1

Starting Soon: LNAPLs Training – Part 3 of 3

Poll Question

- Light Non-Aqueous Phase Liquid (LNAPL) Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (LNAPL-3, 2018) - https://lnapl-3.itrcweb.org/
- Download PowerPoint file
  - Clu-in training page at https://clu-in.org/conf/itrc/LNAPL-3/
  - Under "Download Training Materials"
- Download information for reference during class
  - Figure 1.1 (from the LNAPL-3 guidance document)
- Using Adobe Connect
  - Related Links (on right)
    - Select name of link
    - Click "Browse To"
  - Full Screen button near top of page
- Follow ITRC

How many different LNAPL remedial technologies have you APPLIED/USED at your sites?

A. 1-4

B. 5-8

C. 9-12

D. 13-16

E. 17 or more

2

Welcome – Thanks for Joining this ITRC Training Class

Based on ITRC Guidance Document:
Light Non-Aqueous Phase Liquid (LNAPL) Site Management: LCSM Evolution, Decision Process, and Remedial Technologies (LNAPL-3, 2018)

3-Part Training Series: Connecting the Science to Managing Sites

Part 1: Understanding LNAPL Behavior in the Subsurface

Part 2: LNAPL Conceptual Site Models and the LNAPL Decision Process

Part 3: Using LNAPL Science, the LCSM, and LNAPL Goals to Select an LNAPL Remedial Technology

Sponsored by: Interstate Technology and Regulatory Council (www.itrcweb.org)
Hosted by: USEPA Clean Up Information Network (www.cluin.org)

The newly updated LNAPLs (Light Non-Aqueous Phase Liquids) training courses help users set appropriate LNAPL remedial goals in the context of a site-specific LNAPL conceptual site model, provide tools to screen LNAPL remedial technologies to identify an optimal LNAPL remedial technology to achieve the goals, and provide example performance metrics that would be set to gauge remedial effectiveness and demonstrate achievement of the goals.

- A sound LNAPL understanding is necessary to effectively characterize and assess LNAPL conditions and potential risks, as well as to evaluate potential remedial technologies or alternatives. The ITRC LNAPLs Team's updated training courses provide:
- a technical understanding of LNAPL key concepts and behavior in the subsurface
- LNAPL conceptual site model (LCSM) development
- framework for making LNAPL remediation and management decisions
- informed remedial technology selection and appropriate technology application

LNAPL Training Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - Connecting the Science to Managing Sites

Part 1 explains how LNAPLs behave in the subsurface and examines what controls their behavior. Part 1 also explains what LNAPL data can tell you about the LNAPL and site conditions. Relevant and practical examples are used to illustrate key concepts.

LNAPL Training Part 2: LNAPL Conceptual Site Models and Remedial Decision Framework - Do you know where the LNAPL is and how to address LNAPL concerns?

Part 2 addresses LNAPL conceptual site model (LCSM) development as well as the overall framework for making LNAPL remediation and management decisions. Part 2:

- discusses key LNAPL and site data
- when and why those data may be important, and
- how to effectively organize the data into an LCSM.

Part 2 also discusses how to resolve LNAPL concerns by selecting appropriate goals and objectives, choosing applicable technologies, and assigning remedial performance metrics and endpoints. Part 2 concludes with a special focus on LNAPL Transmissivity and how it may be used to improve LNAPL decision making.

LNAPL Training Part 3: Using LNAPL Science, the LCSM, and LNAPL Goals to Select an LNAPL Remedial Technology

Part 3 of the training fosters informed remedial technology selection and appropriate technology application. Part 3:

- discusses remedial technology groups,
- introduces specific remedial technologies,
- provides a framework for technology selection, and
- introduces a series of tools to screen the several remedial technologies addressed in the updated ITRC document.

A case study demonstrates the use of these tools for remedial technology selection, implementation, and demonstration of successful remediation.

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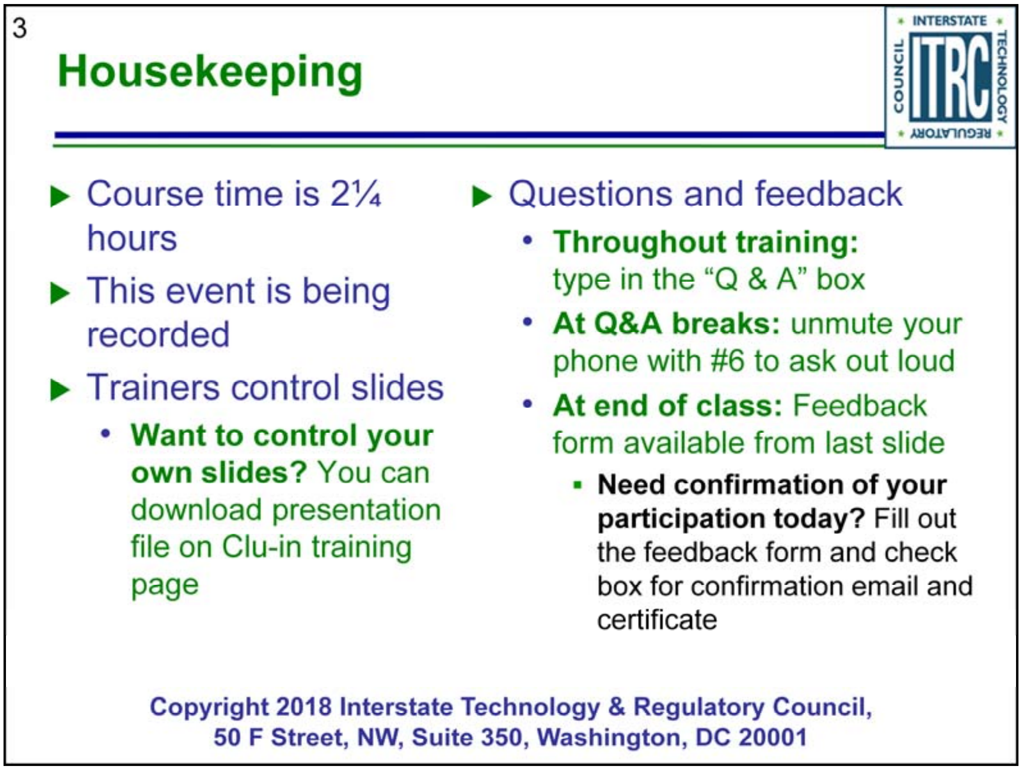
ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419



Notes:

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.

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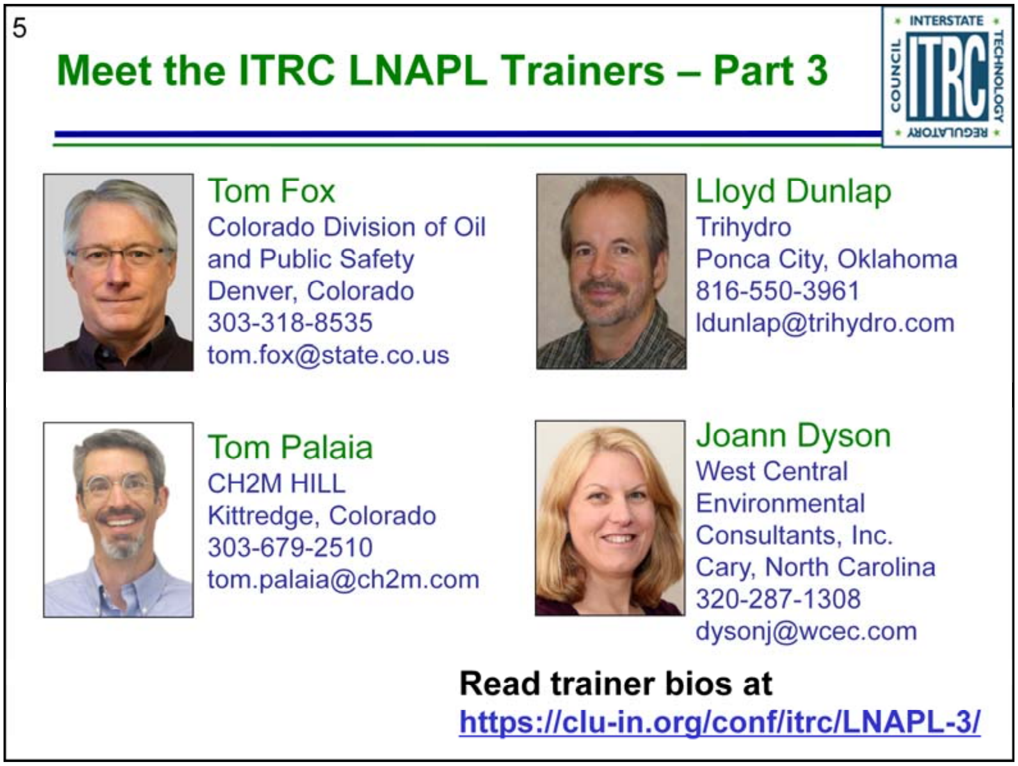

Tom Fox is an Environmental Protection Specialist in the Division of Oil and Public Safety (OPS) within the Colorado Department of Labor and Employment in Denver, Colorado. Tom has worked with the OPS since 2007. General duties include reviewing site characterization reports and corrective action plans; and providing guidance to optimize technical and economic feasibility of corrective actions, implementation/operation of systems, and reimbursement via the state fund. In addition, Tom has been involved in special projects such as developing electronic reporting formats, assessing the success of carbon injection for petroleum cleanups, and modifying Colorado's policy on LNAPL recovery. Prior to joining OPS, Tom was a petroleum geologist with ARCO from 1982-1986 doing exploration in the western US, and an environmental consultant on petroleum projects for several companies during 1986-2007. Tom has authored several articles, papers and presentations on assessment and corrective action techniques. Tom earned a bachelor's degree in earth science (geology) from Millersville State College (Pennsylvania) in 1980 and a master's degree in geology from Michigan State University in 1982. He maintains a license as a Professional Geologist in Wyoming.

Tom Palaia is a Principal Technologist at Jacobs Engineering in Denver, Colorado. Since 1992, Tom has worked at Jacobs/CH2M specializing in characterization and remediation of petroleum non-aqueous phase liquids (NAPL). As the Petroleum NAPL Community of Practice leader for Jacobs, Tom's central role for the firm is focused on quality control and ensuring that state-of-the-practice remediation approaches are implemented on projects world-wide. Additionally, he is responsible for participating in technical workgroups, conducting seminars, and presenting new technology applications to site owners and regulatory agencies. Tom has dedicated a large part of his career to facilitating application of best practice and technology transfer, and training of many practitioners within CH2M/Jacobs. Tom is passionate about the future direction of advanced technology for remediation and is working hard to expedite the advance and practical use of new science. Tom is new to ITRC's training team, active in the ITRC LNAPL Update Team since 2016. Tom earned a bachelor's degree in civil engineering from the Lafayette College in Easton, Pennsylvania in 1990 and a master's in environmental engineering from the University of Massachusetts in Amherst, Massachusetts in 1992. Tom is a registered Professional Engineer in the State of Colorado and Province of Alberta, Canada.

Lloyd E. Dunlap is a Senior Geologist with Trihydro in Ponca City, Oklahoma. Lloyd has worked for Trihydro since 2015. Lloyd works on special projects in the hydrocarbon remediation area. He has experience in environmental, energy, and regulatory issues, plus RCRA Corrective Action and Strategic Planning for complex sites. Lloyd worked in multiple environmental positions at BP from 1982 until 2012. He managed projects under the jurisdiction of Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the European Union, administrative orders on consent, and state programs in nearly every state. He has authored numerous publications and often speaks at environmental conferences about regulatory issues and trends. Since 2015, Lloyd has been a member of the ITRC Light Non-aqueous Phase Liquids (LNAPL) and serves as an ITRC trainer. Lloyd earned a bachelor's degree in Geology from the University of Kansas in Lawrence, Kansas, in 1975 and a Master of Science in Geology/Hydrogeology from Kansas State University in Manhattan, Kansas, in 1977. Lloyd is a Professional Geologist in the State of Florida.

Joann Dyson, Ph.D., is a Senior Project Manager with West Central Environmental Consultants (WCEC) based in Morris, Minnesota. She is located in Cary, North Carolina. Joann has worked with WCEC since 1999 and specializes in LNAPL-contaminated site investigation and remediation. She has also been involved with special projects such as international LIF investigations; state terrorism preparedness - determining environmental and logistical issues associated with potential WMD event debris for Minnesota's largest cities; providing emergency response ICS training for cities, counties, and government agencies such as the Air National Guard and the Minnesota Pollution Control Agency (MPCA); and assisting the MPCA with Ebola response preparation. Joann has presented at a variety of environmental and physics conferences. Joann has been active in the ITRC since 2016 as a member of the LNAPL Update team and the Implementing Advanced Site Characterization Tools team. She received the 2017 Industry Affiliates Program Award for contributions to the LNAPL Update team. Prior to environmental consulting, Joann was an Assistant Professor of Physics at Beloit College (1996-1998) and Gettysburg College (1994-1996). Joann earned a Bachelor of Science degree in physics from Wake Forest University in Winston-Salem, North Carolina in 1988 and a Ph.D. in physics from the University of Georgia in Athens, Georgia in 1994.

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Your Online LNAPL Resource
https://lnapl-3.itrcweb.org/

- Expansion of LNAPL Key Concepts
- Development of a LNAPL Conceptual Site Model (LCSM) Section
- Emphasis on identifying SMART goals
- Expansion of Transmissivity (Tn) and Natural Source Zone Depletion (NSZD) via Appendices

Welcome to Part three of our ITRC LNAPL training series. We assume everyone attended Part 1 and 2 and we will quickly move into our Part 3 content.

As a reminder, the ITRC LNAPL-3 document in on the web-site (link provided on the slide). The updated included the expansion of key concepts, a completely new LCSM section, a focus on SMART goals, and expanded content on Tn and NSZD. We encourage you to use the document.

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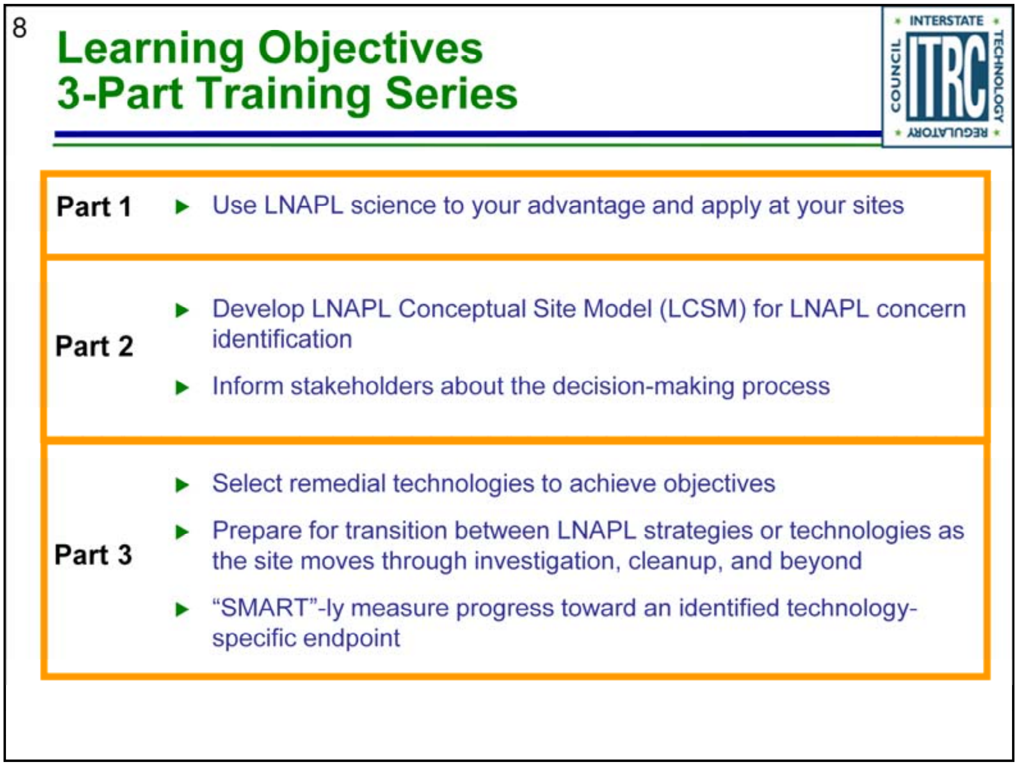
LNAPL Part 1 and 2 Summary

LNAPL Science: Key to Improving Decision-making

- Use LNAPL science and its application to make good decisions at your site
- Develop LCSM for LNAPL concern identification and establish appropriate LNAPL remedial goals and objectives

It is important to use your LCSM to help select remedial technology to achieve goals

The main take away from Parts 1 and 2 is that you need to Use LNAPL science and its application to make good decisions at your site. And use that information to Develop a LCSM for LNAPL concern identification and establish appropriate LNAPL remedial goals and objectives



As noted in the previous parts of the training, our 3-part training series provides you with the knowledge and skills so you can apply the newest ITRC LNAPL guidance at your sites (and for the case of you regulators, potentially help you integrate LNAPL science into your own state guidance).

Our learning objectives for this 3-part series.

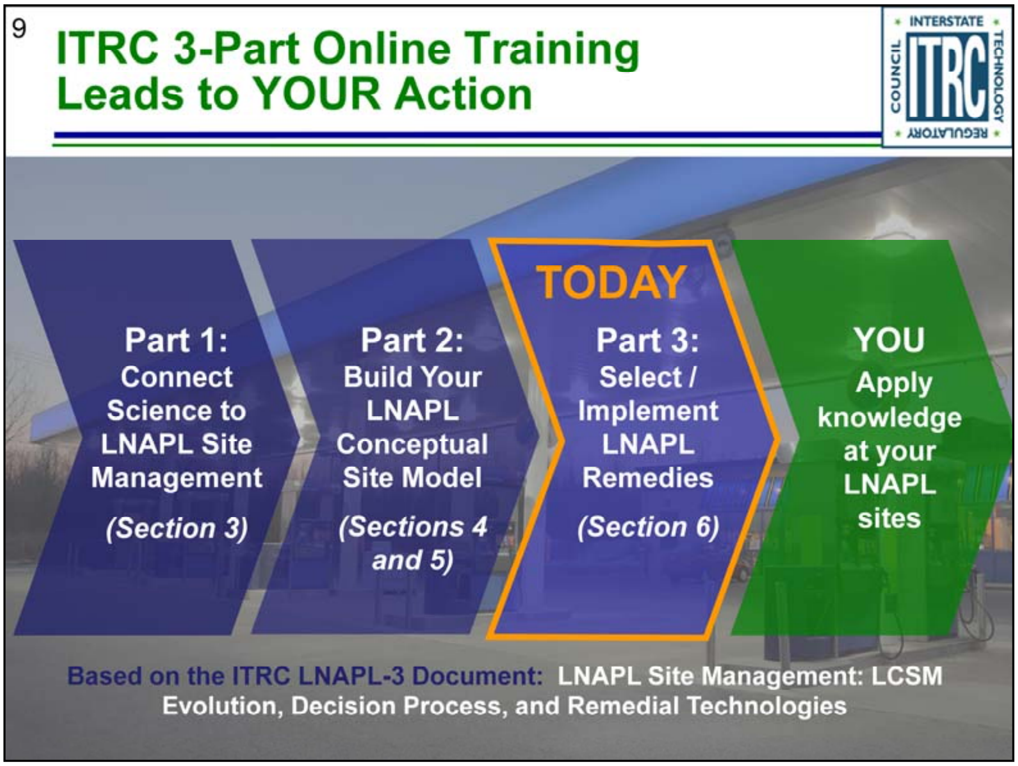
Part 1 we covered key concepts to help you understand LNAPL science and how it can be applied to your advantage at your sites.

Last week in Part 2 we covered

1. Develop a comprehensive LCSM for the purpose of identifying specific LNAPL concerns.
2. From that, establish appropriate LNAPL remedial goals and specific, measurable, attainable, relevant, and time-bound (or SMART) objectives for these concerns.
3. Inform stakeholders of the capability and limitations of various LNAPL remedial technologies.

Part 3 (today)

1. Select remedial technologies that will best achieve the overall remedial goals for a site.
2. Describe the process to transition between LNAPL strategies or technologies as the site moves through investigation, cleanup, and beyond.
3. Evaluate the implemented remedial technologies to measure progress toward an identified technology specific endpoint.



Our 3-part training series focuses on helping you:

- Connect Science to LNAPL Site Management
- Build your LNAPL Conceptual Site Model
- *CLICK* Select/Implement LNAPL Remedies

After this training the expectation is that you will have the skills and knowledge to use the ITRC science-based resources improve decision making at your LNAPL sites.

Also, the sections from the document that are covered under each part of the training is provided on the slide.

Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - Connecting the Science to Managing Sites

- Explains how LNAPL behaves in the subsurface
- Examines what controls their behavior
- Explains what LNAPL data can tell you about the LNAPL and site conditions
- Relevant and practical examples are used to illustrate key concepts

Part 1 explains how LNAPLs behave in the subsurface and examines what controls their behavior. Part 1 also explains what LNAPL data can tell you about the LNAPL and site conditions. Relevant and practical examples are used to illustrate key concepts.

Part 2: LNAPL Conceptual Site Models and Remedial Decision Framework - Do you know where the LNAPL is and how to address LNAPL concerns?

•Addresses LNAPL conceptual site model (LCSM) development and the overall framework for making LNAPL remediation and management decisions

•Discusses key LNAPL and site data

•When and why those data may be important

•How to effectively organize the data into an LCSM

•Discusses how to resolve LNAPL concerns by selecting appropriate goals and objectives, choosing applicable technologies, and assigning remedial performance metrics and endpoints

•Concludes with a special focus on LNAPL Transmissivity and how it may be used to improve LNAPL decision making

Part 2 addresses LNAPL conceptual site model (LCSM) development as well as the overall framework for making LNAPL remediation and management decisions. Part 2:

discusses key LNAPL and site data

when and why those data may be important, and

how to effectively organize the data into an LCSM.

Part 2 also discusses how to resolve LNAPL concerns by selecting appropriate goals and objectives, choosing applicable technologies, and assigning remedial performance metrics and endpoints. Part 2 concludes with a special focus on LNAPL Transmissivity and how it may be used to improve LNAPL decision making.

Part 3: Using LNAPL Science, the LCSM, and LNAPL Goals to Select an LNAPL Remedial Technology

•Fosters informed remedial technology selection and appropriate technology application. Part 3:

- Discusses remedial technology groups
- Introduces specific remedial technologies
- Provides a framework for technology selection
- Introduces a series of tools to screen the several remedial technologies addressed in the updated ITRC document

•A case study demonstrates the use of these tools for remedial technology selection, implementation, and demonstration of successful remediation

Part 3 of the training fosters informed remedial technology selection and appropriate technology application. Part 3:

- discusses remedial technology groups,
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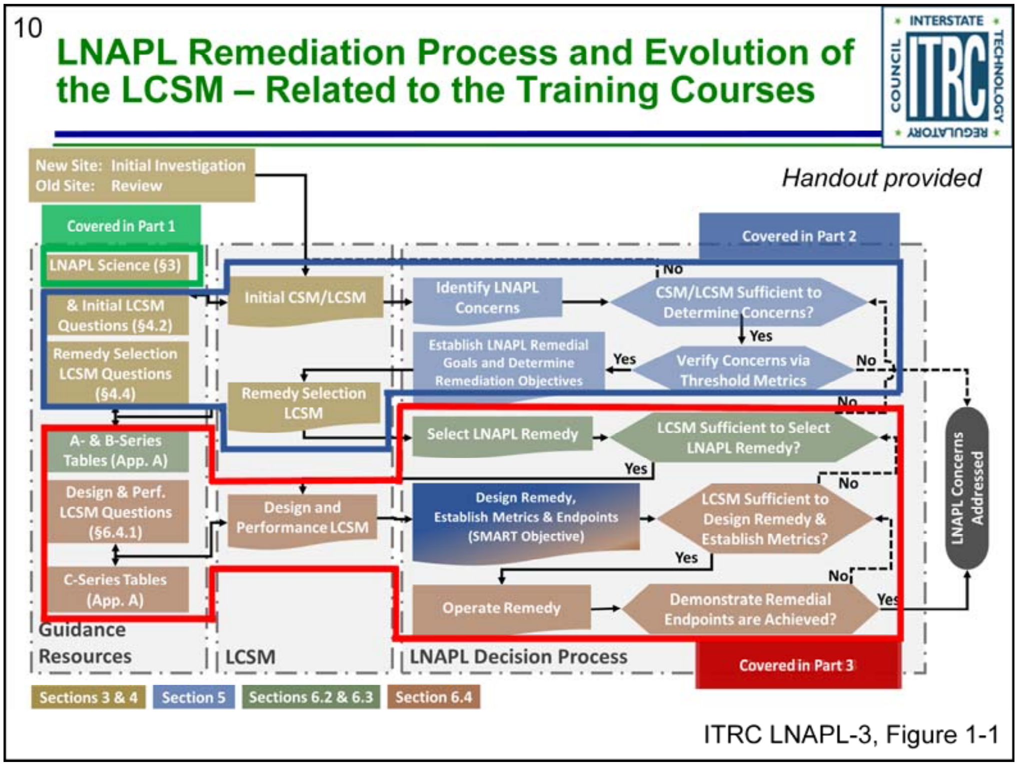
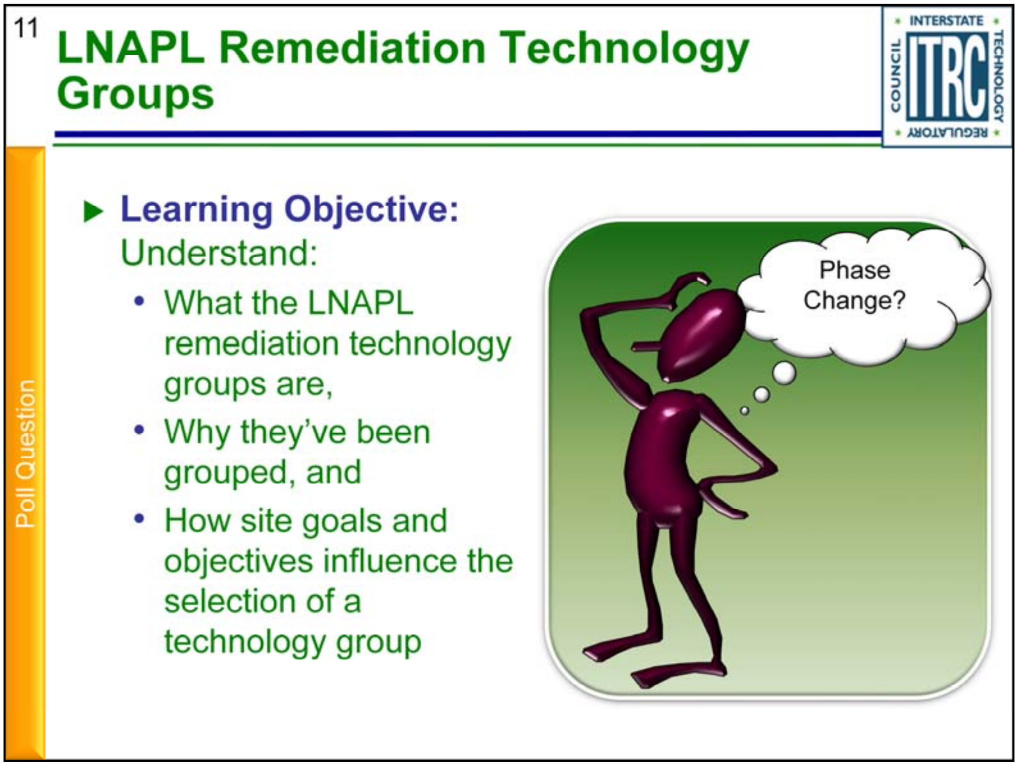


And, to link it back to the main framework flow chart from the document, here is Figure 1-1 and the associated content covered in each part of the training.



