performance expectations
  - Embrace technology transitions

Take-Home Points (cont.)

- Develop a monitoring approach to evaluate whether the remedy is achieving the functional objectives
  - Remember the difference between process, performance, and compliance monitoring
- Routinely re-evaluate the remedy
  - Update CSM
  - Optimize, optimize, optimize!

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