How many different LNAPL remedial technologies have you APPLIED/USED at your sites?

A. 1-4
B. 5-8
C. 9-12
D. 13-16
E. 17 or more

12

Many Technologies Available

(ITRC LNAPL-3 Guidance Table 6.1)

Technology Groups

21 LNAPL remedial technologies addressed:

- Excavation
- Skimming
- Vacuum Enhanced Skimming
- Total Liquid Extraction
- Multi-Phase Extraction
- Water/hot water flooding
- Surfactant-enhanced subsurface remediation
- Cosolvent flushing
- Steam Injection
- Thermal conduction heating
- Electrical resistance heating
- In-situ smoldering
- Air sparging/ soil vapor extraction
- Biosparging/bioventing
- In-situ chemical oxidation
- Enhanced anaerobic biodegradation
- Natural source zone depletion
- Activated carbon
- Phytotechnology
- Physical or hydraulic containment
- In-situ soil mixing (stabilization)

Key Point: Who ya gonna call?

-The LNAPL Technical and Regulatory Guidance includes 21 different remedial technologies.

-These vary from the relatively simple and straightforward such as excavation

-To more complex technologies such as electrical heating.

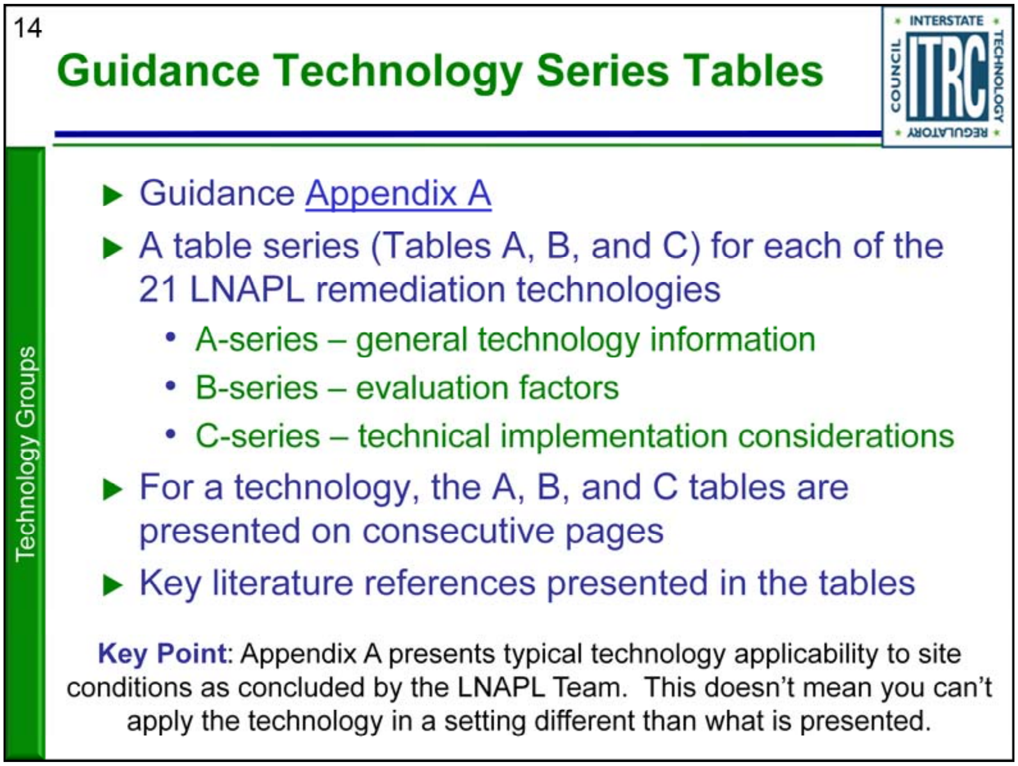
-So how do you know what technology is appropriate for a particular site and objective?

Not Included in Technology Tables

Technology Groups

- Manual Bailing
- Absorbent Socks
- Periodic or Short-term Vacuum Truck Events
- Passive Skimmers

Less intensive LNAPL recovery technologies such as the use of adsorbent socks, manual bailing, passive skimmers, or (periodic, short-term) vacuum trucks are not included in the technology tables. These methods generally are not considered to be very effective to recover a significant amount of LNAPL. However, depending on local regulations, aesthetic concerns or emergency response action (which are not covered in this document) they may very well end up being used at a site.

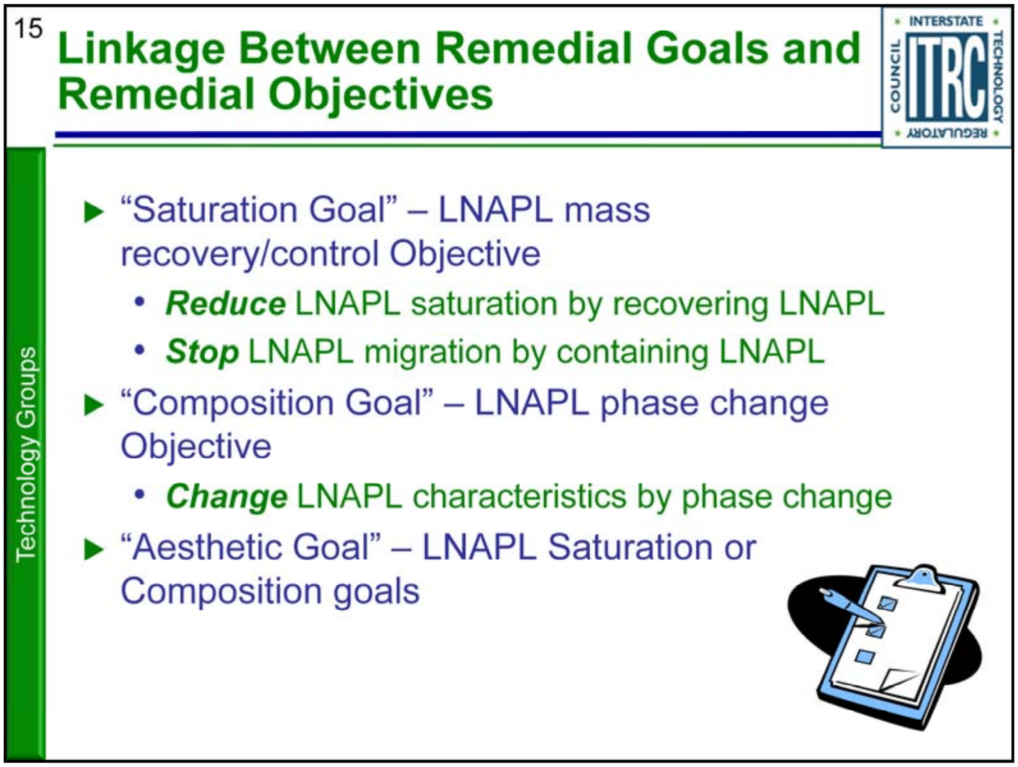


The A series table screens the technologies based on the geologic factors, the B series table will give specific impacts of nine factors for each technology, and the C series table is to determine minimum data requirements which soil permeability or determining LNAPL characteristics.

Technology descriptions in guidance are written for generalized conditions.

- After considering your experience in terms of what you've learned here use experience with local geology and technology applications in the same area to augment the technology information in the LNAPL document.

- Make sure you have confidence in the LCSM and it's consistent with what you have learned.



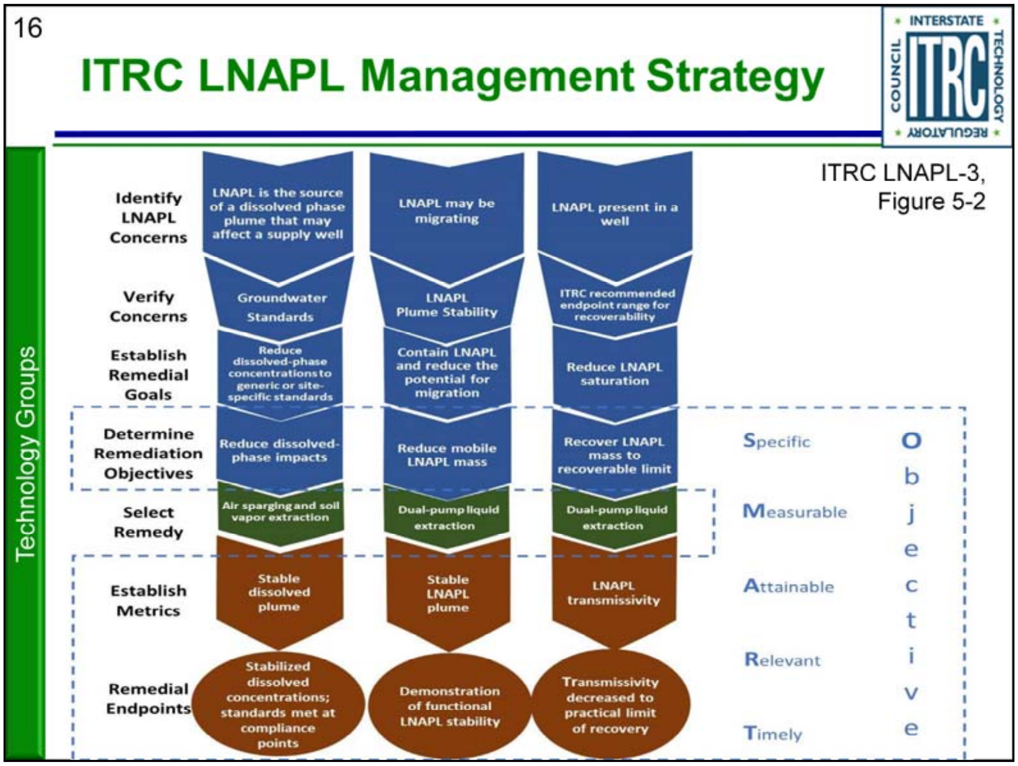
The linkages between different remediation Goals and primary remediation objectives is summarized.

The saturation goal would be achieved by recovering or controlling LNAPL.

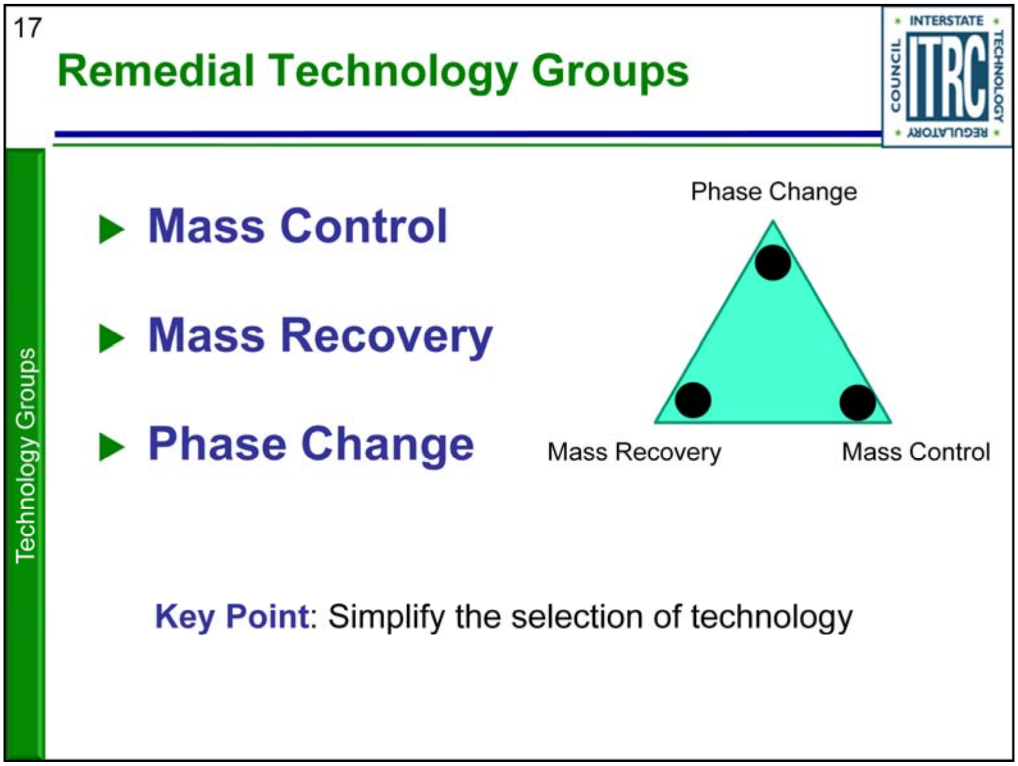
An example of recovery would be skimming which is a mass recovery technology. Containment which is a saturation based goal is achieved through LNAPL mass control technologies, a common example being a slurry wall.

A composition or concentration goal would be achieved primarily through phase change technology, an example being air sparging and soil vapor extraction.

Aesthetic goals can include both a saturation goal for LNAPL mass recovery/control or a composition goal and example being an odor based concern.



This was discussed in more detail in part 2 but I wanted to remind everyone that by following the LNAPL management process your objectives become SMART –Specific Measurable Attainable Relevant and Timely. As we continue to progress through this third training and end with a case study you will see how we continually circle back to define your objectives through the establishment of metrics and remedial endpoints. These SMART objectives are important especially in selecting a specific technology as your remedy.



This slide shows the first cut of how to think about technologies and what they do. In the LNAPL document, this is also referred to as the “primary mechanism” in section 5 of the document by which LNAPL remediation takes place.

In addition to the primary mechanism, most technologies also act in other ways. These “multiple actions” of a technology can be simply represented by the ternary diagram. The dot in the ternary diagram shows where the technology fits in the remedial tech groups.

Clicks notice the dot is in the mass control corner of the ternary diagram click.

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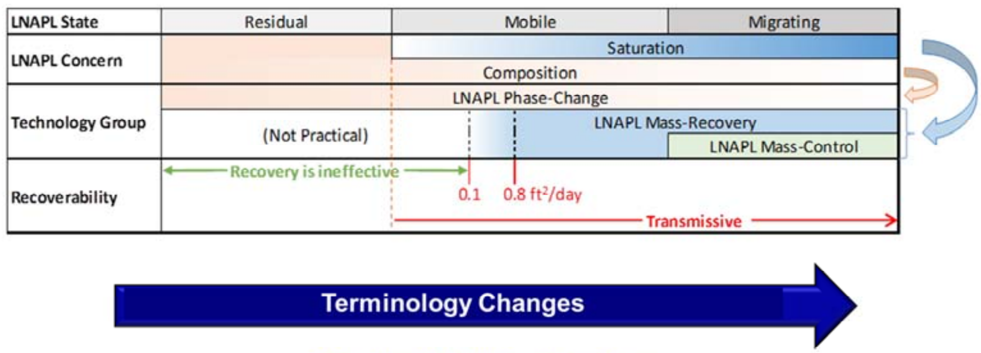
The Name Game & General Technology Group Applicability

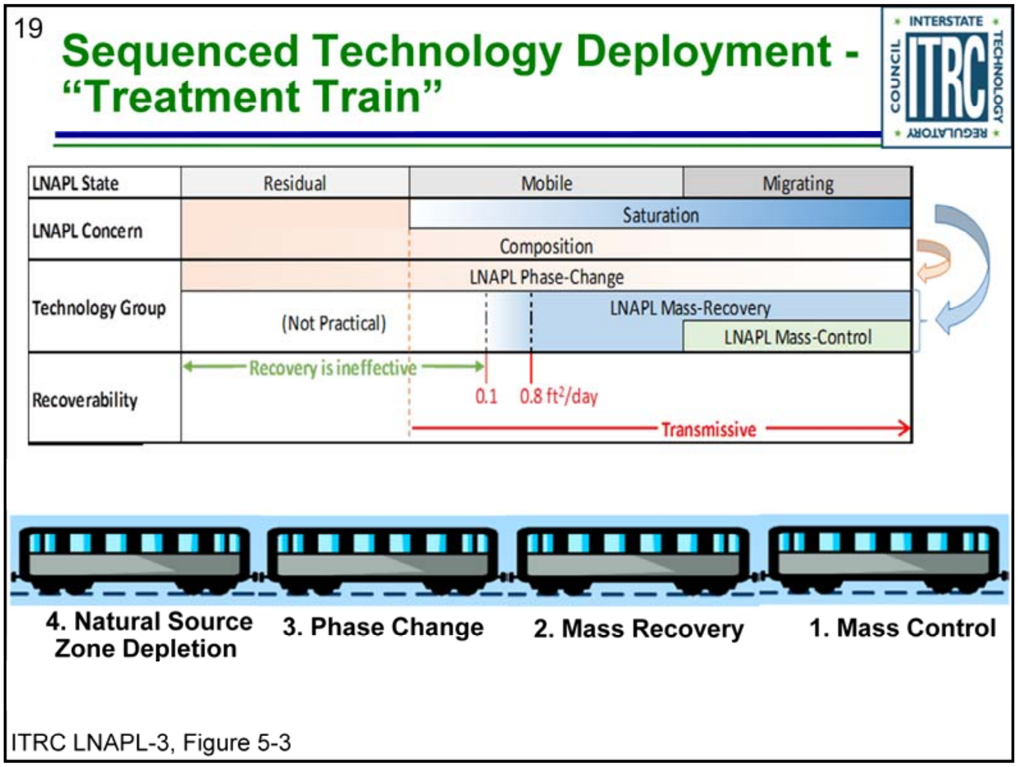


Residual, Mobile, Migrating

ITRC LNAPL-3, Figure 5-3

Mass Control and Mass Recovery is only used when LNAPL saturation is greater than residual:

- Mass control is used when there is an LNAPL migration risk – So in very high saturation conditions
- Mass recovery is used when LNAPL is mobile and practicably recoverable - > Sr
- When LNAPL is less than saturation, only phase change technologies will work. Phase change technologies can also be applied to mobile and even migrating LNAPL.
- Also the recoverability is represented here by the transmissivity number and as you can see mass recovery is ineffective below .1 ft2/day



When selecting technologies consider multiple treatment technologies or treatment trains. For example, you may begin with a slurry wall (click) to control the migration of the LNAPL and then move to dual pump liquid extraction (click) to recover mobile LNAPL. Air sparging and soil vapor extraction (click) may then be used to further remove LNAPL mass and potentially address vapor and groundwater risks, notice we are on the phase chance train car. The final treatment technology may be natural source zone depletion (click).

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Treatment Trains

Technology Groups

Good

- When planned with SMART objectives, metrics for transition, and endpoints
- Orderly implementation

Bad

- Unplanned, lack specific SMART objectives, metrics for transition, and endpoints
- “Throwing” more technologies at the problem

You want to have the right tool for the job. A Phillips head screw driver works fine but not for a flat head screw.

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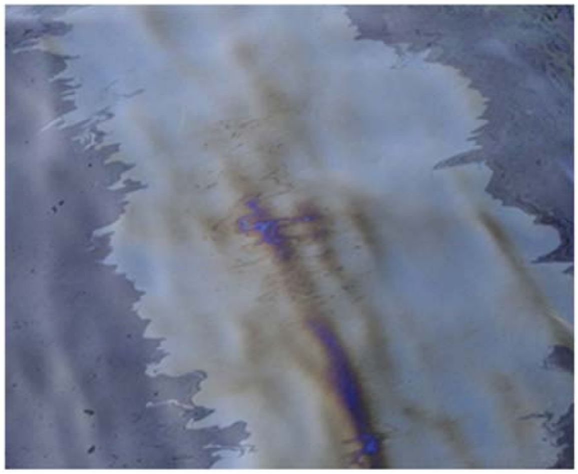
LNAPL Aesthetic (or combination)

Technology Groups



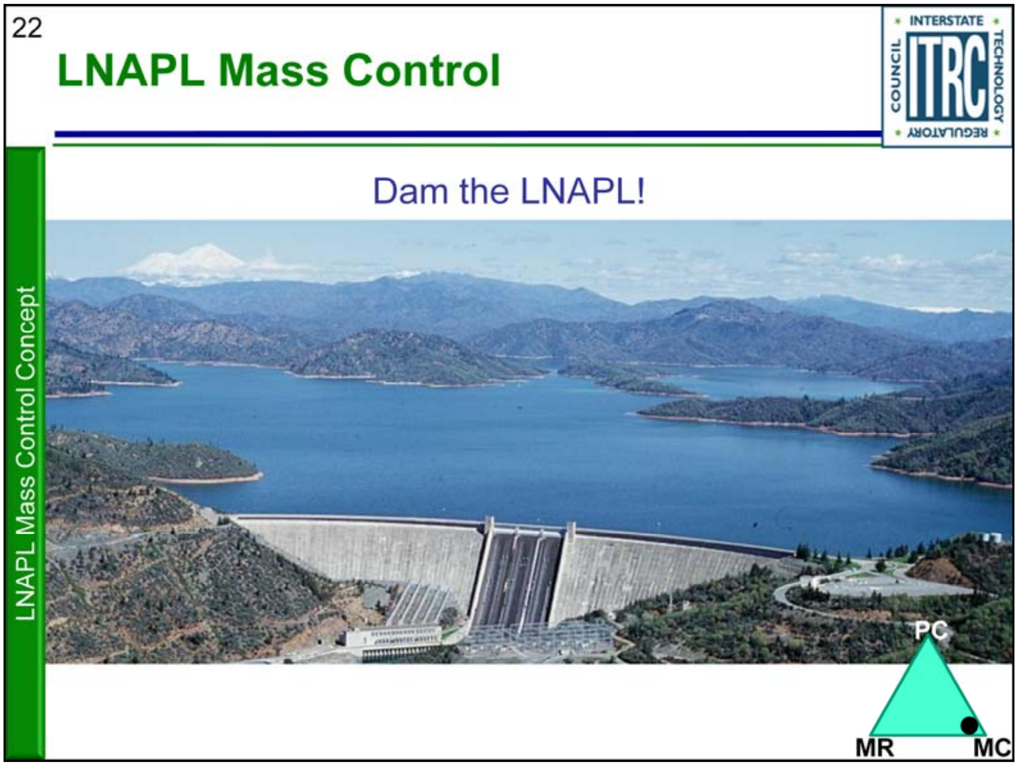
ITRC LNAPL-3, Figure S-1

Aesthetic concerns such as odors, stains or sheens maybe an LNAPL concern that has to be taken into account. Ask yourself a few questions.

Are non-risk odors or surficial stains from the LNAPL a potential nuisance?

Is stakeholder perception of the occurrence of LNAPL a concern?

Not all LNAPL concerns will need remediation, therefore not all LNAPL concerns will generate LNAPL remedial goals and objectives.

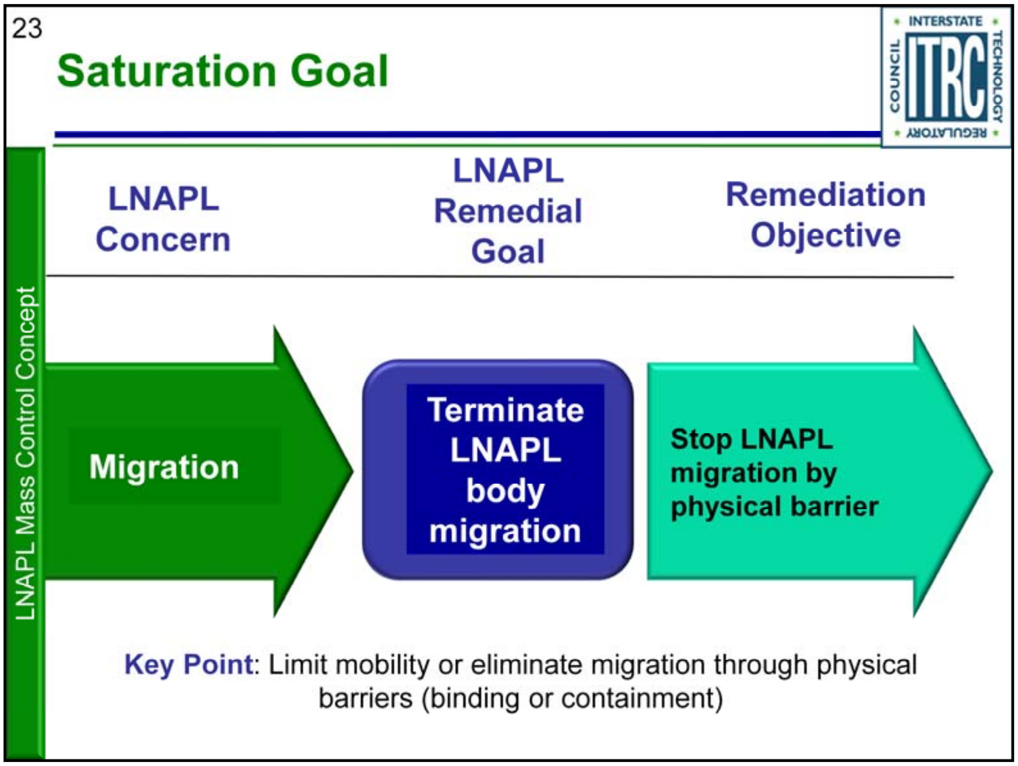


Let's dive a little deeper into the categories of remedial technologies.

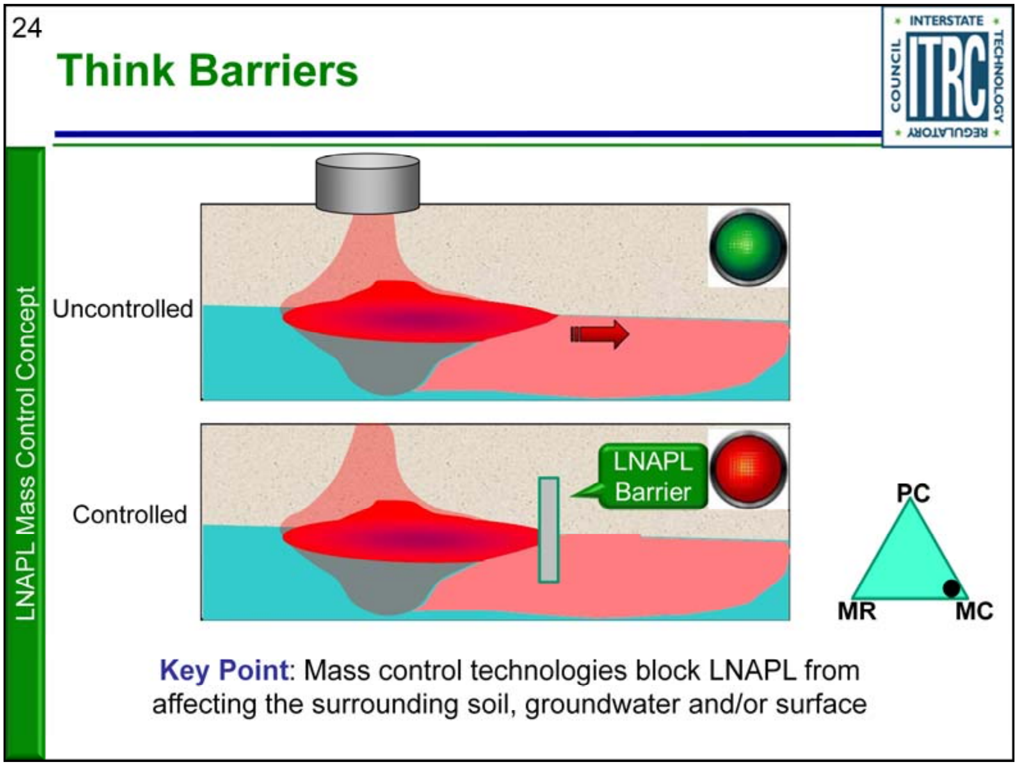
When you have excess saturation as a remedial goal and are concerned about migration

LNAPL Mass Control technologies may be used. These technologies function by blocking the effects of the LNAPL from reaching somewhere else. Like a dam across a river holds back the water.

Note the ternary diagram in the lower right. The dot is placed at the Mass Control (MC) corner.



This slide links concerns, goals, and objectives. The LNAPL concern here is migration which is linked to a saturation-based goal which is to terminate the LNAPL body migration and reduce the potential for LNAPL migration and then linking that goal to a remediation objective which is to stop LNAPL with a physical barrier. This migration concern can be addressed by a Mass Control technology.



In the top panel, you can see the uncontrolled migration of LNAPL away from the point of initial release and highest LNAPL saturation.

Think of this type of technology as containing LNAPL migration due to high saturation.

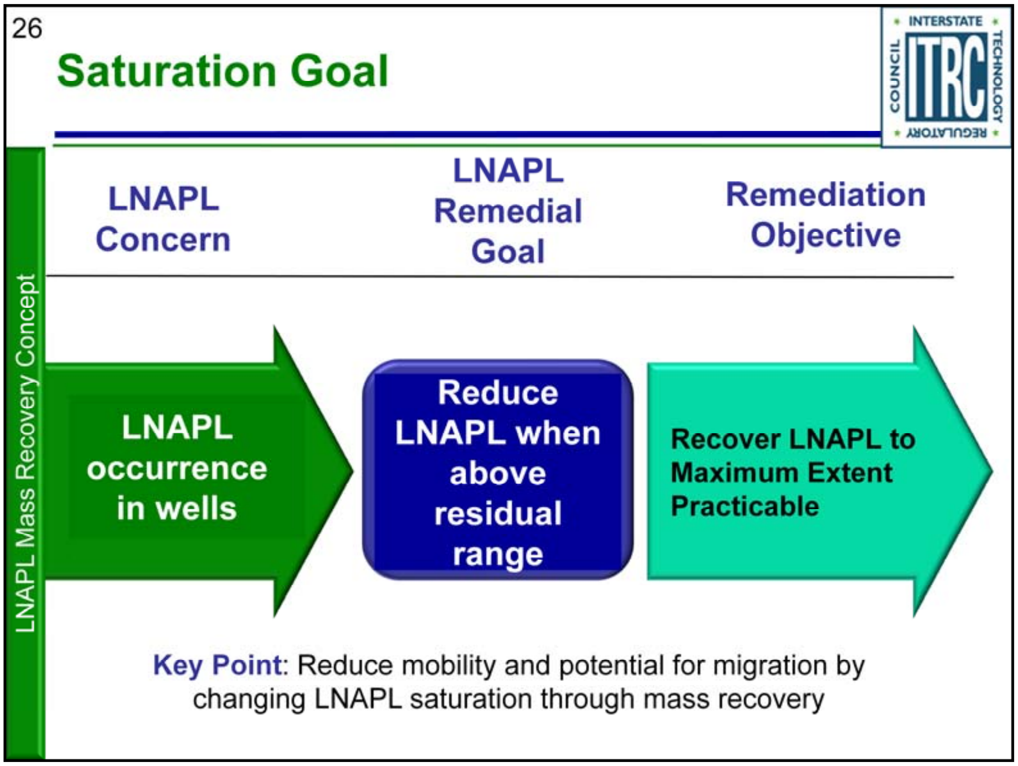
In the bottom panel, you can see that these effects can be mitigated by putting a barrier across the path of LNAPL migration. This is mass control. LNAPL is not removed, just controlled in place. An example of this type of mass control technology is a slurry wall.

The next category of remedial technologies to describe is LNAPL Mass Recovery.

A conceptual example is vacuuming up a spill. In this example, water is being removed (recovered) from the footprint of the spill.

This is a good analogy for mass recovery. Will the shop vac get all the water up? No, but it will remove enough to keep it from spreading further. The shop vac would recover less of the spilled water if the floor was carpet (finer-grained soil) instead of concrete (coarser-grained soil). Recovery will also allow for faster natural drying so the life cycle of the spill is reduced.

Note that on the ternary diagram the dot is now in the Mass Recovery (MC) corner.



This slide links the LNAPL concern of LNAPL occurrence in wells to a saturation-based goal of reducing LNAPL when LNAPL is above the residual range and the remediation objective of recovering LNAPL to the maximum extent practicable.

•You can achieve this goal by recovering enough LNAPL to reduce LNAPL saturation, mobility, and gradient. This concern, goal, and objective would be addressed through the mass recovery technology group.

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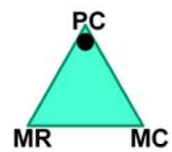
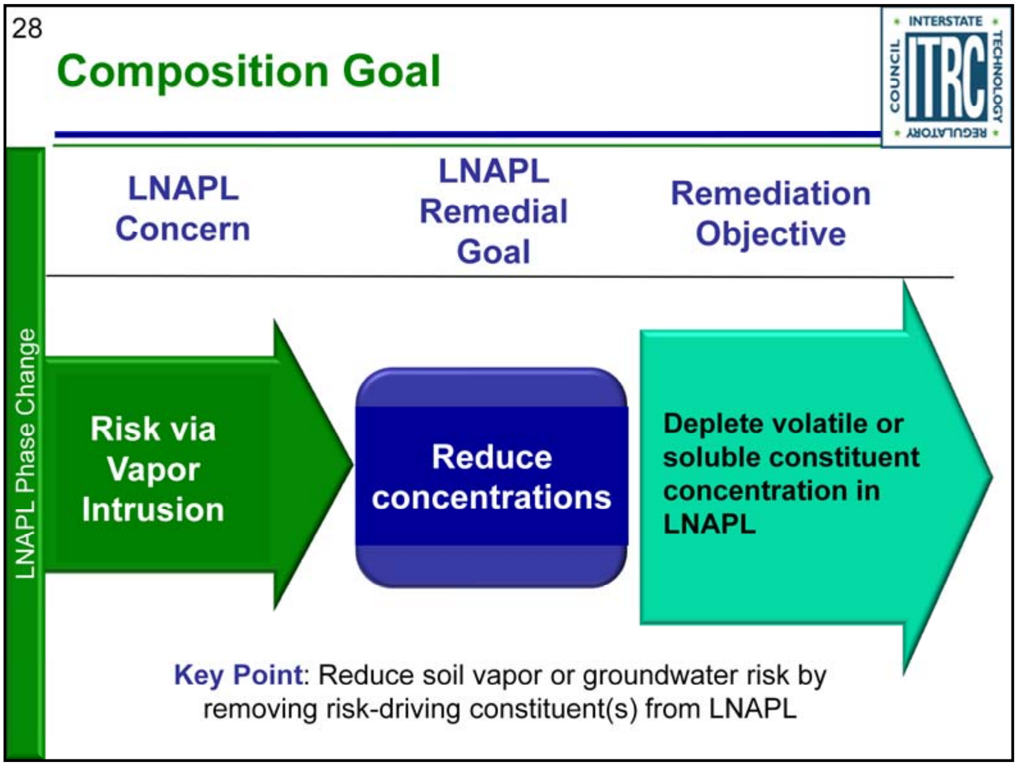
LNAPL Phase Change

LNAPL Phase Change



No it’s not time for a coffee break, it’s time for a phase change.

Note dot on ternary diagram is at the Phase Change (PC) corner



The LNAPL concern here is risk of petroleum vapor intrusion overlying an LNAPL source. This is a compositional based goal to reduce the constituent concentrations in soil vapor and/or the dissolved phase from an LNAPL source. The remediation objective would then be to abate the unacceptable vapor accumulation by depleting the volatile constituents in LNAPL. This concern, goal, and remediation objective would then be addressed by a technology in the phase change group.

29

LNAPL Composition

LNAPL Phase Change

- Modified by increasing rates of volatilization and dissolution from LNAPL body – phase change from liquid to vapor phase or liquid to dissolved phase
- Example technologies
  - Soil vapor extraction, or in combination:
    - Air sparging
    - Heating
    - Steam injection
  - Enhanced aerobic biodegradation
  - Enhanced anaerobic biodegradation
  - In-situ chemical oxidation

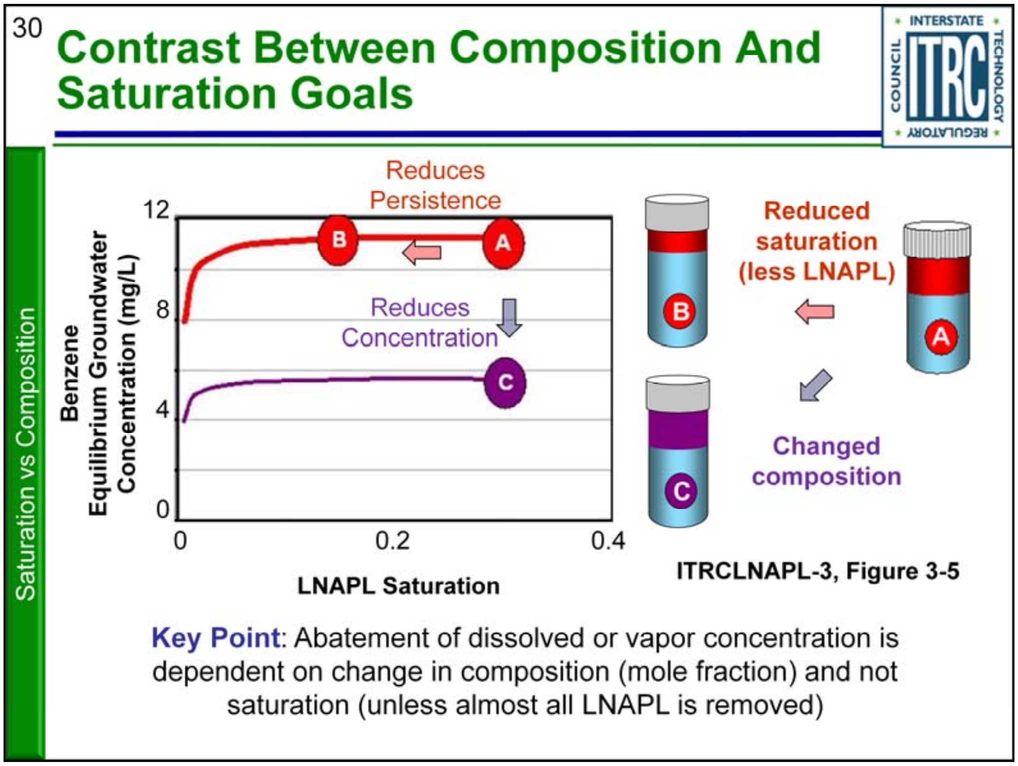
How does phase change modify the LNAPL composition

-increases rate of volatilization

-Increases rate of dissolution

Vapor technologies, increase the vapor gradient between LNAPL and the native environment, increase the rate of volatilization out of the LNAPL and changing the LNAPL composition to a low volatile content. These technologies may leave LNAPL in place, but can reduce or eliminate other pathway concerns such as explosive vapor accumulations, inhalation of toxic vapors, or ingestion of dissolved compounds.

For example steam injection, increases the volatility, changing the composition by reducing the composition of the volatile fraction of the LNAPL composition.



Why is composition change important? It is a more effective way to target constituents of concern that are a small fraction of the total LNAPL, for example, benzene is just one of many hydrocarbons that makes up gasoline, but in many cases it's the only component driving risk. So using a phase change technology to reduce the benzene concentration in the gasoline (A to C) is going to be more effective than recovering some, but not all, of the bulk gasoline (A to B).

The composition and saturation goals are conceptually compared. The first scenario from A to B shows how a 50% reduction in saturation has little effect on the dissolved benzene concentration. In contrast a 50% reduction in the mole fraction of benzene from A to C has a corresponding 50% reduction in benzene concentration. The key point is that the dissolved benzene concentration is dependent on the change in composition and mole fraction. Research has shown that a reduction in saturation has little affect on the dissolved concentration unless almost all the LNAPL from a source zone is removed (e.g., see API LNAST model, publications by David Huntley)

31

Knowledge Check

Poll Question

What are the three technology groups?

A. Unconfined, Perched, and Confined
B. Mass Control, Mass Recovery, and Phase Change
C. Air Sparging, Skimming, and Excavation
D. Aesthetics, Saturation, and Composition

No associated notes.

32

Technology Groups Overview Takeaways

Technology Groups

- Select your Remedial Goals - Saturation or Composition based
- Determine your Remedial Objectives (vapor abatement, remove mobile LNAPL)
- Select your technology from the 3 technology groups
- The 3 groups are:
  - Mass Control
  - Mass Recovery
  - Phase Change
- Sequence your technology deployment and use the "treatment train"

No associated notes.

"Thanks. Let's spend a little additional time on the NSZD remedial technology, dive into the understanding of NSZD, and how to estimate its rates."

It is an important part of most LCSMs and LNAPL remedial technology evaluations.

It is also of significance because engineered remedial actions typically do not always completely remediate soils and NSZD may be useful to address the residual hydrocarbon.

Initial Poll: Starting Knowledge Level

Have you measured NSZD rates and incorporated into it into your LCSM and/or used NSZD for remediation decision making?

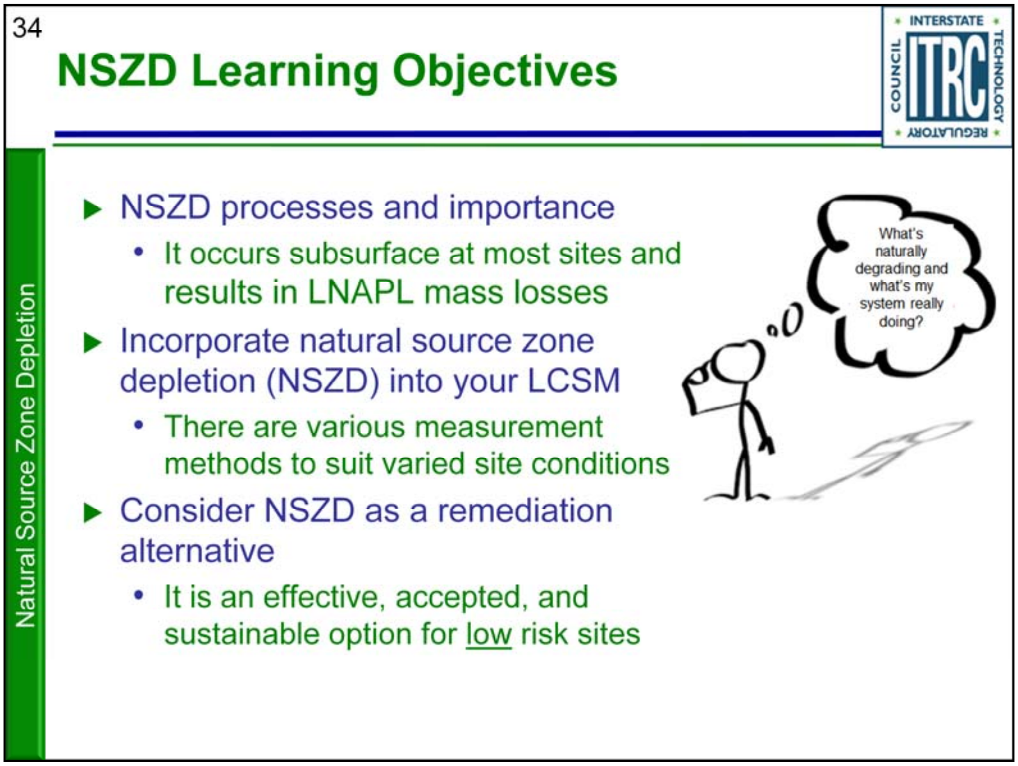
Yes

No

Quick poll to assess our collective starting knowledge position.

To reiterate what was said about NSZD – "People want to know more about NSZD, it has its own appendix, and people are still learning about NSZD. Also, NSZD is not like the other techs because it's already happening (at some rate) and my opinion is you can't fully develop a remedial strategy unless you understand the natural processes at your site."

Note that the discussion will include a summary of old (ITRC, 2009) and new information that is presented on NSZD. LNAPL-1 was really only about the saturated zone and soil gas profiling and the gradient method; new methods have emerged. Detailed new information on NSZD is presented in Appendix B of LNAPL-3.



First, we'll cover the details of LNAPL biodegradation

Next we'll discuss NSZD as a component of the LCSM

Initial - natural degradation processes, stability

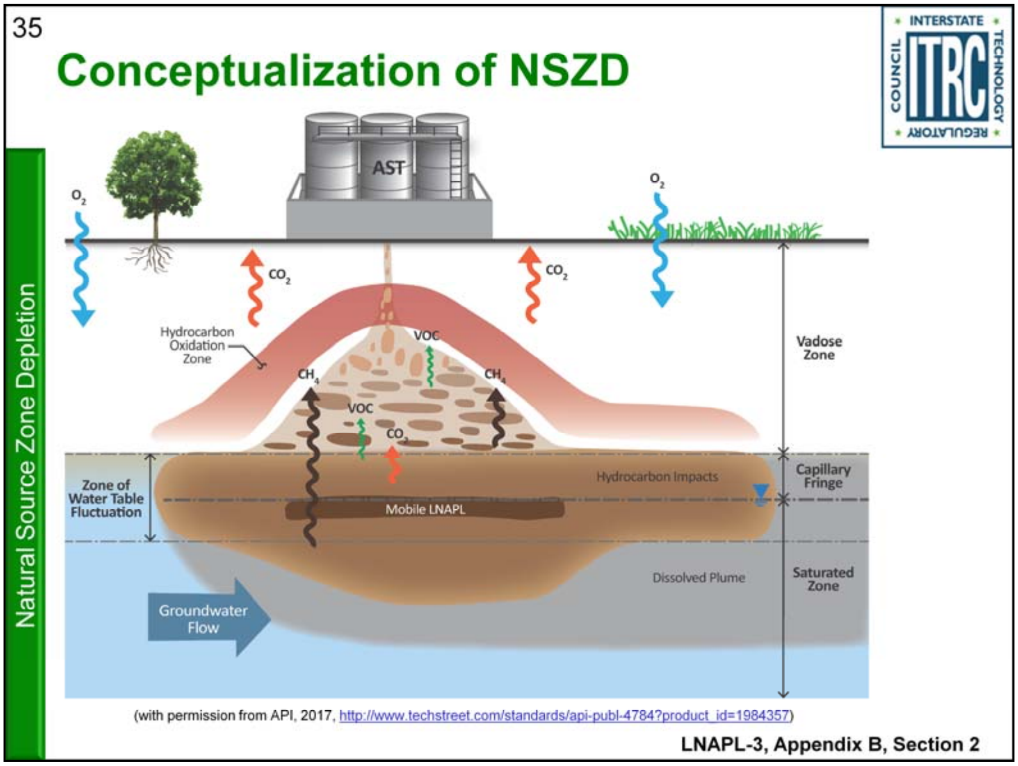
Remedy selection - phase change technology option

Design and performance - rate used as a performance metric

Finally, NSZD is a remedial technology option and is of significance because it occupies a position in the spectrum of remediation options that can be used as a basis for comparing the performance and relative benefit of other remediation options.

It is a phase change technology – addresses composition and saturation objectives. It can be used as a stand-alone technology or and option for treatment train transition.

NSZD is applicable to risk-based closure and low threat sites, and long-term management.



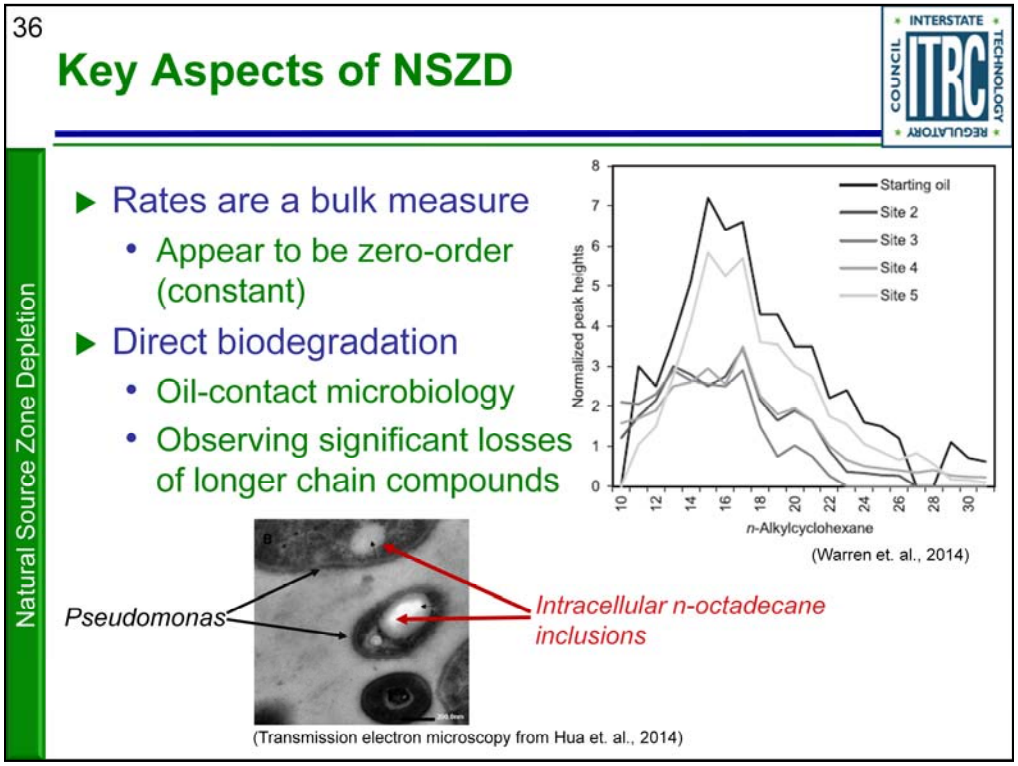
New conceptualization from prior monitored natural attenuation (MNA)-based version that focused on saturated zone and aqueous manifestations of NSZD. This is all about the LNAPL source zone, an extension of dissolved phase MNA.

1. NSZD is biodegradation throughout the source zone – saturated and vadose. At many sites, it is typically about the residual LNAPL mass that is left behind in the saturated zone
2. Methanogenesis typically dominates
3. Produces significant gases that are transported into the vadose zone
4. The gaseous expression can be used to estimate mass losses
5. Vapor-based losses >> aqueous-based losses (at most sites)

Key Elements of LCSM for NSZD:

- Ambient temperature clime - warmer temperatures, higher NSZD rates
- Soil type and moisture - fine-grained, high-moisture limit NSZD
- Ground cover and permeability - impervious ground cover may results in methane in shallow soil gas
- LNAPL distribution (unconfined, confined, or perched) - effects bio processes and gas expression patterns

WRT to concerns with distances to nearby structures, if NSZD is to used as a remedial strategy, then see Figure 3-5 of the ITRC Petroleum Vapor Intrusion (PVI) guidance (2014).

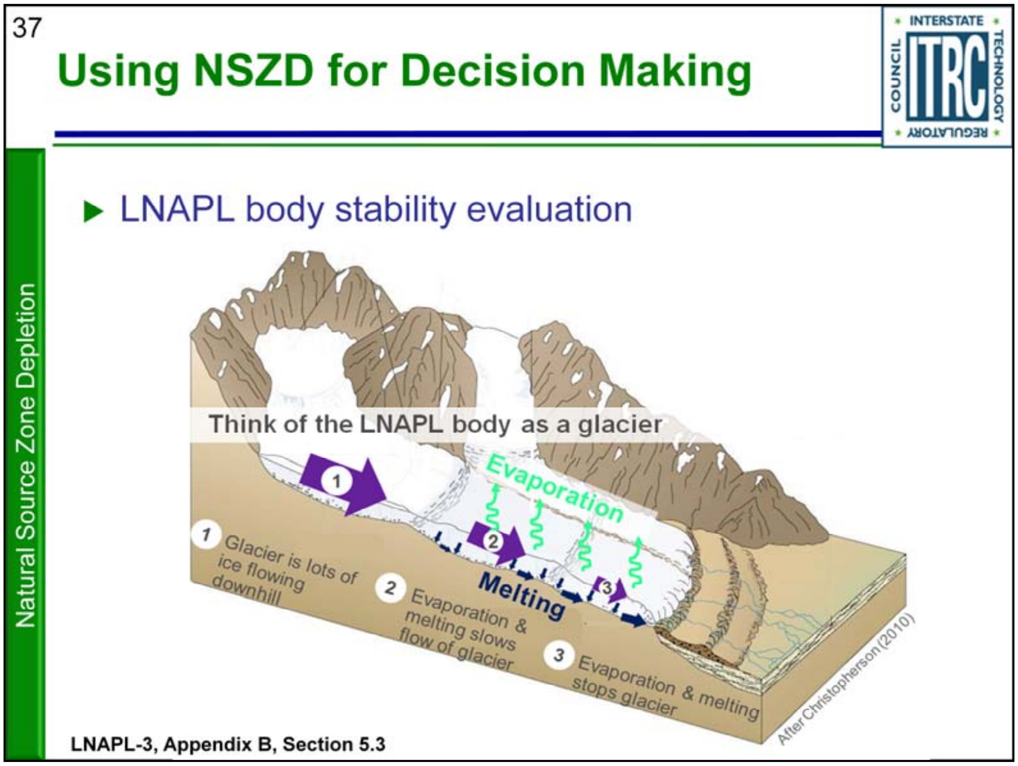


As measured, NSZD rates are in units of total petroleum hydrocarbons (TPH), not chemical-specific (yet). Granted, while the knowledge of the science is still young, we see little change in rates over time. Of note, estimation of remedial timeframe via NSZD are a work-in-progress, new models are being developed to update the fundamentals and improve predictions.

The biodegradation processes of NSZD do not reduce LNAPL mass solely via dissolution into the aqueous phase. LNAPL mass may also be depleted by direct oil contact biodegradation. This is a significant improvement in understanding of NSZD.

Direct-contact biodegradation occurs within the pores in the immediate proximity to the LNAPL. The image (bottom-left) shows LNAPL inclusion into bacteria cells via microscope. By-product gases from this reaction are directly outgassed to the vadose zone.

The net effect of the NSZD processes is degradation of all hydrocarbons in the LNAPL, not just the short chain or more soluble components. In fact, at Bemidji, as shown on the figure, they saw more significant degradation of longer-chain compounds.



Think of LNAPL body as a glacier. Processes of melting and evaporation are analogous to NSZD; they are loss mechanisms acting on the body. Where losses exceed rates of glacier (or LNAPL) advance, recession results. This explains the common observation of monitoring wells without in-well LNAPL installed in boreholes with stained soil beyond the leading edge of the LNAPL. This is direct evidence of the former presence of the LNAPL body at this location, and occurrence of NSZD which has reduced the LNAPL saturation to a residual/stained condition. These processes are on-going, and at sites without an on-going release, will ultimately lead to the “residualization” of the entire body.

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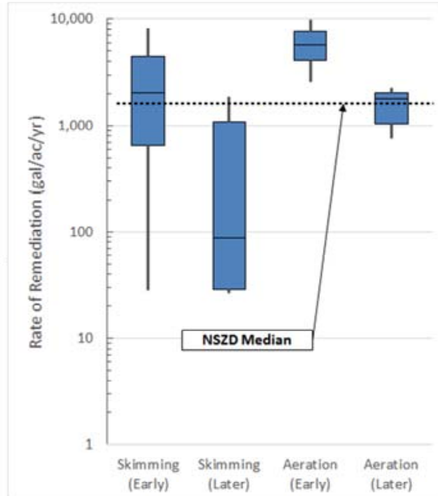
Using NSZD for Decision Making

Natural Source Zone Depletion

- Practicability of recovery
- Endpoint metric for active LNAPL remediation
- Benchmark for enhanced-NSZD remedy design
  - Aeration
  - Enhanced anaerobic
  - Heating



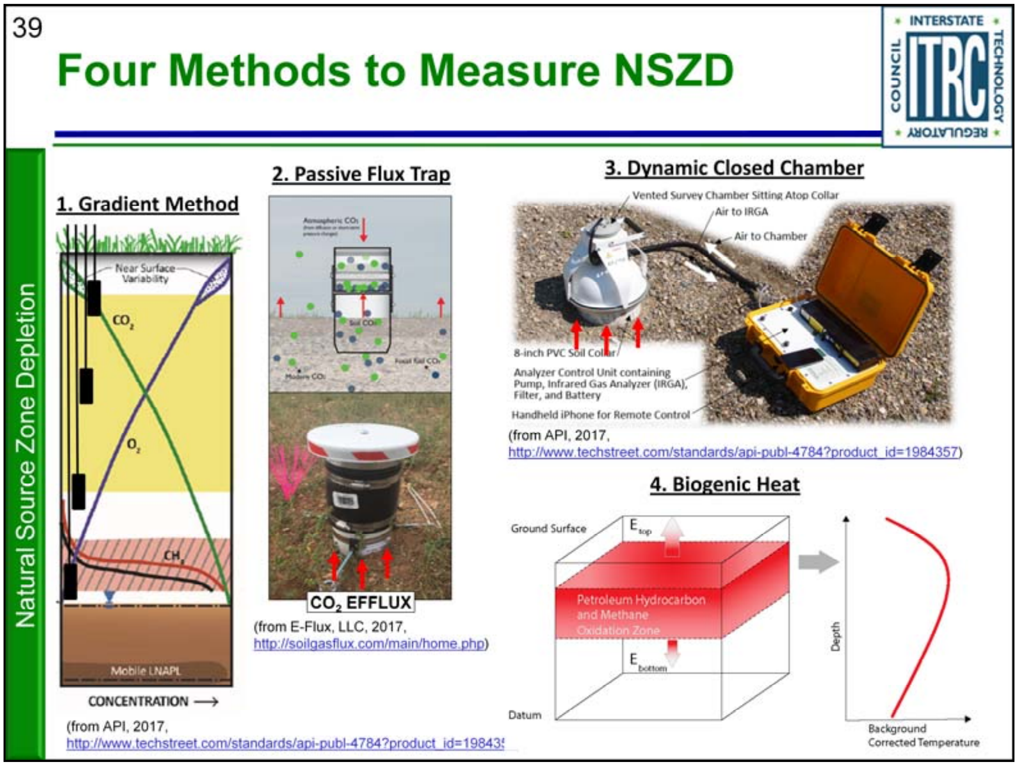
(Median NSZD rate from Garg et al., 2017. System data modified from Palaia, T. 2016. Natural source zone depletion rate assessment. Applied NAPL Science Review 6.)

LNAPL-3, Appendix B, Section 5.3

Garg et al., 2017 – "…the overall sitewide averages…, with the middle 50% of sites falling between 700 and 2800 gallons/acre/year for the 25 sites, giving a representative median NSZD rate of about 1700 gallons/acre/year."

Palaia, 2016 – "…included active remediation mass removal rate data from 29 different systems ranging from LNAPL skimming to multiphase extraction [at various diverse sites]."

It should be noted that implementation of active remediation via aeration changes the subsurface conditions significantly and disrupts NSZD as we've described it (i.e., methanogenic). As shown on the figure, a transition to aerobic conditions can enhance mass losses over NSZD. Other technologies, such as LNAPL skimming would not and in this case, NSZD mass losses would be additive to those from skimming. It's important to account for this.



Measurement method details (how-to) are provided in the LNAPL-3 guidance Appendix B, Sections 4.1 through 4.4.

Important note before closing the methods discussion, as with any environmental monitoring, QA/QC is important –

Background correction

- Use ^{14}C for best accuracy

Standard means:

- Calibrate field instruments
- Field and/or trip blanks
- Duplicates - results can be variable

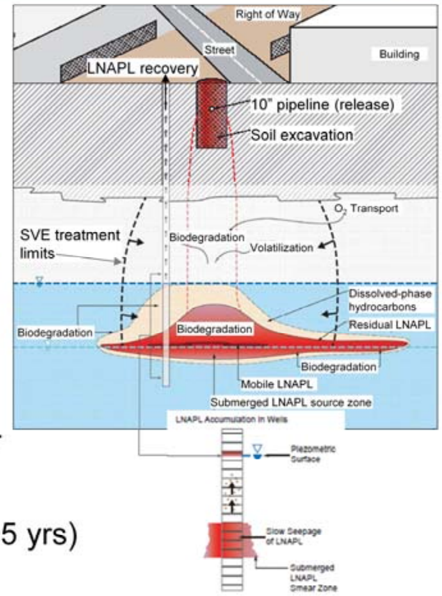
Measurement confirmation with added method

40

Case Study - Transition from LNAPL Fluid Recovery to NSZD

Natural Source Zone Depletion

- Jet fuel pipeline release
- Silt and clay overly silty, fine-grained sand
- Submerged LNAPL
- Historical remedial actions
  - Partial source excavation
  - LNAPL skimming
    - 10,000 gals removed (~10 yrs), <100 gallons/yr
  - SVE system
    - 9,600 gallons removed (~5 yrs)

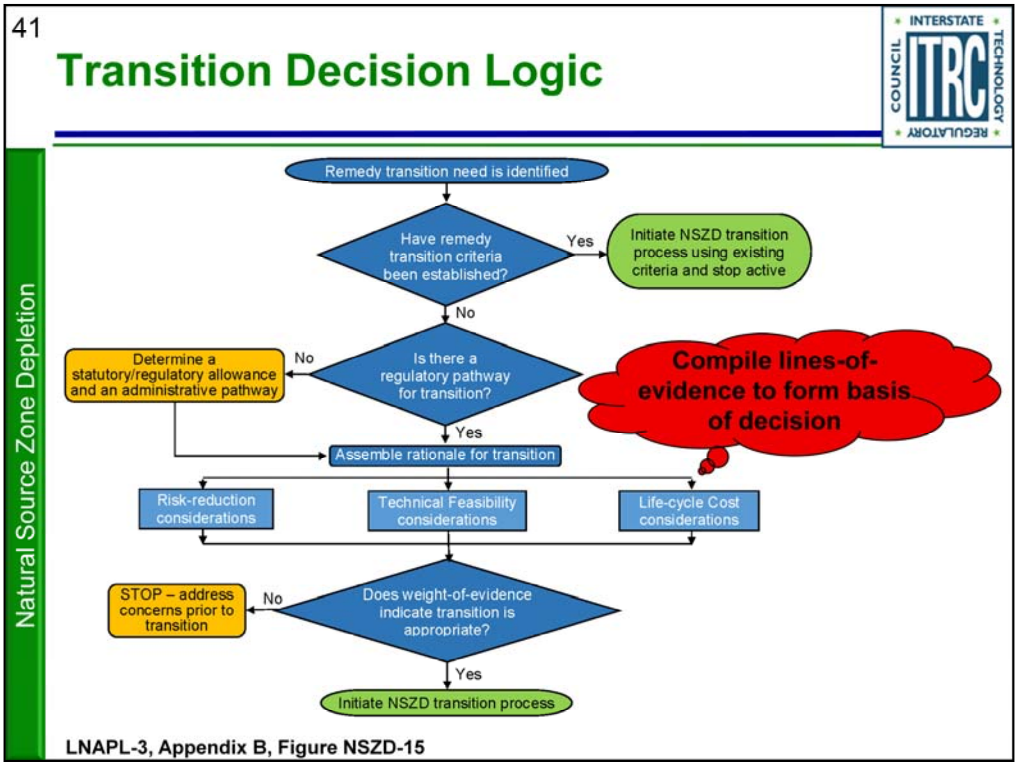


LNAPL-3, Appendix B, Section 5.3.1

Case study to demonstrate that many remedial technologies will progress to relatively low mass removal rates that are insignificant; continued operation will not provide commensurate value in terms of increased environmental protection and/or risk reduction. The practical endpoint of the engineered mass removal technology will have been achieved.

This is the appropriate point for transition. Here is a case study to help demonstrate how to use NSZD for site remediation decision making. Here are the steps you might take to move from inefficient active remedy to NSZD. As detailed in LNAPL-3, Appendix B, it includes use of a multiple lines-of-evidence approach to support the transition decision.

WRT to concerns with distances to nearby structures, if NSZD is to used as a remedial strategy, then see Figure 3-5 of the ITRC PVI guidance (2014).

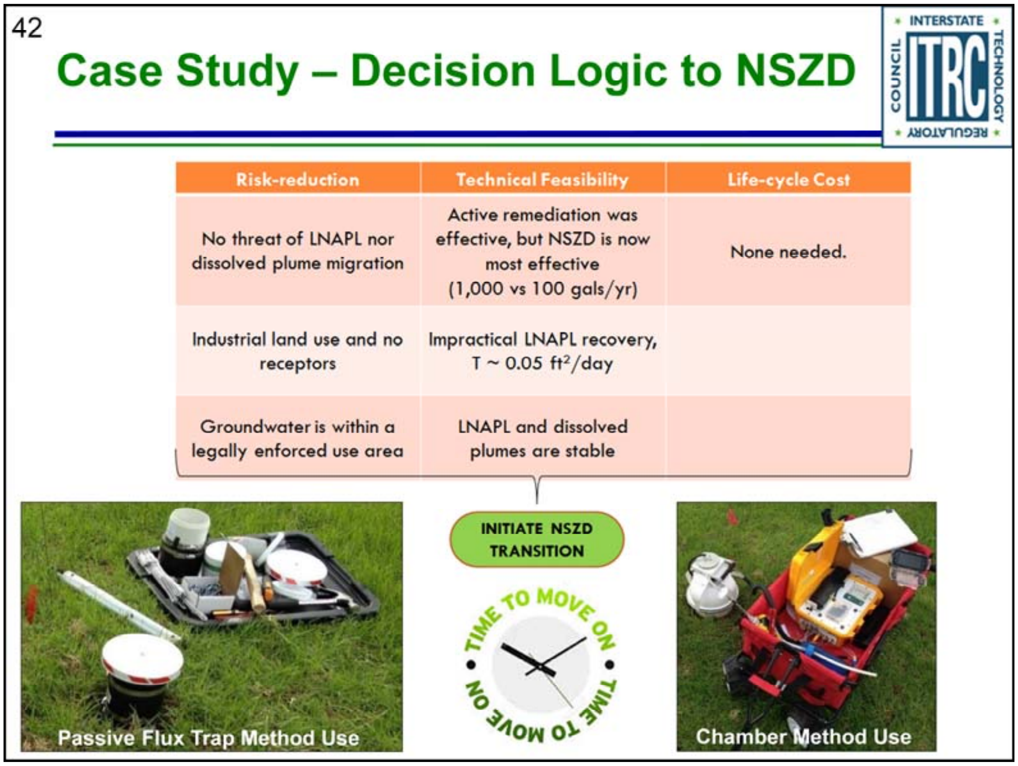


Define a regulatory pathway first

Note the multiple lines-of-evidence approach - practice has evolved to use multiple lines-of-evidence to justify transition. For example, the (NRC 2013) proposes taking:

1. risk reduction,
2. life-cycle costs, and
3. technical feasibility

into account during a transition process that is transparent, reduces long-term risks to an acceptable level, and is practical and cost effective. Based on these considerations, transition to NSZD as the final remediation component will merit consideration at many sites



Using a multiple lines-of-evidence approach:

LNAPL and dissolved phase plumes are stable

Land use is industrial, within a utility R.O.W.

Non-potable aquifer and groundwater rights are strictly legally controlled

Nearest use for refinery process, municipal supply ½ mile upgradient, 300-ft deeper

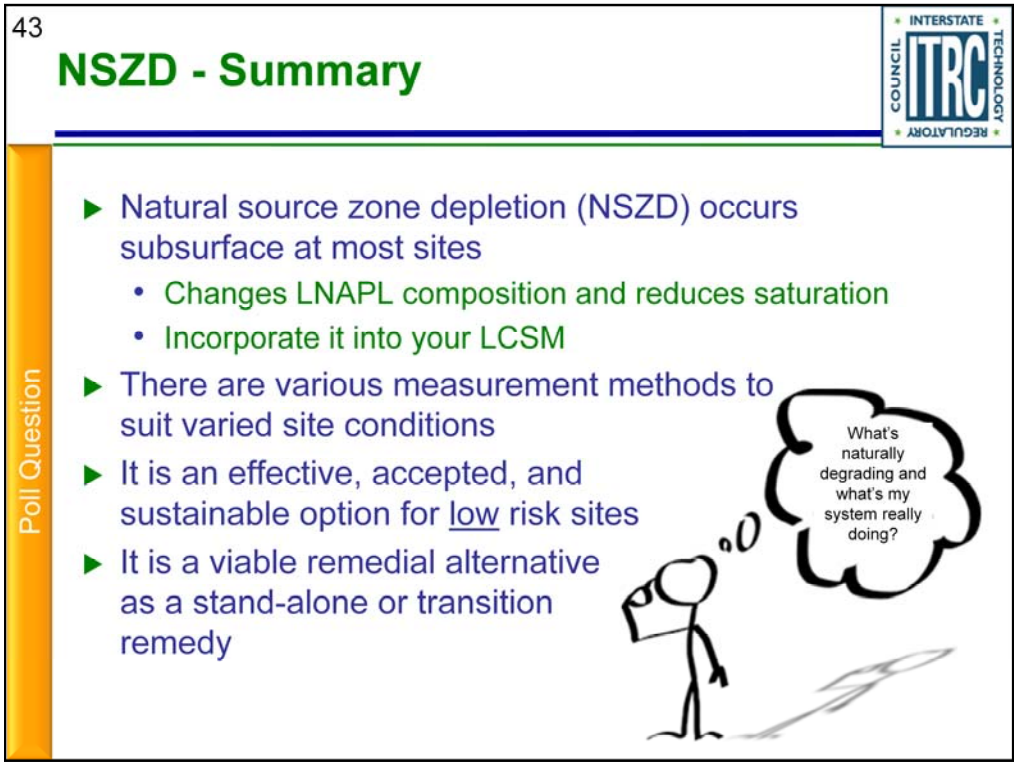
No current or future unacceptable exposure risk

No indoor or ambient health risks identified

Biogeochemical mass budgeting shows 9-12 gallons per year of LNAPL depletion. CO_2 efflux monitoring showed an additional 700-1,300 gallons per year of LNAPL mass losses via NSZD.

Evaluation results were presented to the regulatory agency and the agency agreed. Remedial action transitions to NSZD with annual monitoring using the biogenic heat method.

Emphasize: NSZD is not a walk-away technology – alike MNA, monitoring will be performed and often include contingency to provide an appropriate level of protectiveness and ensure NSZD remedy performance. If the performance of NSZD is not adequate, and the monitoring data indicates that the remedy fails to meet one of the performance metrics, then the remedy must be adjusted or optimized to achieve remedial goals. (ITRC 2006) prescribes decision logic for optimization and contingency planning to achieve the stated performance monitoring objectives.



Exit Poll: NSZD Data Use

Why is it important to understand NSZD at a petroleum remediation site?

- *a. Key fundamental component of the LCSM*
- *b. Establish a benchmark for remedial decision making*
- *c. Support system optimization of active systems*
- *d. All of the above*

NSZD biodegrades LNAPL. Within the ITRC remedial decision making framework presented in this training, it is a phase change technology – addresses both composition and saturation objectives.

NSZD is a valuable component of the LCSM:

Initial - natural degradation processes, stability

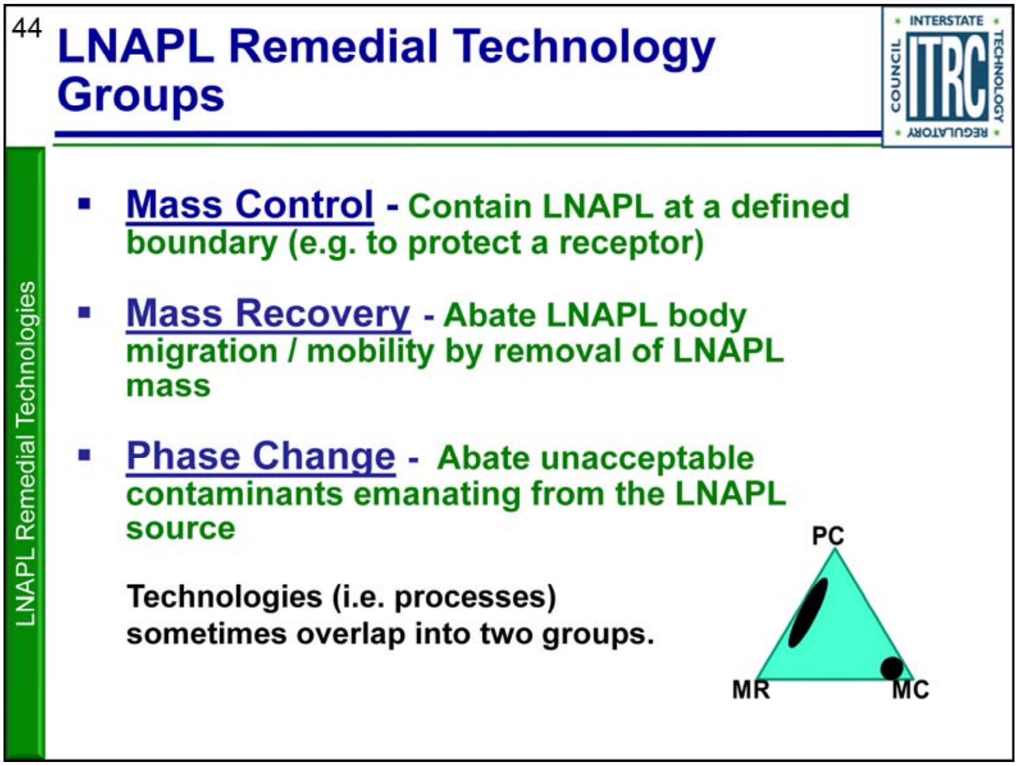
Remedy selection - phase change technology option

Design and performance - rate used as a performance metric

Four different methods are available to measure the rates of NSZD at your site. Selection depends on site conditions and data objectives.

NSZD is applicable to risk-based closure and low threat sites, and long-term management. It can be used as a stand-alone technology or and option for treatment train transition

“Now I’ll turn it over to Lloyd Dunlap of TriHydro Corporation to describe the plethora of additional remedial technologies available to address LNAPL concerns. Lloyd……”

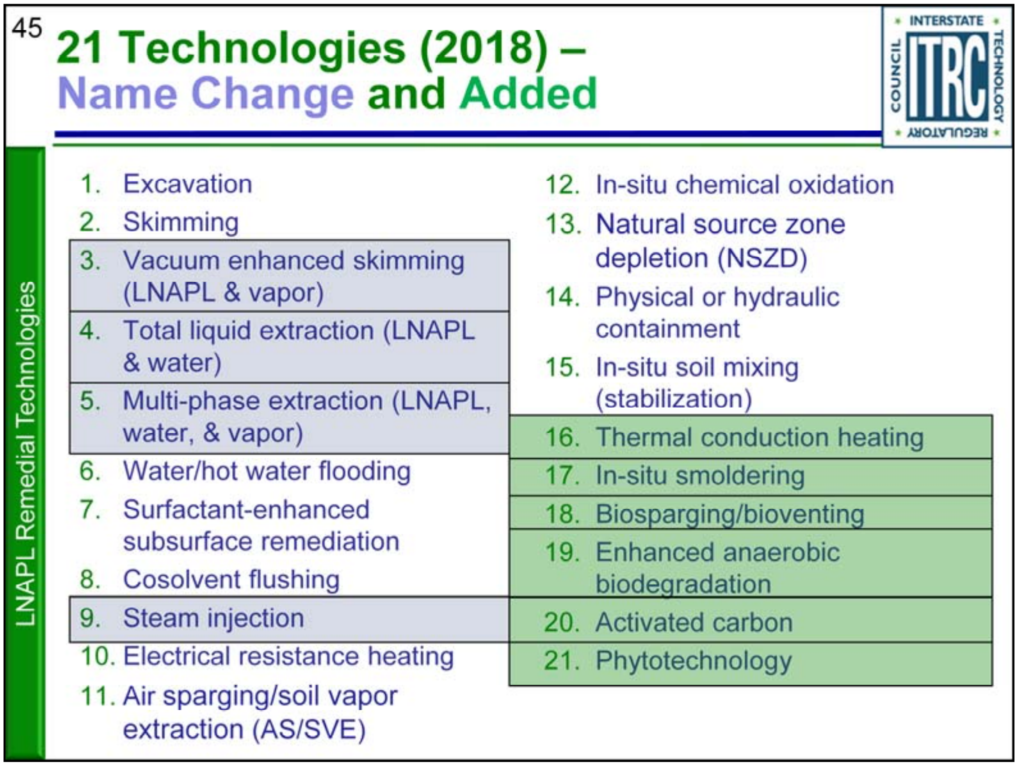


As was mentioned earlier, technologies are broadly grouped in the document by how they address LNAPL concerns. We use this triangular diagram to help identify how a technology can address a concern.

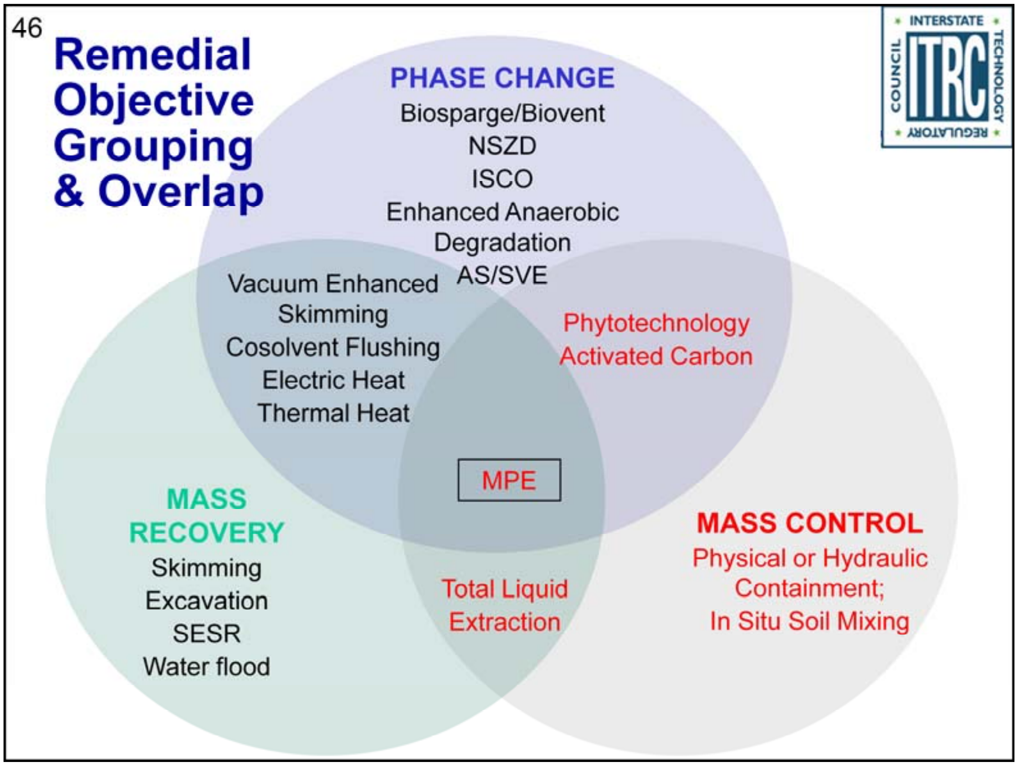
For example, if LNAPL migration is a concern, Mass Control technologies are probably your first group of technologies to look at. Your GOAL could be to “contain LNAPL at a defined boundary”. If LNAPL saturation is a concern, focus on Mass Recovery technologies. Your GOAL could be “abate LNAPL migration by removal of LNAPL mass. And if you have LNAPL residual/compositional effects, then focus on Phase Change technologies. Your GOAL could be “Abate contaminants emanating from the LNAPL source”.

Technology groupings can overlap. This means some technologies can serve within more than one group. This is good, because they can address several LNAPL states at one time. Technologies that don’t overlap may be useful in treatment trains or in combination with other technologies to enhance or accelerate cleanup.

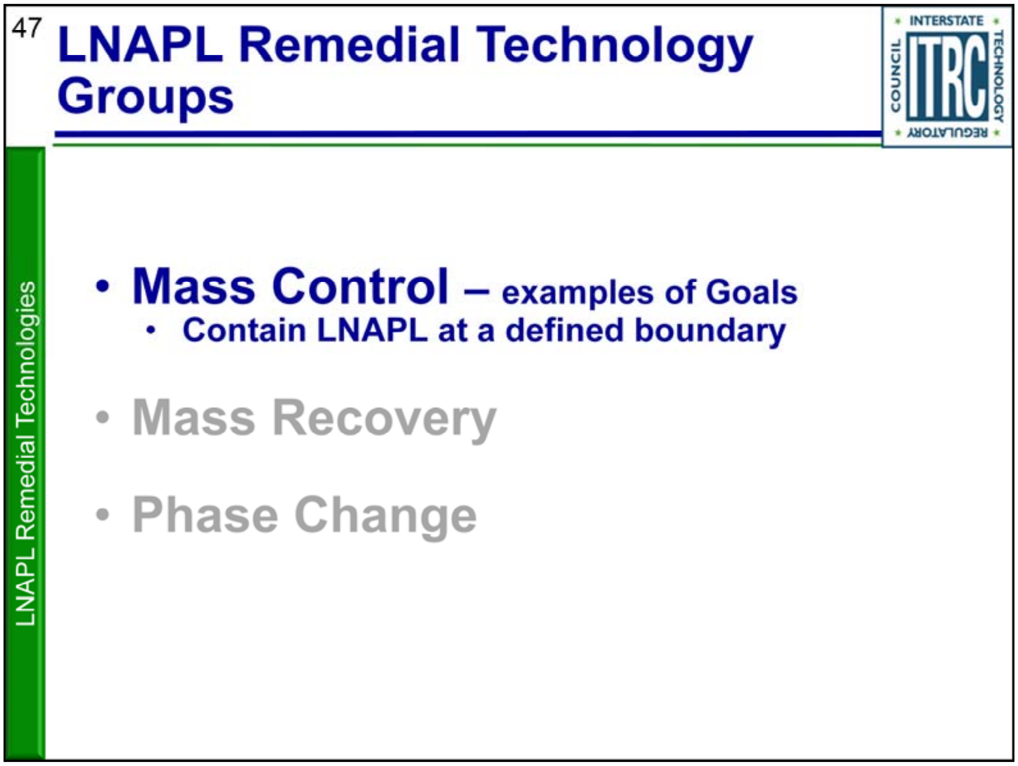
As Justin discussed, we can use these technologies as a treatment train, or even combine them together.



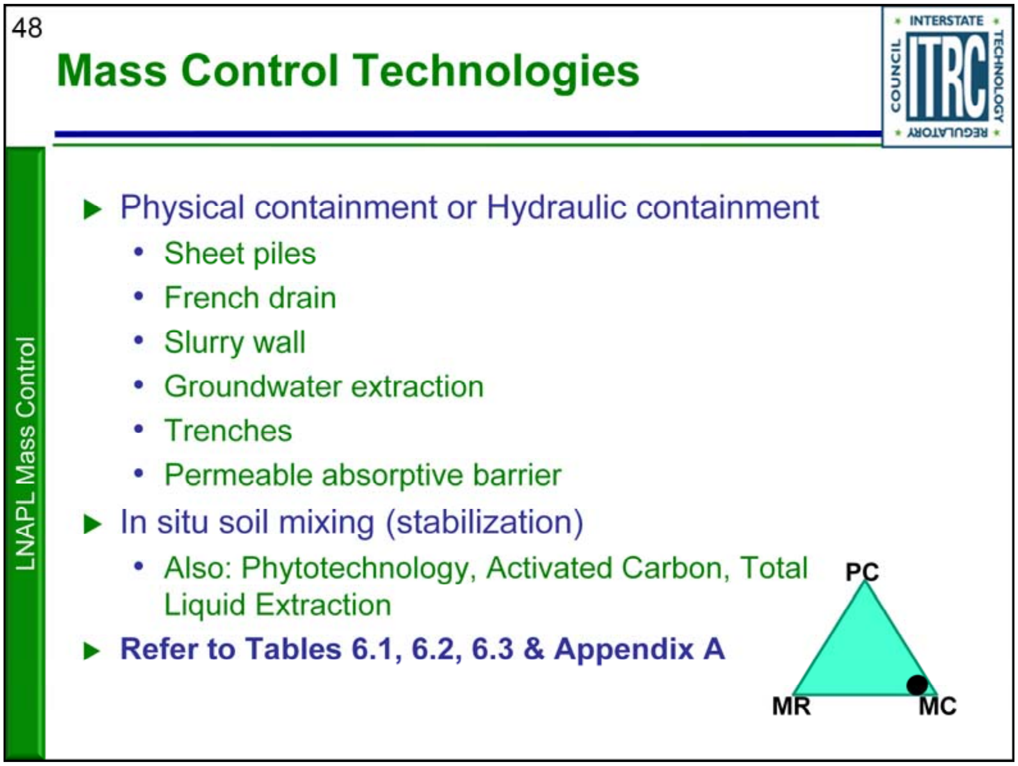
Six new technologies were added (green) in today's guidance. Four technologies in blue had their name changed. These are now the technologies we have in today's guidance document. I am going to talk more about these added technologies a bit later on.



Here is another way to list the technologies within their groups of Phase Change on the top, Mass Control on the right and Mass Recovery on the lower left. As we said some technologies fit within more than one group. An example is Phytotechnology and activated carbon with can fit within both Phase Change and Mass Control.



We are first going to talk about Mass Control technologies. Mass Control technologies typically "contains" LNAPL at a defined boundary.



Mass Control technologies are typically physical containment or hydraulic containment. You can see some examples here that you likely recognize. Another Mass Control technology is In Situ soil mixing, or stabilization. But other technologies that can be used as Mass Control are listed here also.

We will refer to the ternary diagram on the lower right to demonstrate what remedial objectives are being used for each technology. The dot in the lower right shows the remedial objective is MC or Mass Control.

To learn more about these technologies, refer to Tables 6.1, 6.2, 6.3 and appendix A.

49 **Performance Metrics for Mass Control Technologies**

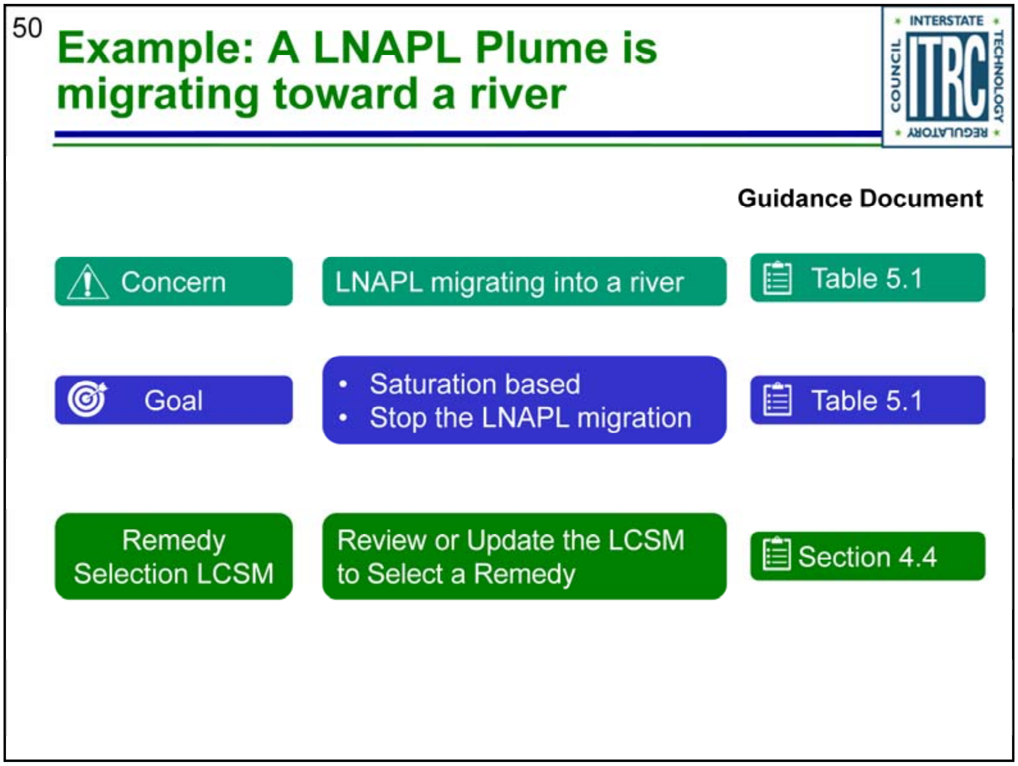
See Tables 5.2 and 6.3 for additional metrics

LNAPL Mass Control

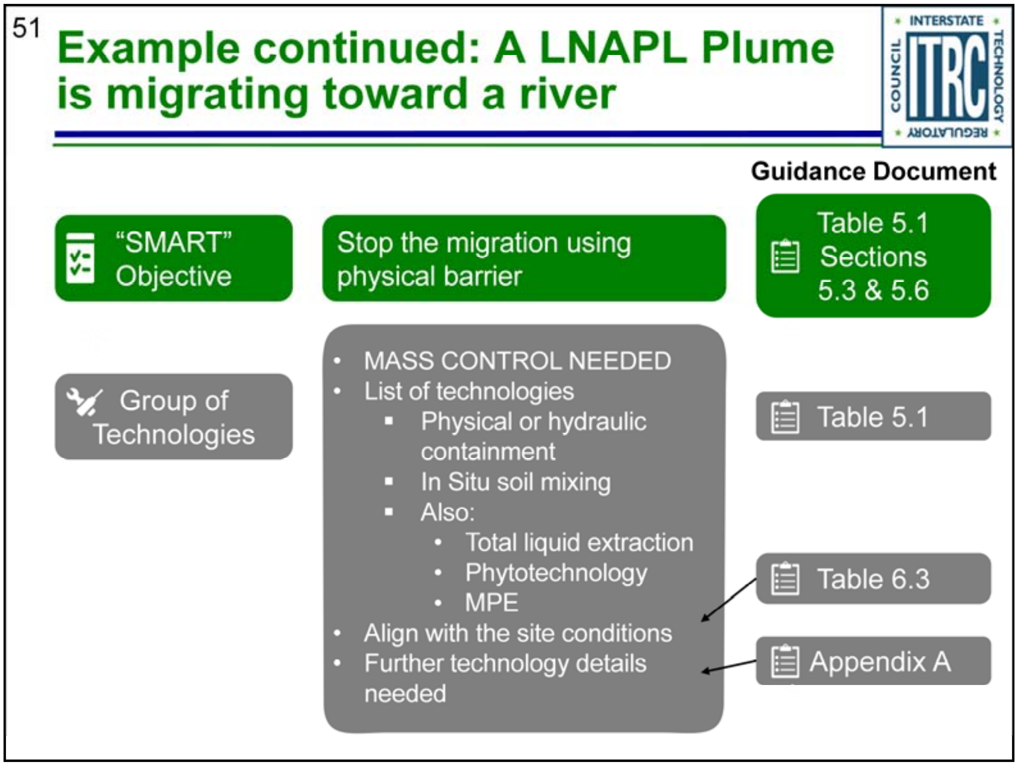
- No first LNAPL occurrence in down gradient sentinel well
- LNAPL body footprint stabilized based on long-term monitoring (quarterly, semi-annual, annual monitoring)

Photo of barrier wall

Here are some example performance metrics for Mass Control Technologies:
You do not detect LNAPL in a downgradient well, or the LNAPL body has stabilized.
Other metrics are found in Tables 5.2 and 6.3.

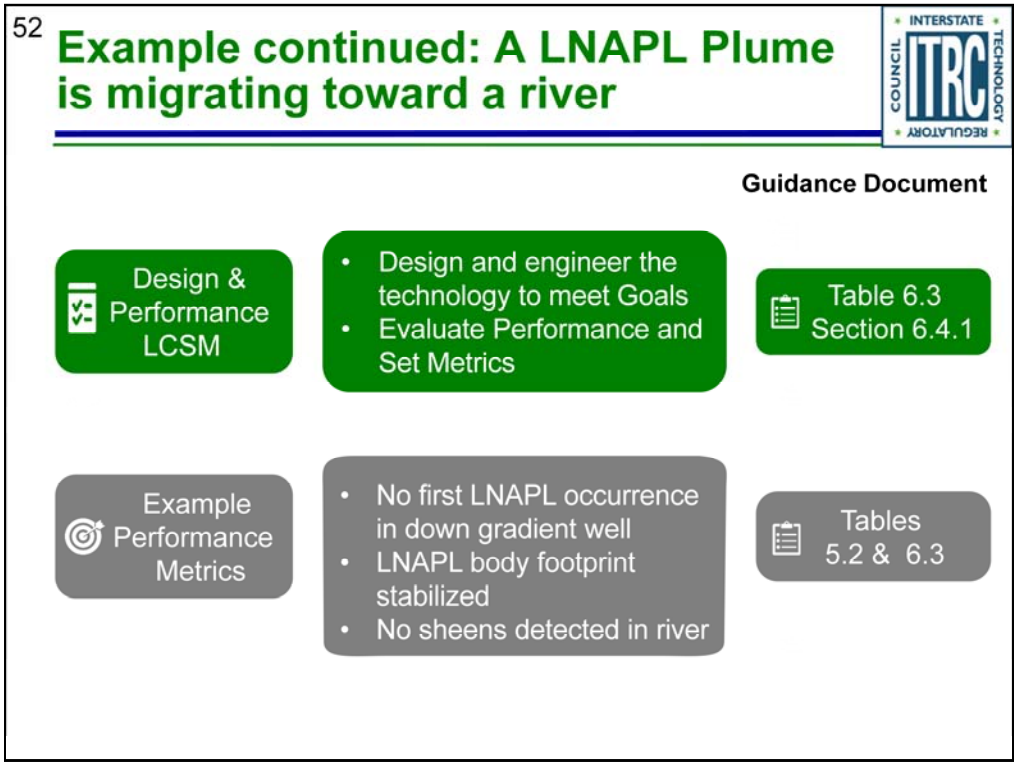


Here is an example of how to select a technology. Let's say you have a site where LNAPL is migrating toward a river. From the process we learned in Session 2, our CONCERN can be labeled as LNAPL migrating into a river. This process is found in Table 5.1 of the Guidance Document. Our GOAL is LNAPL saturation based, we want to stop the LNAPL migration. We use the Remedy LCSM to review or update the LCSM to select a remedy. What might you need to know? There may be other considerations that influence the LNAPL conceptual site model and remedy selection, such as results of testing or modeling, or other factors, including cost and liability concerns. More about this is found in Section 4.4.



Our SMART OBJECTIVE is to use a physical barrier to stop the migration. A "SMART" objective is (Specific, Measurable, Attainable, Relevant and Timely). More about this can be found in Table 5.1 and Sections 5.3 and 5.6

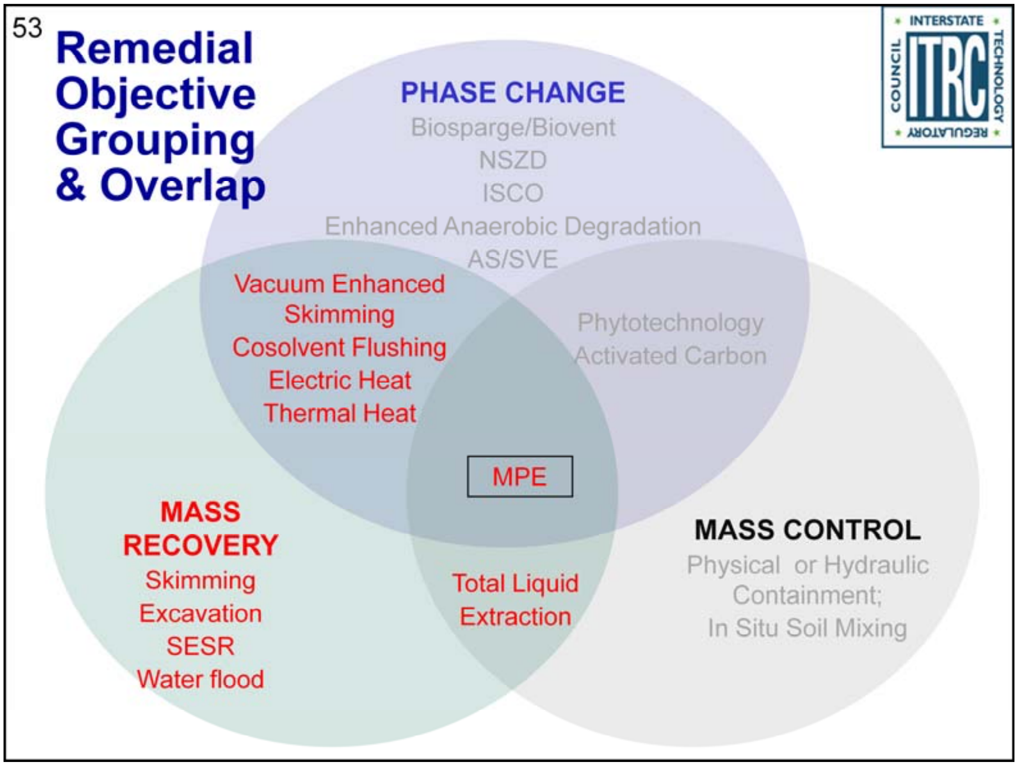
We select a Technology Group that provides Mass Control. The list of technologies within Mass Control are physical or hydraulic containment; other technologies are listed also. You next align your technology with the site conditions using Table 6.3. Appendix A gives you more details about the technology.



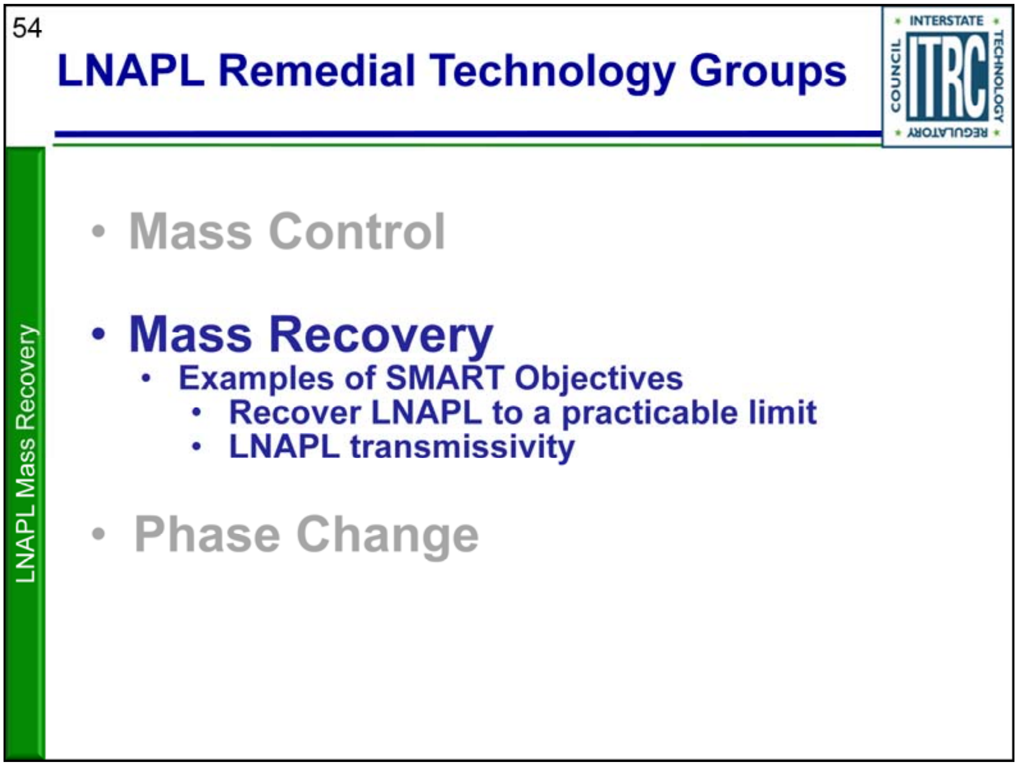
We then go to the Design and Performance LCSM. We design and engineer the technology to meet the goals. Then we evaluate the performance and set metrics. Some SMART metrics for this example could be

Other metrics can be found in the Guidance Document in Tables 5.2 and 6.3.

Justin and Joanne will outline a case study in a few minutes that will give further details on these concepts.

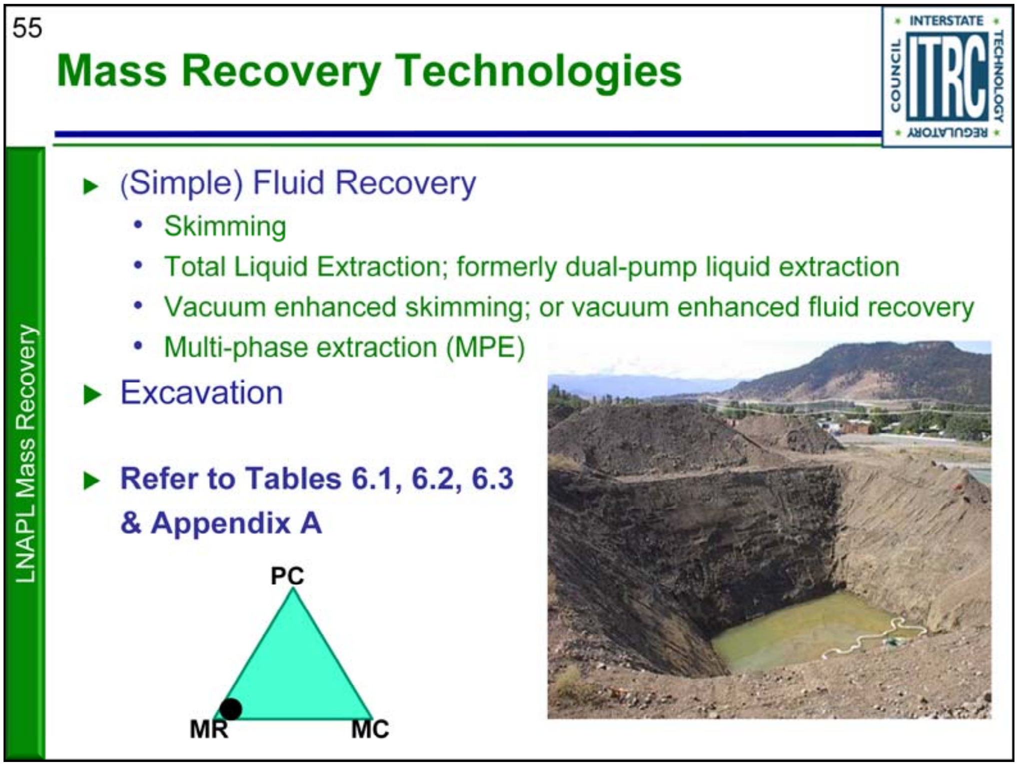


We will next talk about Mass Recovery technologies. The most familiar technologies to you are likely skimming, excavation, SESR or water flooding. But as you can see some technologies like Total Liquid Extraction are both Mass Recovery and Mass Control.



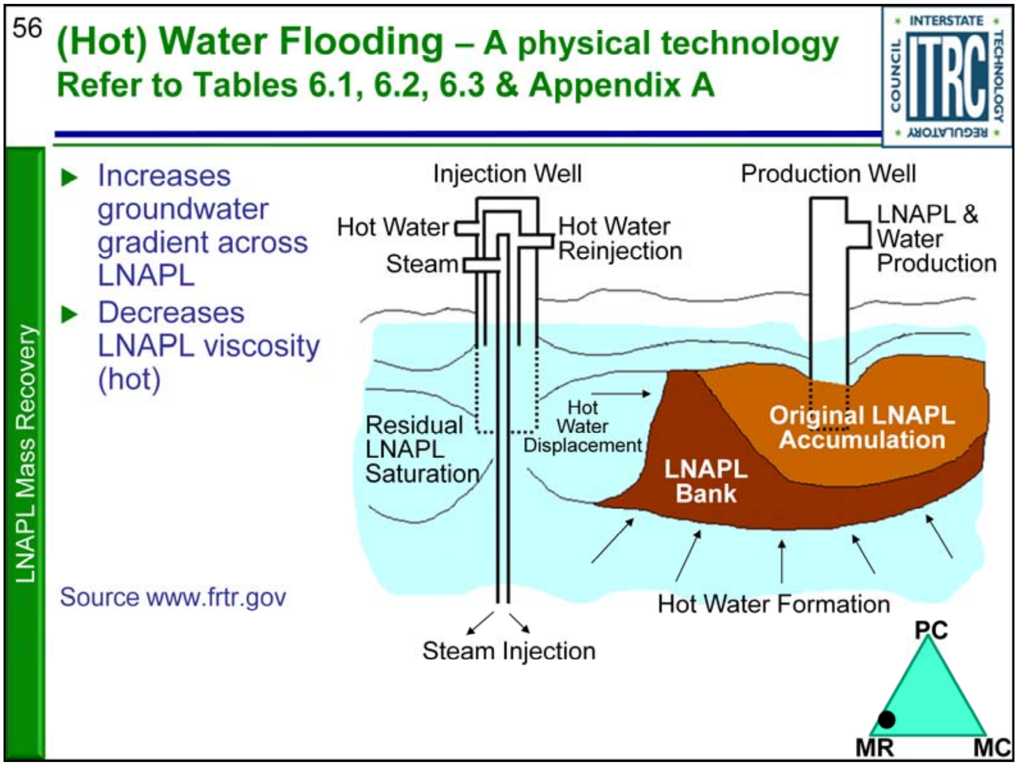
Here are two examples of a Mass Recovery SMART objective. With Mass Recovery, we "recover" the LNAPL body migration by removal of the LNAPL mass.

With Mass Recovery, we address saturation-based LNAPL remediation goals. These technologies recover LNAPL via physical removal such as excavation of LNAPL saturated soils or fluid recovery like LNAPL pumping or skimming.



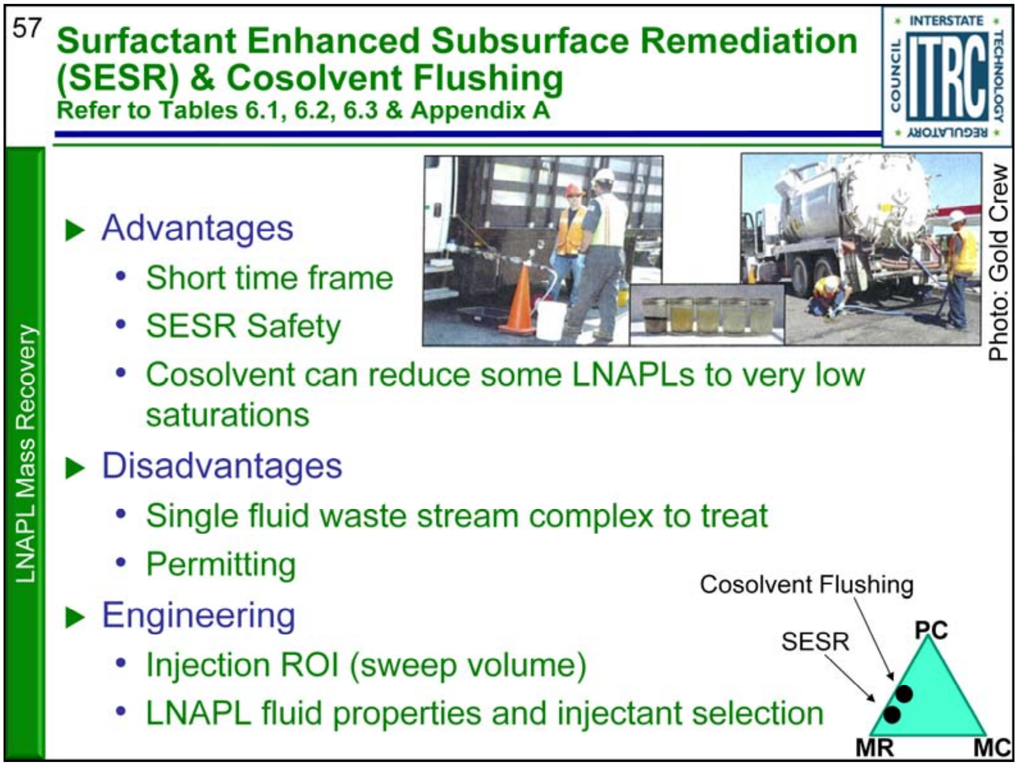
So here is our ternary diagram on the lower left. The dot indicates we are talking about Mass Recovery Technologies. Here are four examples of "simple" Fluid Recovery technologies. Skimming, Total Liquid Extraction, Vacuum enhanced skimming, or multi-phase extraction. As we have shown, technologies like Total Liquid Extraction, Vacuum enhanced skimming and MPE can also overlap into other groups such as Mass Control or Phase Change. You can refer to Tables 6.1 through 6.3 and Appendix A to learn more about these technologies.

We all know what excavation is. Excavation can also remove residuals. It is limited by what you can reach.



I will give you some high level examples of the mass recovery technologies
Water flooding without using hot water only increases the gradient
But Hot water flooding: also reduces the viscosity

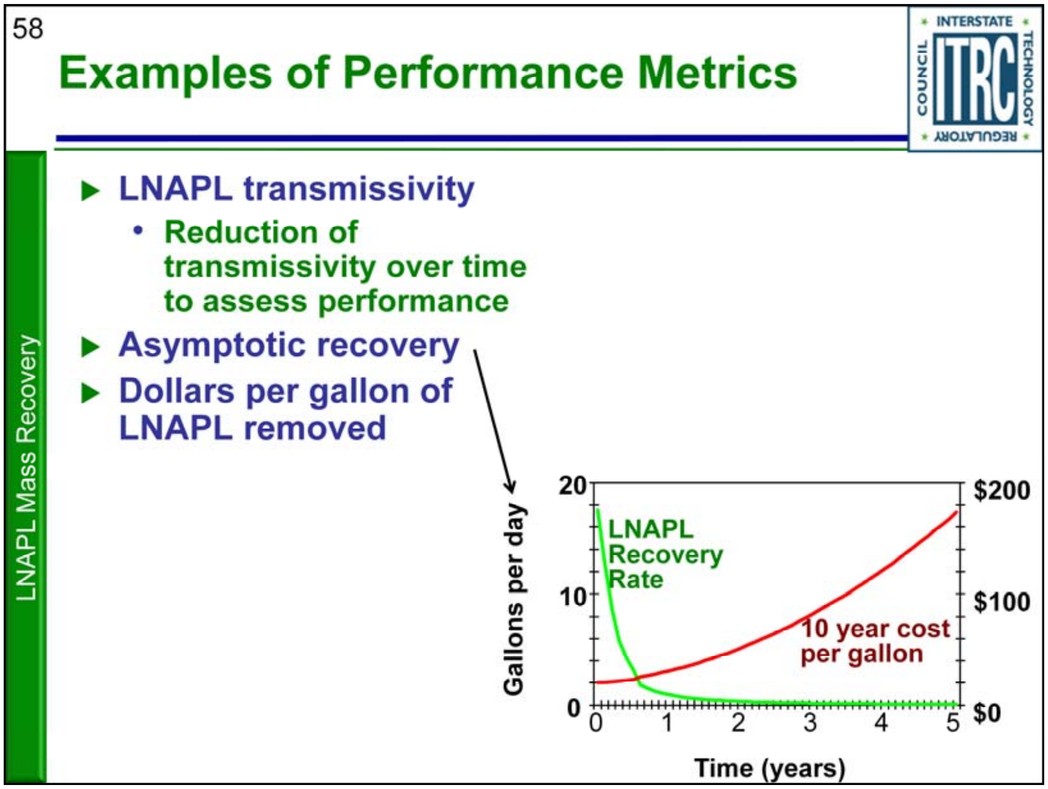
Image source: http://www.frtr.gov/matrix2/section4/D01-4-38.gif



This is (Surfactant Enhanced Subsurface Remediation) SESR and Cosolvent flushing. These are chemical processes. You can see here the advantages, disadvantages and engineering requirements.

Graphic shows surfactant injection followed by EFR/MPE type recovery in same well

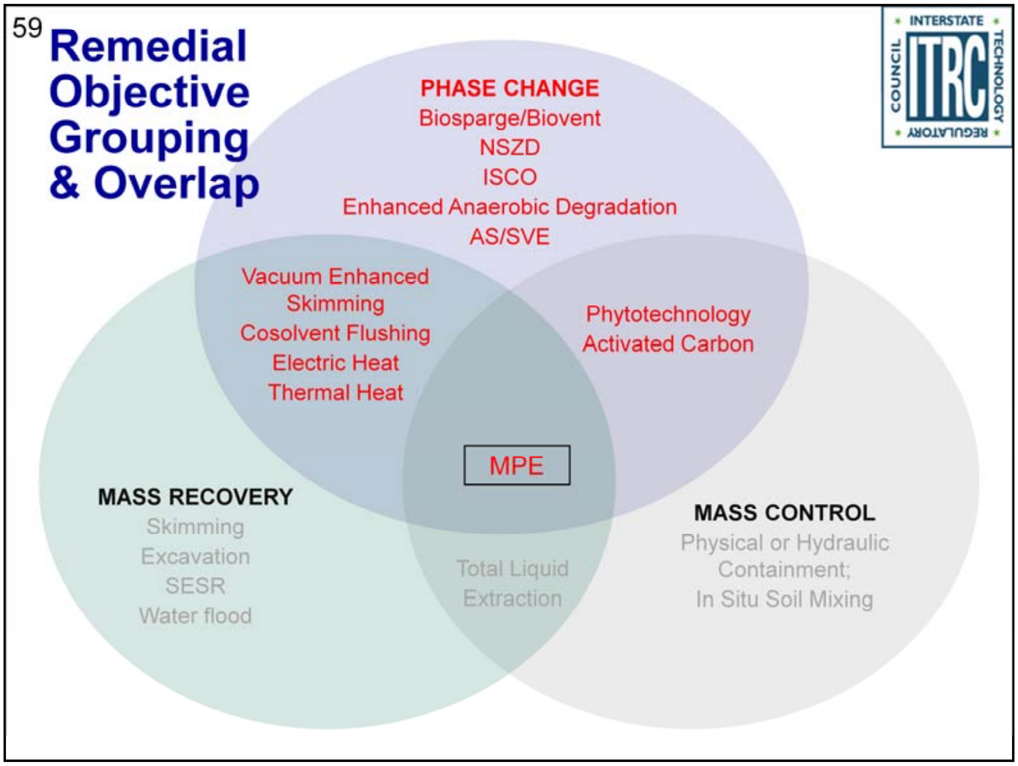
Gold Crew Release.



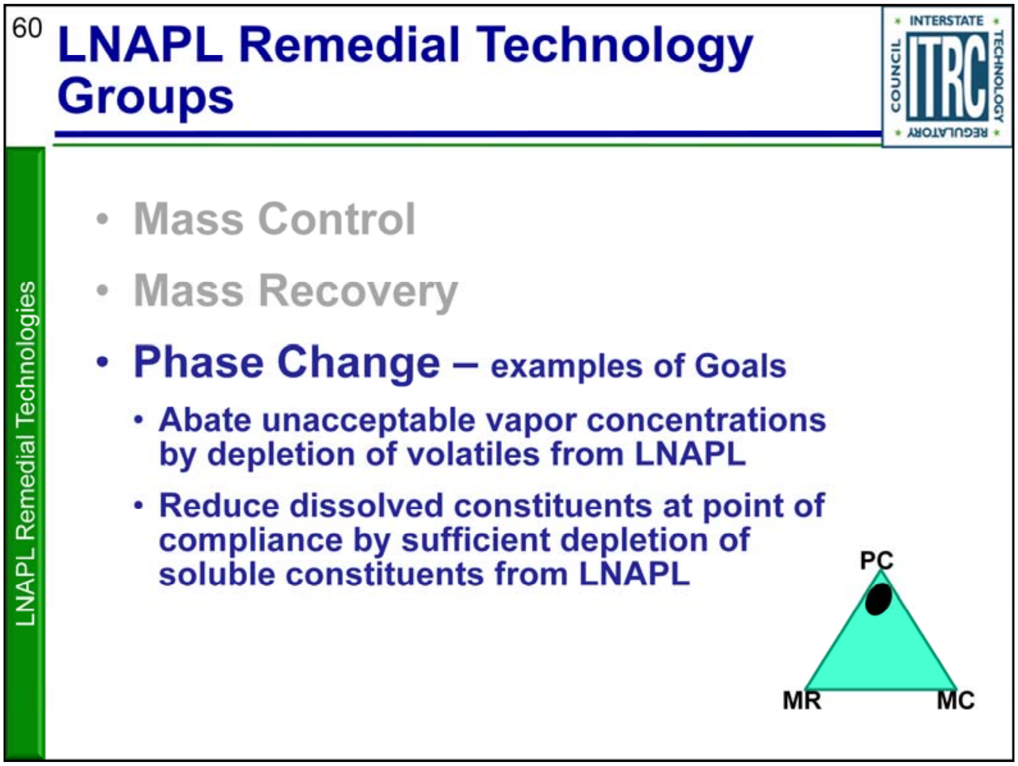
Example metrics are all about when a system has met its technological endpoint.

Here are some examples of performance metrics; Others are found in Table 5.2 and 6.3 in the Guidance Document

- The LNAPL transmissivity is low, making recovery ineffective
- You can use a decline curve analysis to indicate whether the system has reached its effectiveness.
- The unit cost of incremental mass removal can be a metric. The cost may outweighs the benefits of the amount of LNAPL recovered. Graphic: Shows a $/gallon or LNAPL removed metric. As systems approach their endpoint, less LNAPL is recovered, while O&M costs may remain at a constant level, increasing the cost of LNAPL removing as measured as $/gallon.



We will next talk about Phase Change Technologies. As we said some technologies fit within more than one group. An example is Phytotechnology and activated carbon with can fit within both Phase Change and Mass Control. MPE is a technology that fits into all three Groups. This is why it is often a successful technology.



Phase Change technologies do not directly remove LNAPL as do the mass recovery technologies. Instead, LNAPL phase change technologies change LNAPL to other phases. It does this by increasing the rates of volatilization, dissolution or degradation of the LNAPL constituents.

In Phase Change technologies, an example of a Goal can be

- abate vapor concentrations in the soil or vapor intruding into a building by depleting volatile constituents in the LNAPL.
- Or you reduce groundwater dissolved concentrations at a point of compliance by removing soluble constituents from the LNAPL. An example is reducing benzene in the LNAPL to reduce the benzene concentrations moving into the groundwater.

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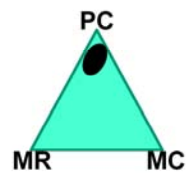
Phase Change Technologies

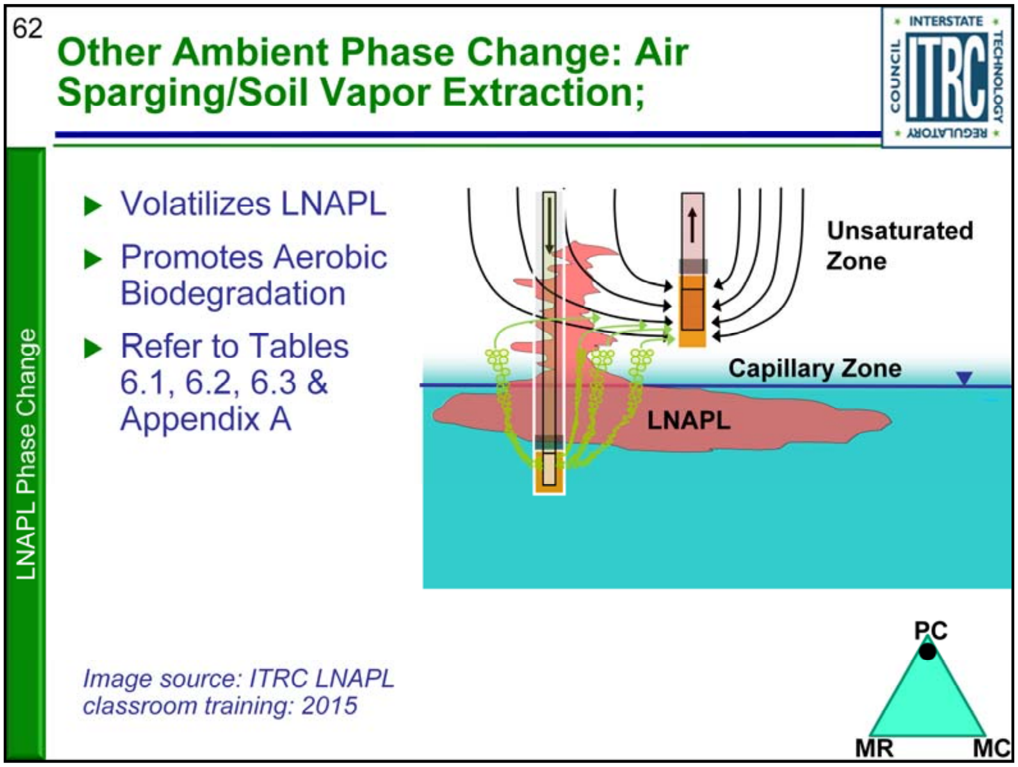
- **Ambient**
  - Natural Source Zone Depletion (NSZD)
  - AS/SVE
  - Biosparging and bioventing
  - MPE; Phytotechnology
- **Refer to Tables 6.1, 6.2, 6.3 & Appendix A**



We will now talk about ambient phase change technologies. LNAPL phase change technologies are primarily applicable to composition-based LNAPL remediation goals. The composition of the LNAPL is changed by loss of constituents that readily degrade, volatilize or dissolve from the LNAPL. Notice the dot in the ternary is now at the top, indicating Phase Change or PC.

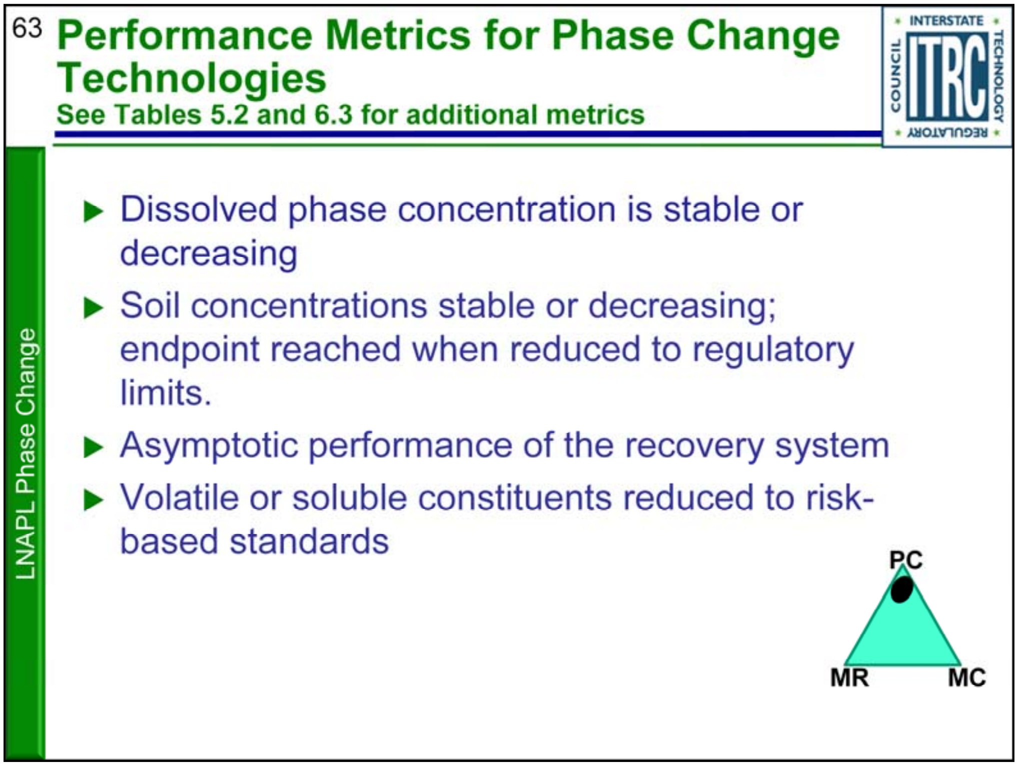
The ambient technologies are NSZD, Air sparge and SVE, Biosparging. MPE and Phytotechnologies can also be a phase change technology

photo source: BP



Here is the example of air sparging and soil vapor extraction

Above the water table LNAPL, is removed through soil vapor extraction while below the water table air sparging removes LNAPL. Since soil vapor extraction relies on soil gas flow to remove hydrocarbon constituents that are volatilized, the permeability and the moisture content of the soil are important, since this will affect rate at which pore flushings and hydrocarbon removal will occur. The volatility of LNAPL is another important factor. Volatile products such as gasoline will be removed much faster than for example diesel, for which a significant fraction is non-volatile and will not be removed by soil vapor extraction.



Here are some example SMART performance metrics for Phase Change Technologies:

- The dissolved phase concentration is stable or decreasing
- The soil concentrations are stable or decreasing
- you see an asymptotic performance of the recovery system
- volatile or soluble constituents of concern are reduced to risk-based regulatory standards in media of concern

Other possible metrics are suggested in Tables 5.2 and 6.3

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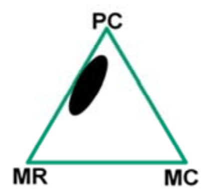
In Situ Thermal Technologies

- Mass Control
- **Mass Recovery**
- **Phase Change**



Finally, we will next talk about In Situ Thermal technologies.

These are both mass recovery and phase change technologies.

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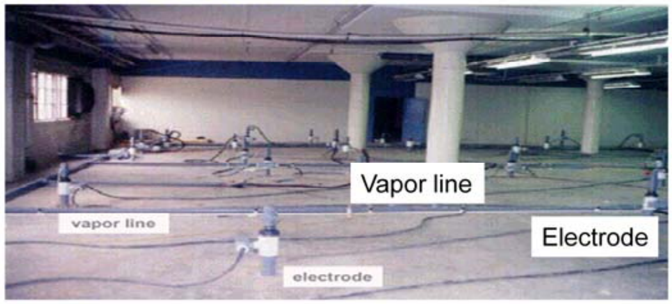
Heating Technologies

LNAPL Phase Change

- **Steam / Hot Air Injection**



- Others
  - **In Situ Smoldering (primarily combustion)**
  - **Thermal Conduction Heating**
  - **Electrical Resistance Heating**

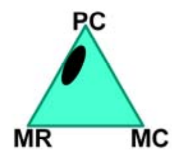
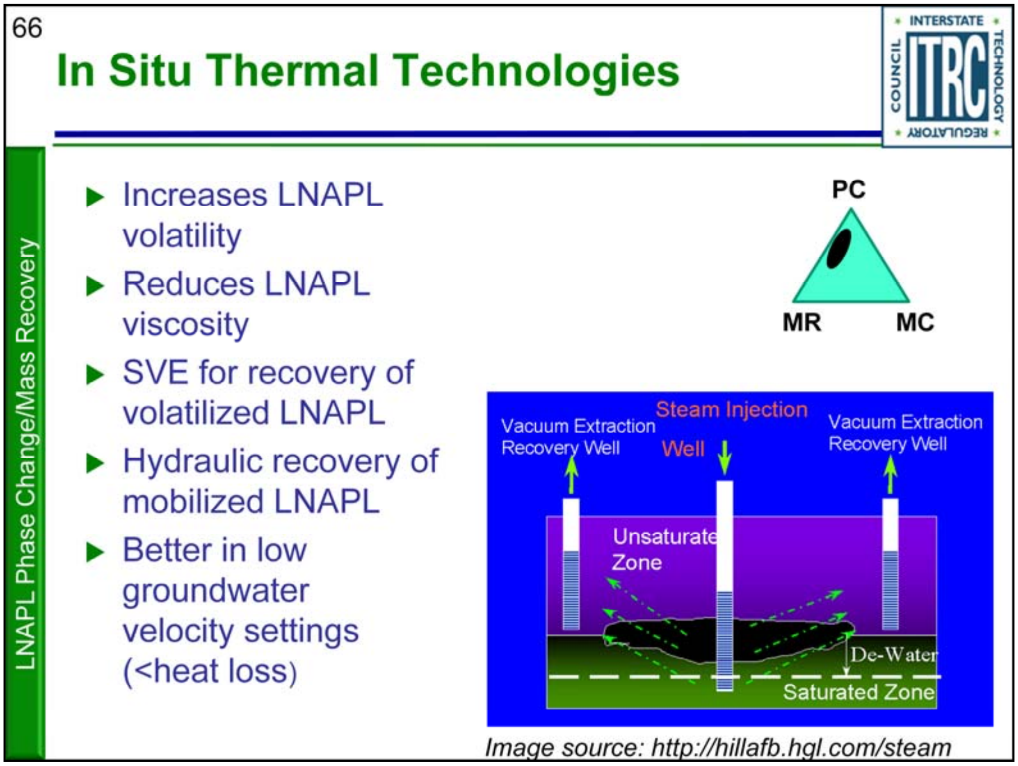


Image source: http://hillafb.hgl.com

The photo is an example of Steam or Hot Air injection. Another technology is In Situ smoldering, which is primarily a combustion process.

Others are thermal conduction heating and electrical resistance heating.

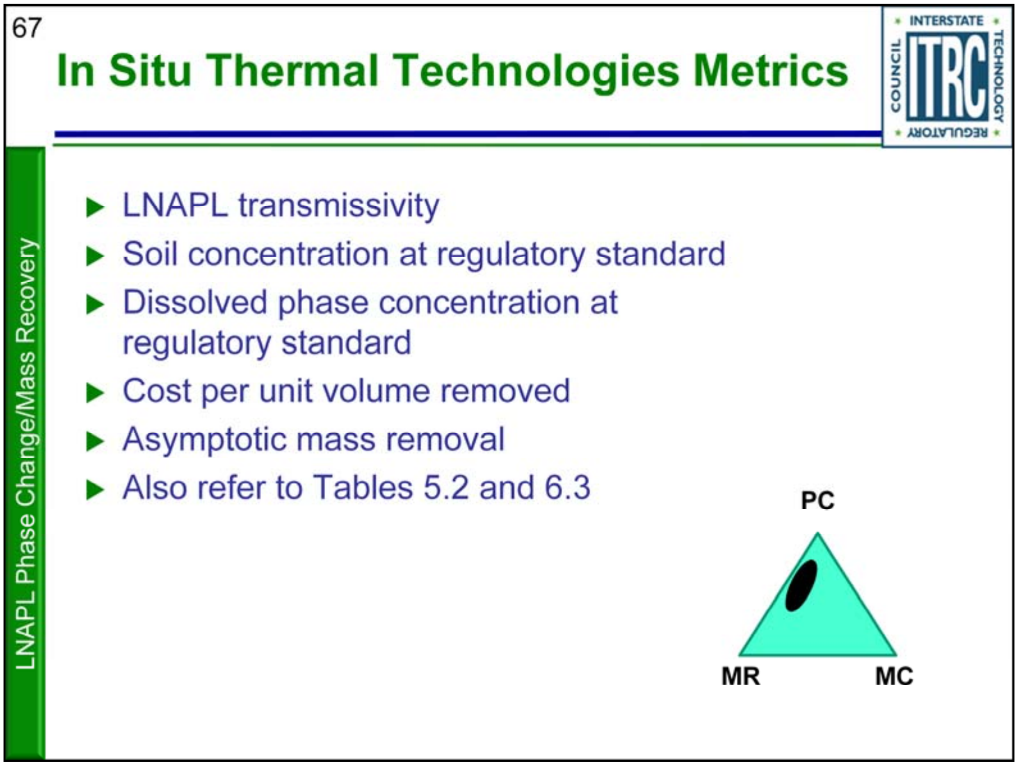
Image source: http://hillafb.hgl.com/steam_cartoon.gif



These In Situ heating technologies increase the LNAPL volatility and reduces the viscosity. For these technologies, both SVE for volatilized LNAPL and hydraulic recovery is likely needed. And they are better in low groundwater velocity settings.

So now you have a snapshot of the 21 technologies, their groupings and how to select them. You can find more about all of these technologies in the Guidance Document.

Next I will turn it over to Justin Meredith and Joann Dyson.



Here are some example metrics for In Situ Thermal Technologies. They are similar to other technologies. LNAPL transmissivity is a good one. You can have soil concentrations or dissolved phase concentrations at regulatory standards. And also like we have discussed: Cost per unit volume removed and asymptotic curve for mass removal. Just make sure and refer to Tables 5.2 and 6.3 in the guidance document.

So now you have a snapshot of the 21 technologies, their groupings and how to select them. You can find more about all of these technologies in the Guidance Document.

Next we will have a Q&A. Then we will turn it over to Justin Meredith of the Tennessee Department of Environment and Conservation and Joann Dyson of West Central Environmental Consultants.

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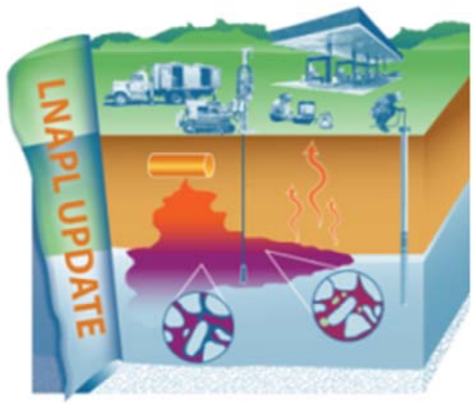
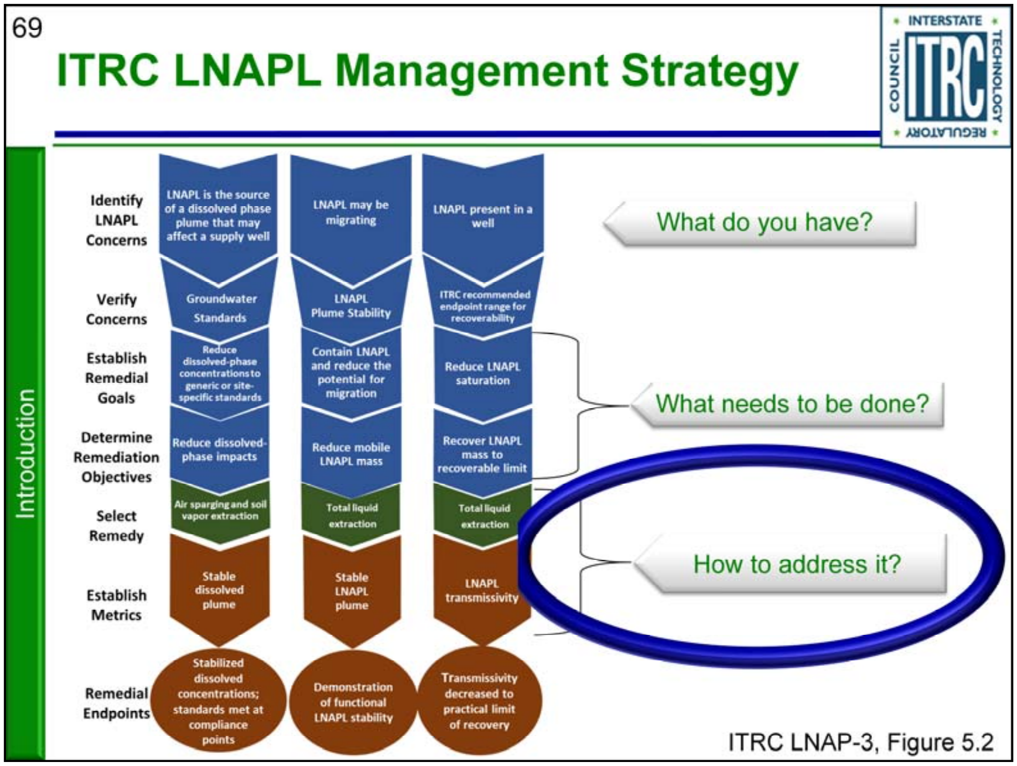
Q&A Break

Follow ITRC



- 1st Question and Answer Break

No associated notes.



[Regulator]

Let's take another look at this flow chart to remind us where we are in the LNAPL management strategy presented in the Guidance document.

[CLICK] The previous two training sessions covered how to determine "what you have" and "what needs to be done". **[CLICK]** Now we can start making informed decisions about remedial technology selection to address it.

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LNAPL Remediation Technology Selection

Objectives

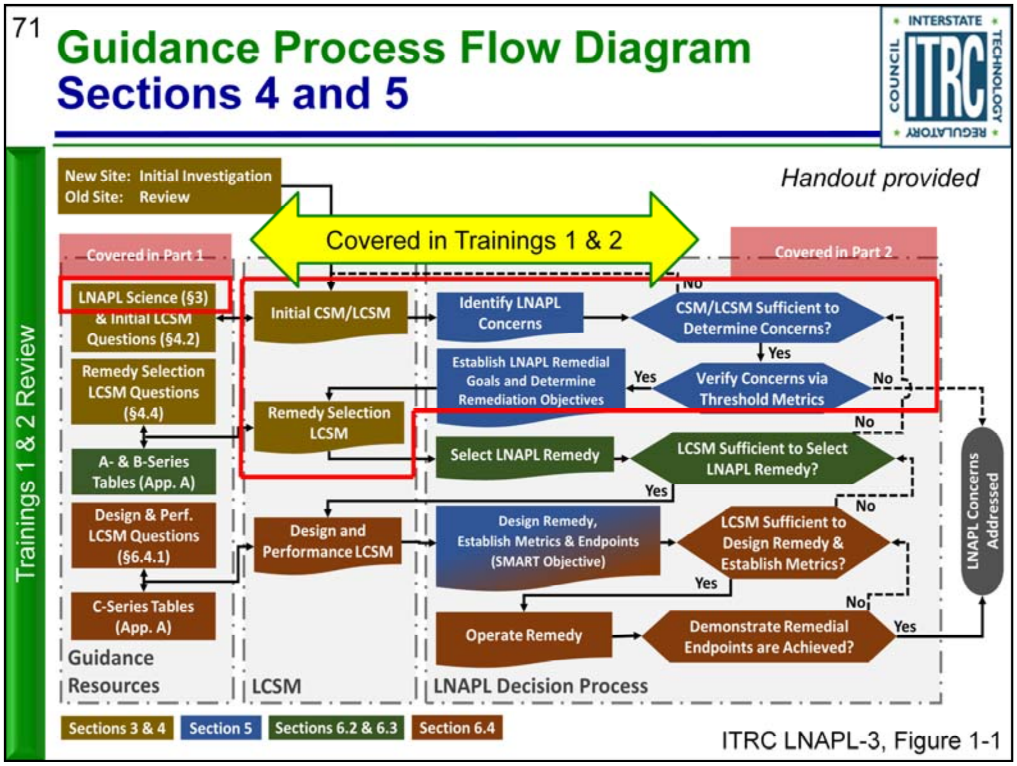
Learning Objectives:

- Learn about the Technology Selection Process
- Apply Remedy Selection Process to a real site

[Regulator]

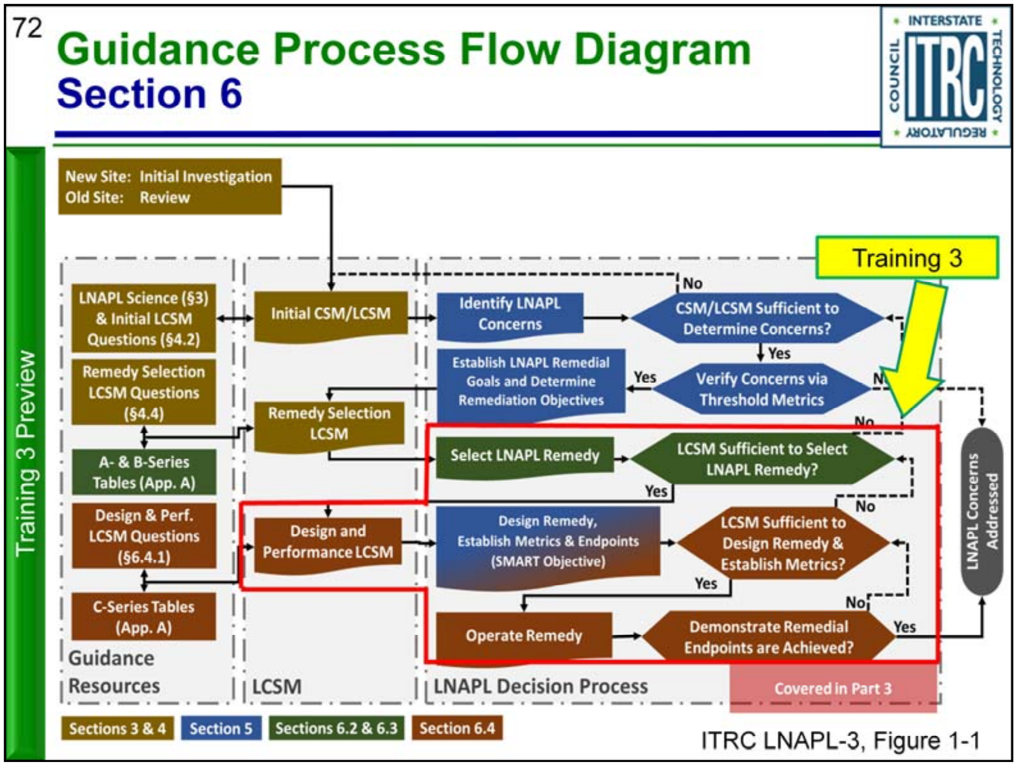
The objectives for this portion of the training are to learn the technology selection process and, ultimately, to be able to apply the Guidance from start to finish to a real site, which incorporates all three trainings.

[CLICK] We're going to start with an overview of the technology selection process.



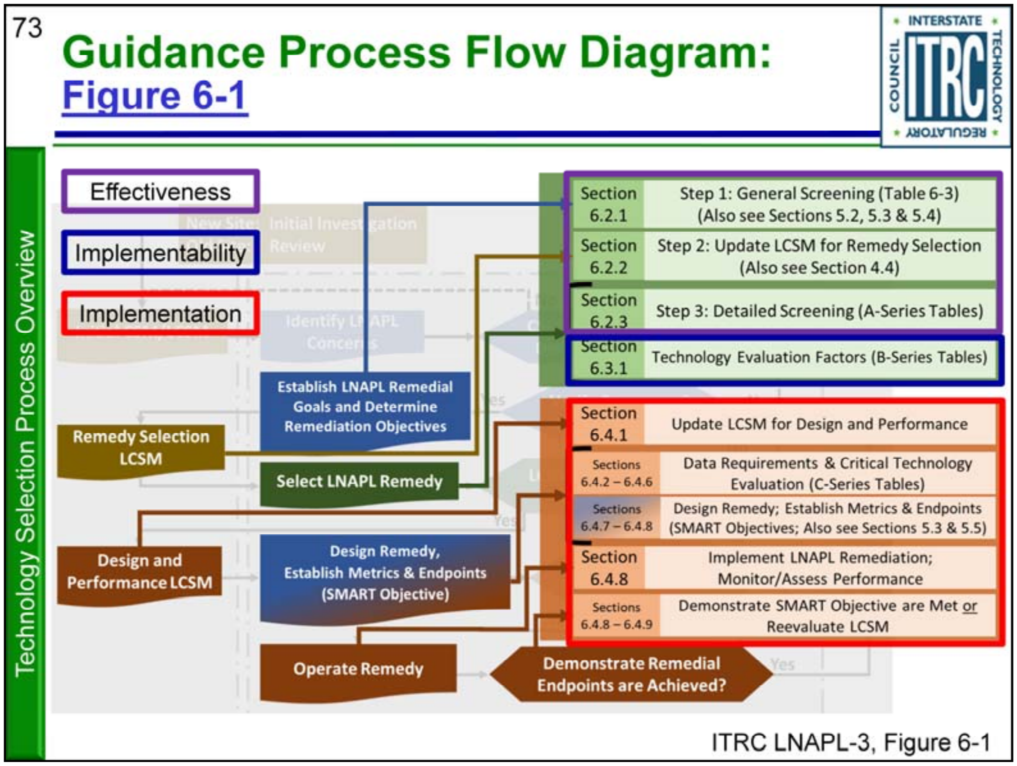
[Regulator]

Trainings 1 & 2 covered topics in this portion of the Guidance Process Flow Diagram.



[Regulator]

In Training 3, we will cover topics in this portion of the Guidance Process Flow Diagram, but you will see that we will be using the knowledge gained from Trainings 1 & 2.

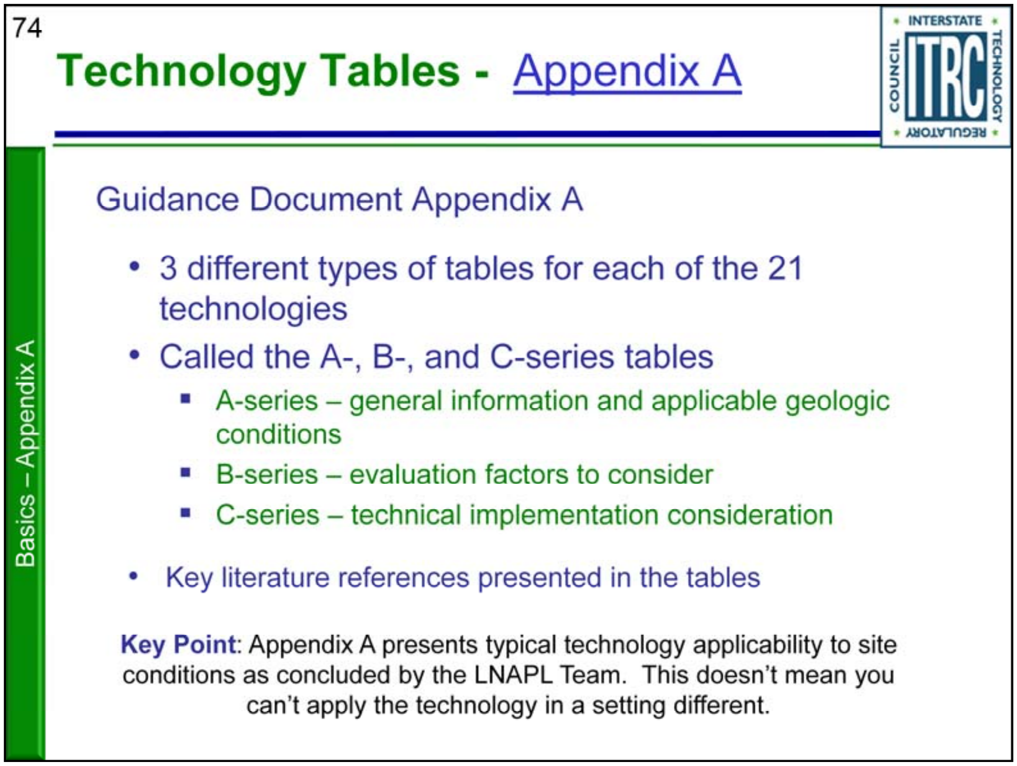


[Regulator]

Here's a portion of the process flow diagram with details added to show you that each box in the diagram can represent more than one action. This is Figure 6-1 in the LNAPL Guidance.

The remedial technology selection process involves a **[CLICK]** preliminary screening, which screens the technologies for effectiveness. The goal of Step 1 is to identify all possible LNAPL technologies for your site from the list of 21 technologies presented in this Guidance. Step 1 uses your site-specific LNAPL concerns, remedial goals and remediation objectives along with Table 6-3 to determine a subset of technologies that fit your site. So all of the information from the three training classes comes together when it's time to determine a remedial technology. In step 2, you reevaluate your LCSM based on your list of technologies from Step 1 and determine whether it needs updating. This may include collecting additional data or further evaluating goals & objectives. In Step 3, you further screen the technologies in your list based on site-specific geologic factors and information found in the A-series tables in Appendix A. This completes the preliminary screening, leaving a short list of possible technologies to further consider for your site.

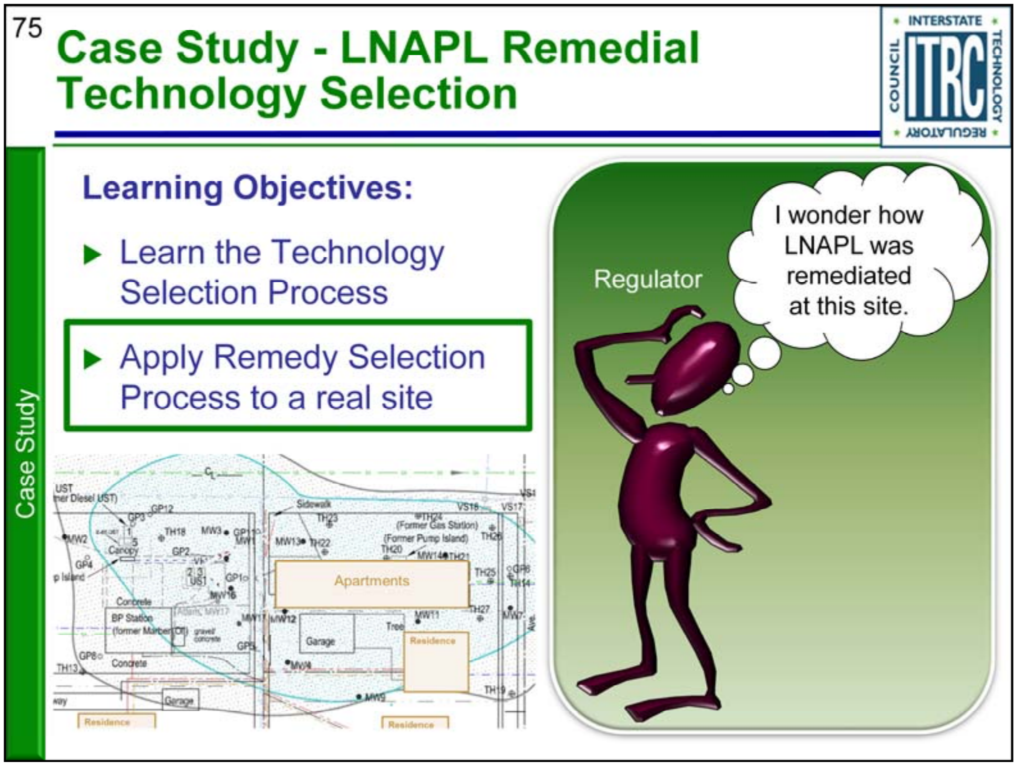
This initial screening is followed by **[CLICK]** an evaluation of the technologies in your short list for implementability using factors found in the B-series tables in Appendix A. **[CLICK]** The remaining steps evaluate the technologies for implementation using the C-series tables in Appendix A. Keep in mind that at several points throughout the technology selection process, you should reevaluate your LCSM and update it, if necessary.



[Regulator]

I'm going to take a minute here to discuss Appendix A. Appendix A contains three different types of tables for each technology. These three tables are called the A-, B-, and C-series tables. The A-series table contains general information about a technology and geologic conditions under which the technology is applicable. The B-series table lists more detailed factors to use in evaluating a technology for your site. And the C-series table will contain technical information to consider before implementation.

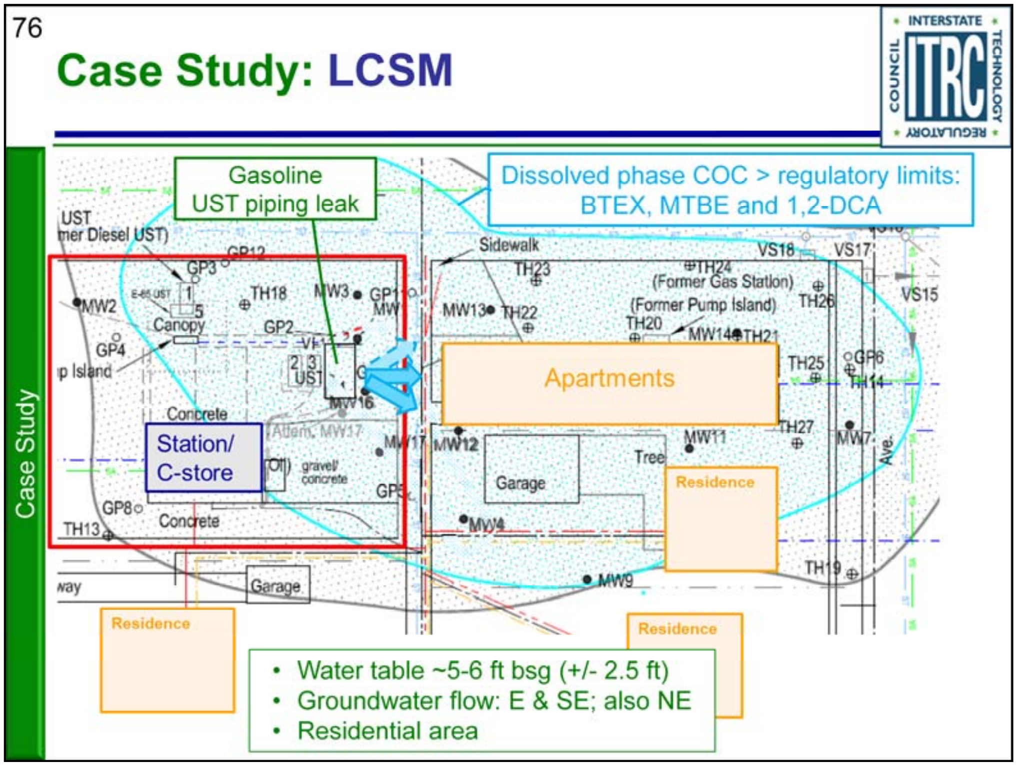
These tables are a good place to start if you want to learn about a specific technology, but we will show you how to use the information during the remedy selection process to help narrow the list of possible technologies.



[Regulator]

That was a quick overview of the technology selection process. Now we'll go through a case study so we can show you how to apply the document to a real site and the details of each of those steps. Here to help me is…..[Consultant].

I'm a regulator and I'm interested in knowing more about this LNAPL site that you remediated and how you used this LNAPL process as a consultant. Can you tell me about it?

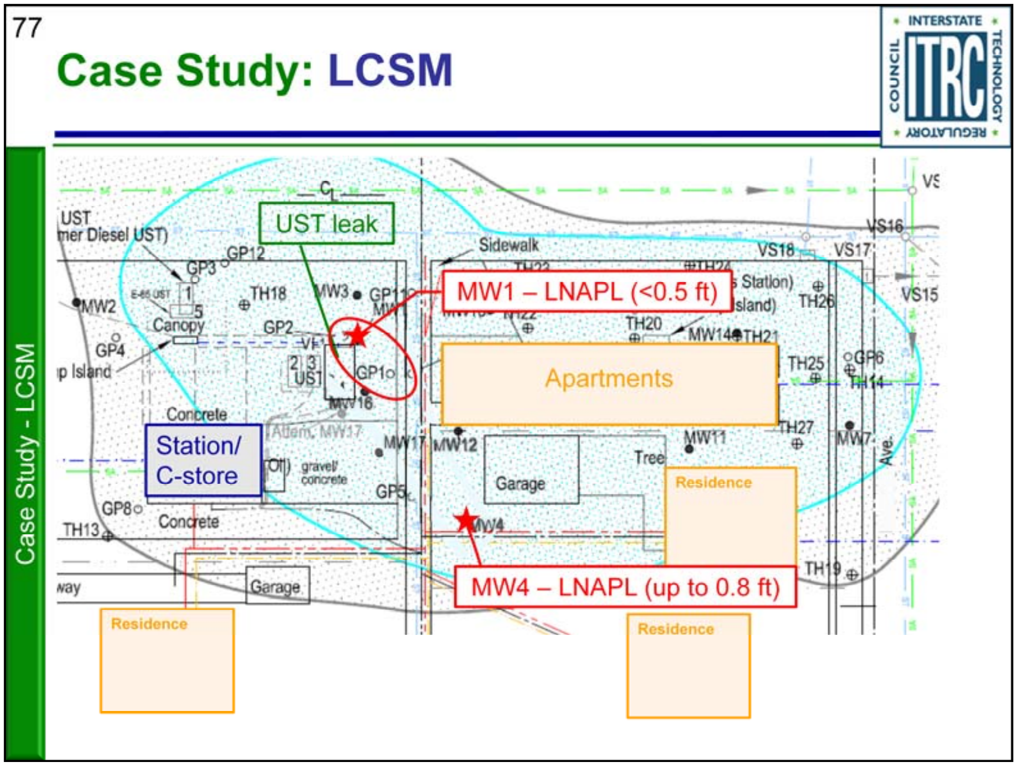


[Consultant]

I'd be happy to discuss this project with you. First I'll tell you about the site. This was an active filling station with a small convenience store. In 2000 **[CLICK]**, a leak was discovered that was determined to be a piping leak from a gasoline underground storage tank. Through groundwater monitoring over several years, we knew the water table **[CLICK]** was typically 5-6 feet below surface grade, but fluctuated seasonally as much as 2.5 feet above and below this level. Groundwater flow was observed to the E and SE the majority of the time **[CLICK]**, but was also observed to the NE. The dissolved-phase contaminants of concern **[CLICK]** above regulatory limits were BTEX compounds, MTBE, and 1,2 dichloroethane (or 1,2-DCA). There were apartments and residences surrounding the station, and the residences all have basements and sump pumps, and there's an alley that runs between the site and apartments with a utility corridor.

All of this information was used to build our initial LCSM for the site. Section 4 of the LNAPL Guidance discusses the evolution of the LCSM through corrective action. Section 4.2 provides key questions to guide the development of the initial LCSM, such as…"is the source and extent of the LNAPL known", "are dissolved or vapor plumes characterized", and "are exposure pathways complete"?

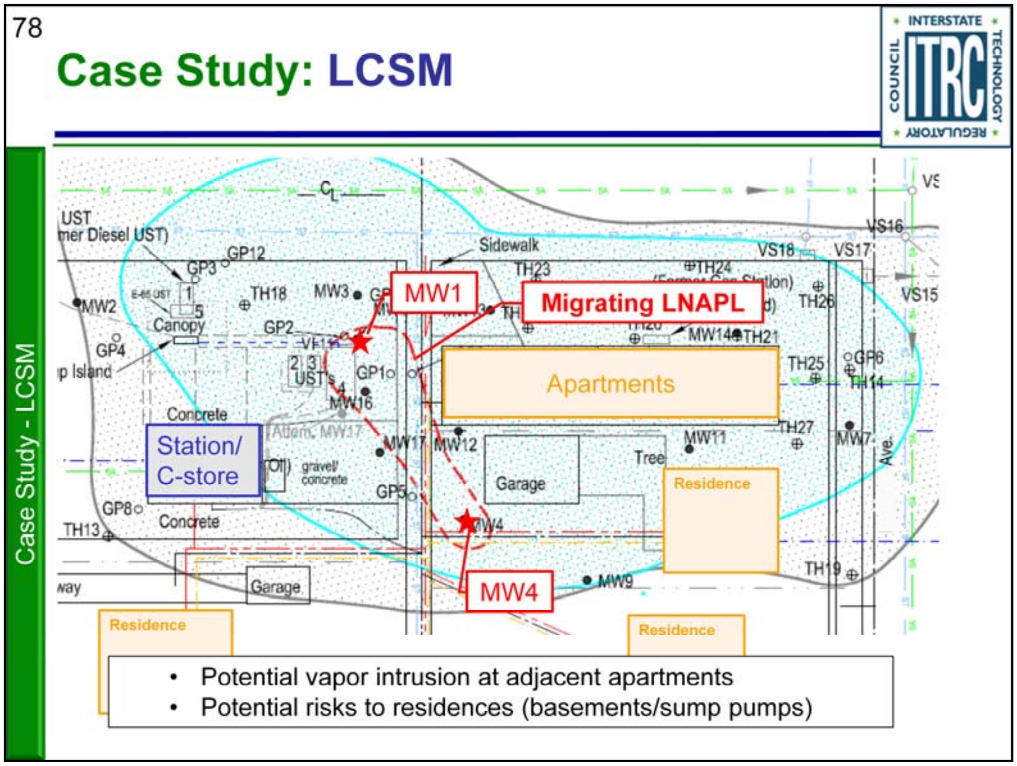
At this point in our investigation, the source appeared to be limited to the tank basin area, and we had characterized the dissolved phase plume. The source area was likely larger at one time based on the size of the dissolved-phase plume. Since vapors were a concern, we referred to the ITRC Petroleum Vapor Intrusion (or PVI) document. Section 3.3 shows we would need a vertical separation of at least 5 feet between the building foundation and the water table due to the dissolved phase plume to say we have an incomplete pathway with no further investigation needed. At this site, our water table was typically 5-6 feet bsg, but fluctuated, so the vertical separation was too small to discount vapor intrusion, especially since the basements are approximately 6 feet bsg. Since we needed to learn more about the exposure pathways, we started monitoring the vapors below the apartment building and soil gas near the downgradient residences.



[Consultant]

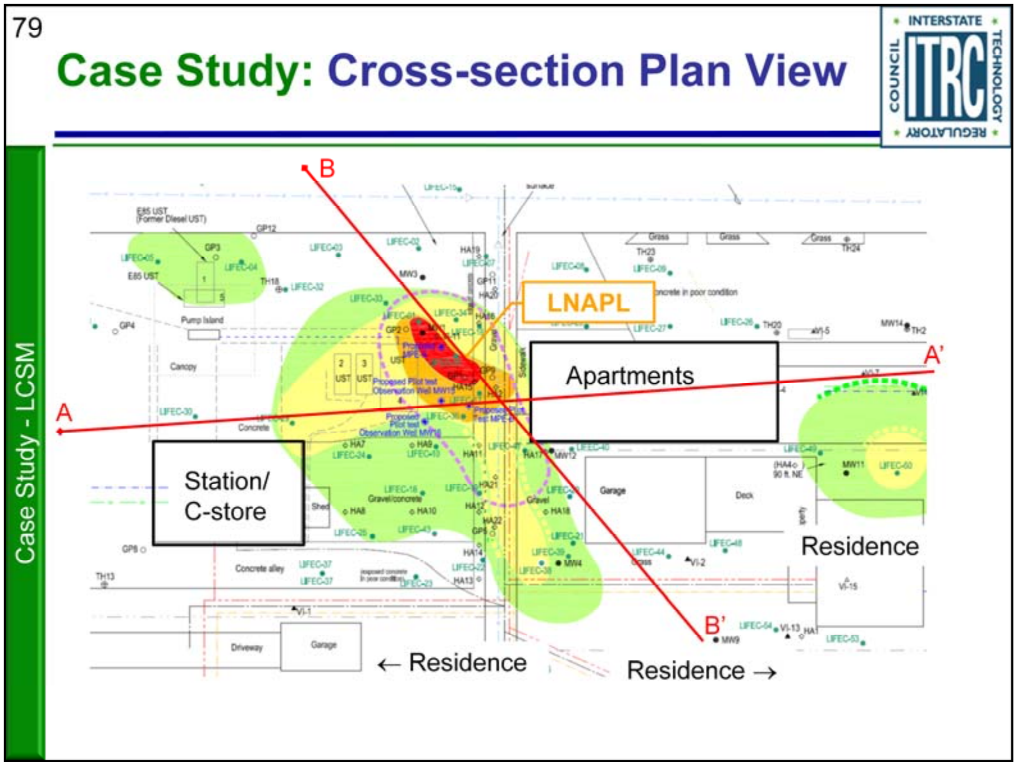
After about 3 years of groundwater monitoring, LNAPL appeared in monitoring well MW1 with thicknesses always less than 1/2 foot. With this new observation, we clearly needed to define the extent of LNAPL outside the tank basin and re-develop our LCSM. An LIF investigation was performed to delineate the source and determine the extent of LNAPL. This investigation indicated a gasoline LNAPL body around MW1 **[CLICK]** and to the SE toward the alley, with LNAPL at a depth of approximately 8 feet bsg.

About 8 yrs. after the release, **[CLICK]** LNAPL was observed in the downgradient offsite well MW4 at thicknesses up to 0.8 feet. We noticed this occurred when the water table at the site dropped 3-5 feet. An additional LIF investigation was conducted, to see if we could determine if LNAPL had migrated in the past from MW1 to MW4 and was now exposed by the dropping water table, or if LNAPL was migrating during current low water table conditions.



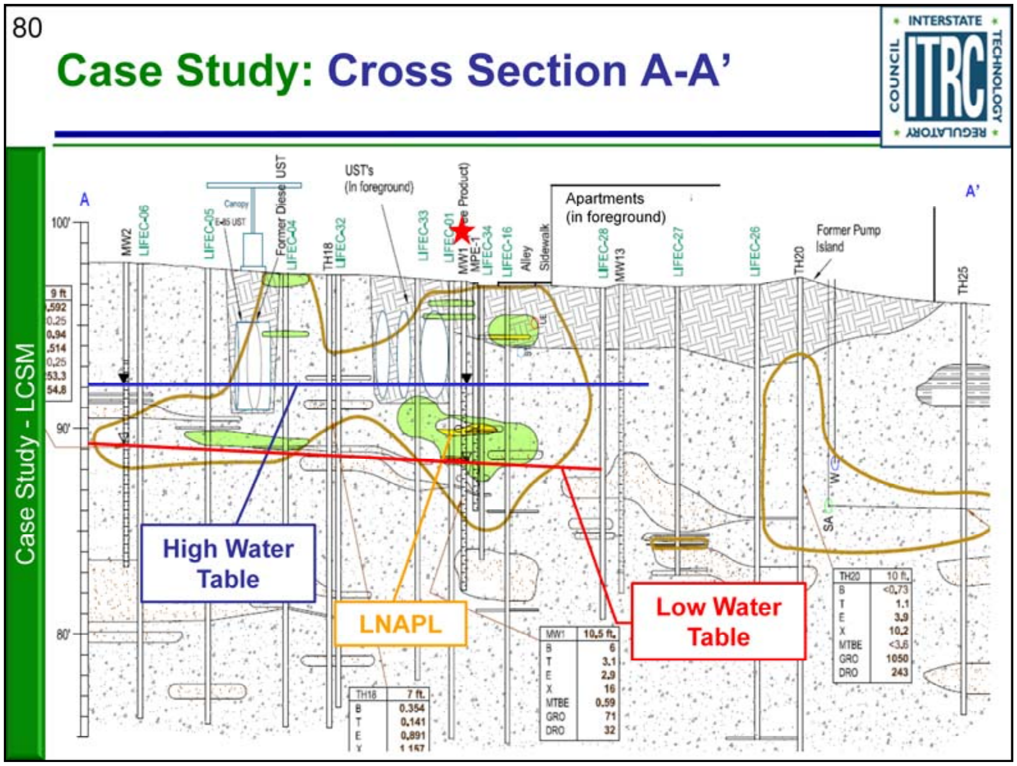
[Consultant]

This additional LIF investigation showed LNAPL along the path from MW1 to MW4 that was previously not observed, indicating LNAPL had migrated under the current low water table from the area around MW1 to the residential property to the SE. **[CLICK]** We already knew there were potential vapor intrusion risks at the adjacent apartments and nearby residences due to dissolved-phase contamination, but now there was a potential risk of LNAPL in basements or sumps of downgradient residences if migration continued. Referring back to the question in Section 4.2 of the Guidance about the LNAPL source and extent – we now knew the LNAPL body was not stable, but migrating to the SE, so the extent was unknown.



[Consultant]

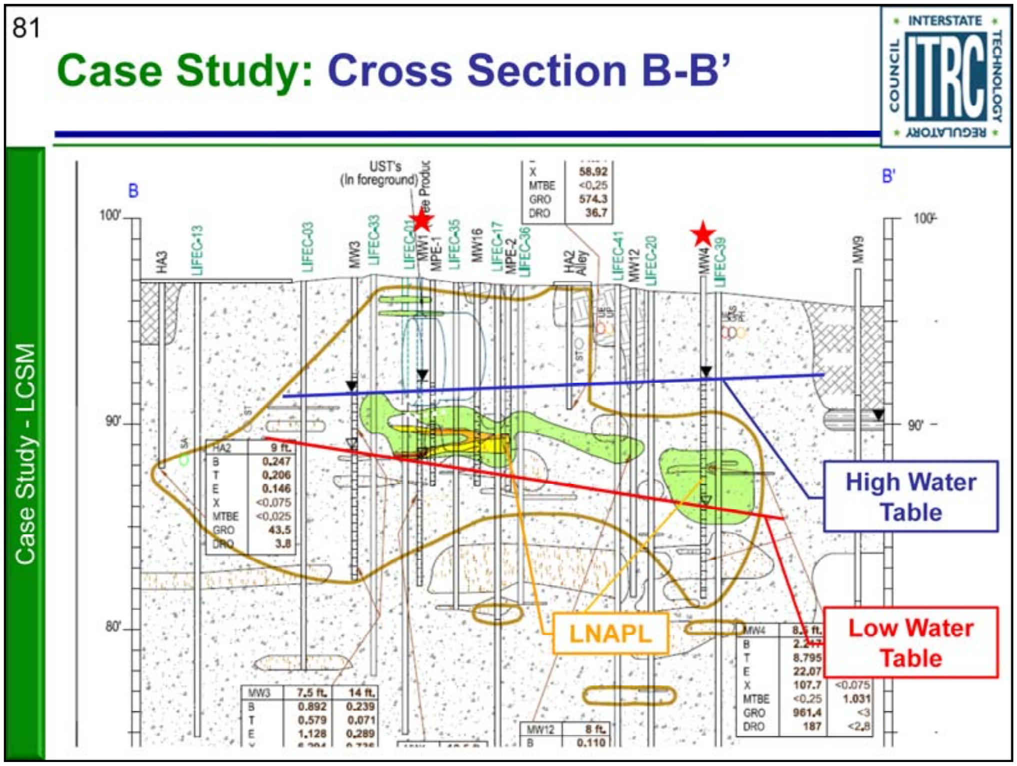
This plan view shows the LNAPL plume determined from the LIF investigations, with the red indicating the most saturated area. Next, we'll look at two cross-sections where we can see the site heterogeneity and the vertical distribution of the LNAPL **{CLICK}** Cross-section A-A' runs west to east across the site and includes the tank basin area and the apartments. **[CLICK]** Cross-section B-B' runs northwest to southeast and includes the LNAPL migration path from MW1 to MW4.



[Consultant]

Cross Section A-A' shows that the

- Native soil is mainly clay-rich till. There are sand lenses from 4 inches to 5 ft thick located throughout at depths of 5-26' bsg.
- High water table is shown by the blue line. Low water table is shown by the red line.
- LNAPL body below MW1 is labeled.



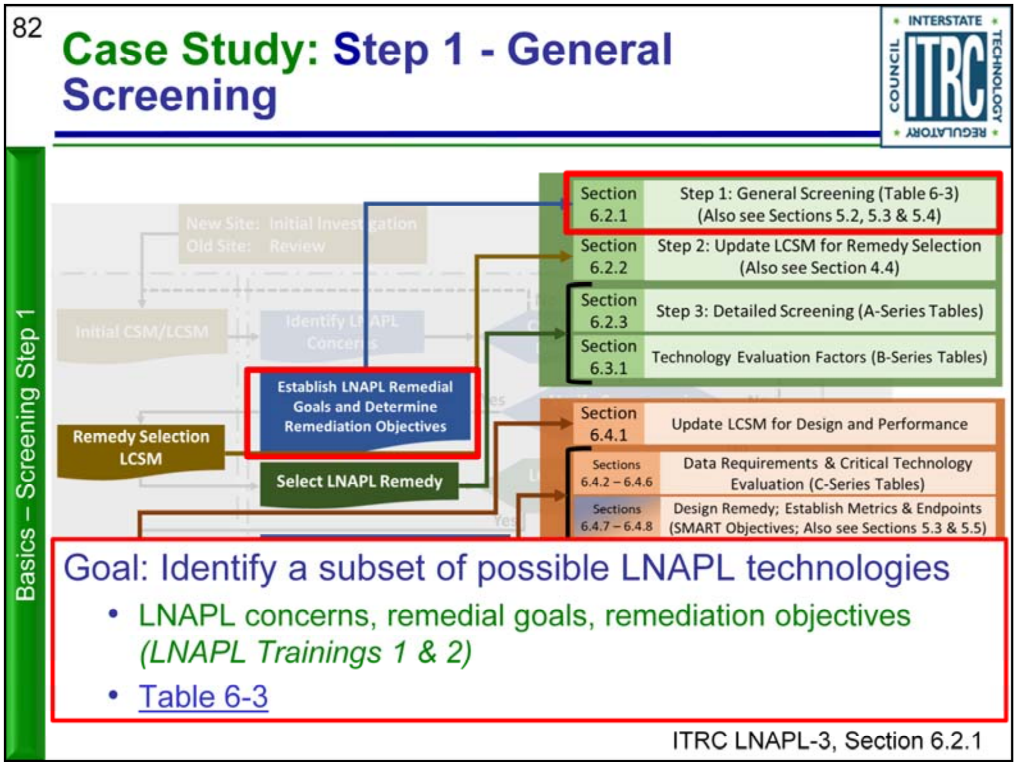
[Consultant]

Cross Section B-B' includes MW1 and MW4:

Again, the high water table and low water table.

And the LNAPL body can be seen below MW1 and MW4; the smear zone around MW4 is only in the lower half of the fluctuating water zone.

(No apparent permeable sand lenses observed in the upper depths.).



[Regulator]

It looks like you developed a thorough LCSM for this site. I know the first step in remediation selection is to determine remedial goals and remediation objectives based on site concerns, and use those along with Table 6-3 to develop a sub-set of possible technologies. So this step uses concepts that were developed in Trainings 1 & 2. From a Regulator perspective it looks like there are a lot of concerns for this site involving the protection of human health and the environment. Can you take me through this first screening step for your site?

Case Study: Site LNAPL Concerns

Case Study – Step 1

- LNAPL migrated SE during low groundwater elevations
- Large dissolved plume above regulatory limits
  - COC: BTEX, MTBE and 1,2-DCA
- Vapor plume
  - Potential vapor intrusion at adjacent apartments
  - Potential risks for residences (basements/sump pumps)

**Site moved to aggressive site status by Agency

[Consultant]

There were several concerns at this site – mobile LNAPL migrating to the SE during periods of low groundwater; dissolved-phase contamination above regulatory limits; and potential vapor intrusion issues. Although not a concern, an additional factor we did have to consider was that the site was added to “aggressive site cleanup” status by the regulatory agency.

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Knowledge Check

Poll Question

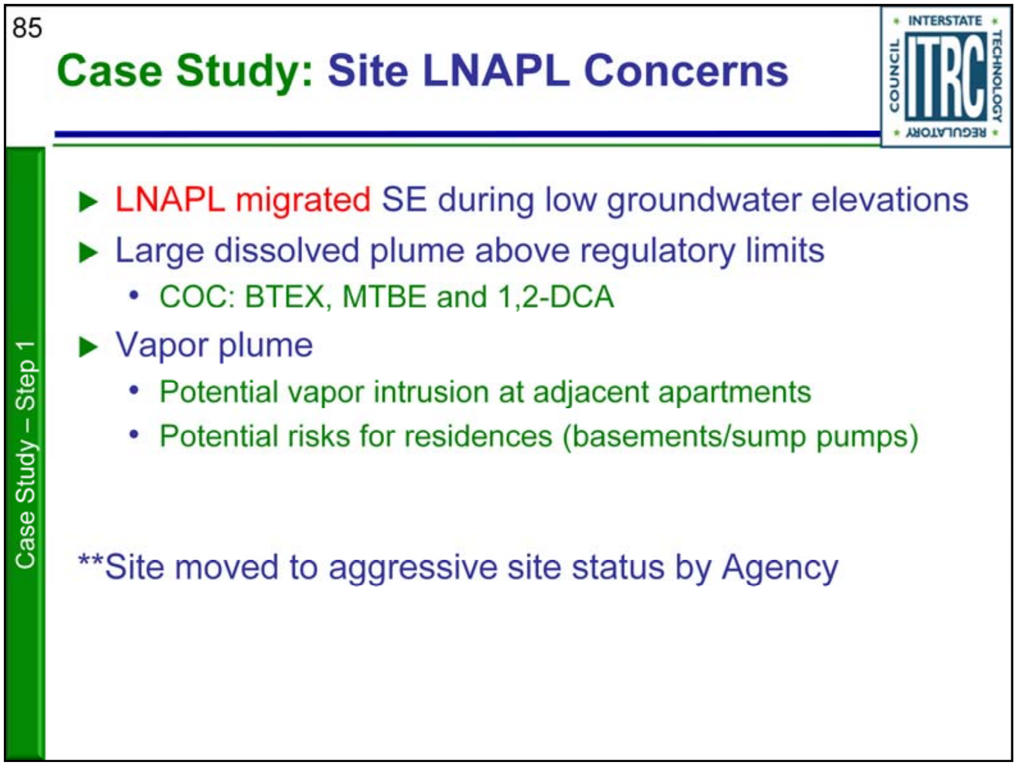
- Which concern would you consider to be the highest priority for this site?
  A. Migrating LNAPL
  B. Large dissolved plume above regulatory limits (COCs: BTEX, MTBE, 1,2-DCA)
  C. Vapor plume/vapor intrusion risks to off-site properties

[Regulator]

Let’s do a poll (knowledge check) question.

Results…

Joann what did you decide for this site?



[Consultant]

We decided to concentrate on the migrating LNAPL, knowing that in addition to the risk of the LNAPL itself entering a basement or sump, this could create higher dissolved-phase and vapor intrusion risks at the downgradient residences if migration continued. We also realized that it may be possible to address more than one concern with the right technology.

Case Study: Step 1 – Goals, Objectives & Table 6-3

Case Study - Step 1

Table 6.3 Preliminary screening matrix

LNAPL remedial goal	LNAPL remediation objective	Technology group	Potentially useful LNAPL technology	Applicable Site Conditions					
				Geology (a)		Zone (b)		LNAPL type (c)	
LNAPL saturation-based remedial objectives									
Terminate LNAPL body migration and reduce potential for LNAPL migration	Abate LNAPL body migration by sufficient physical removal of mobile LNAPL mass	LNAPL mass recovery	• Excavation	F	C	U	S	LV/LS	HV/HS
			• Skimming		C		S	LV/LS	HV/HS
			• Vacuum enhanced skimming	F	C	U	S	LV/LS	HV/HS
			• Total liquid extraction		C		S	LV/LS	HV/HS
			• MPE	(F)	C	U	S	LV/LS	HV/HS
	Stop LNAPL migration by physical barrier	LNAPL mass control	• Phytotechnology	F	C	U	S	LV/LS	HV/HS
			• Physical containment	F	C		S	LV/LS	HV/HS
			• In situ soil mixing	F	C	U	S	LV/LS	HV/HS
Reduce LNAPL saturation when LNAPL is within residual range	Recover LNAPL to practicable limit	LNAPL mass recovery	• Excavation	F	C	U	S	LV/LS	HV/HS
			• Skimming		C		S	LV/LS	HV/HS
			• Vacuum enhanced skimming	F	C	U	S	LV/LS	HV/HS
			• Total liquid extraction		C		S	LV/LS	HV/HS
			• MPE	(F)	C	U	S	LV/LS	HV/HS

[Consultant]

For Step 1 of the screening process, we needed to identify a goal and objective to remediate our migrating LNAPL concern. Here's a Section of Table 6-3. The columns are…remedial goals, remediation objectives, technology groups, possible technologies, and applicable site conditions. The full table includes an additional column after site conditions with examples of performance metrics that we will discuss later.

For Step 1, we determined that the LNAPL remedial goal from Table 6-3 **[CLICK]** that corresponded to our concern was "Terminate LNAPL…".

The remediation objective we selected **[CLICK]** to accomplish our goal was "Abate LNAPL…".

To achieve this objective, we would use technologies **[CLICK]** in the LNAPL mass recovery technology group, which includes **[CLICK]** these 5 LNAPL technologies: **"**Excavation, Skimming…." So these are the technologies we initially considered.

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Case Study: Table 6-3 Geologic Factors

Basics – Table 6-3

Table 6.3 Preliminary screening matrix

LNAPL remedial goal	LNAPL remediation objective	Technology group	Potentially useful LNAPL technology	Applicable Site Conditions: Geology (a)		Zone (b)		LNAPL type (c)	
LNAPL saturation-based remedial objectives									
Terminate LNAPL body migration and reduce potential for LNAPL migration	Abate LNAPL body migration by sufficient physical removal of mobile LNAPL mass	LNAPL mass recovery	• Excavation	F	C	U	S	LV/LS	HV/HS
			~~• Skimming~~		C		S	LV/LS	HV/HS
			• Vacuum enhanced skimming	F	C	U	S	LV/LS	HV/HS
			~~• Total liquid extraction~~		C		S	LV/LS	HV/HS
			• MPE	(F)	C	U	S	LV/LS	HV/HS

- Geology
  - Fine grained soils (F)
  - Coarse grained soils (C)
- Zone
  - Unsaturated zone (U)
  - Saturated zone (S)
- LNAPL type
  - Low Volatility/Low Solubility (LV/LS)
  - High Volatility/High Solubility (HV/HS)

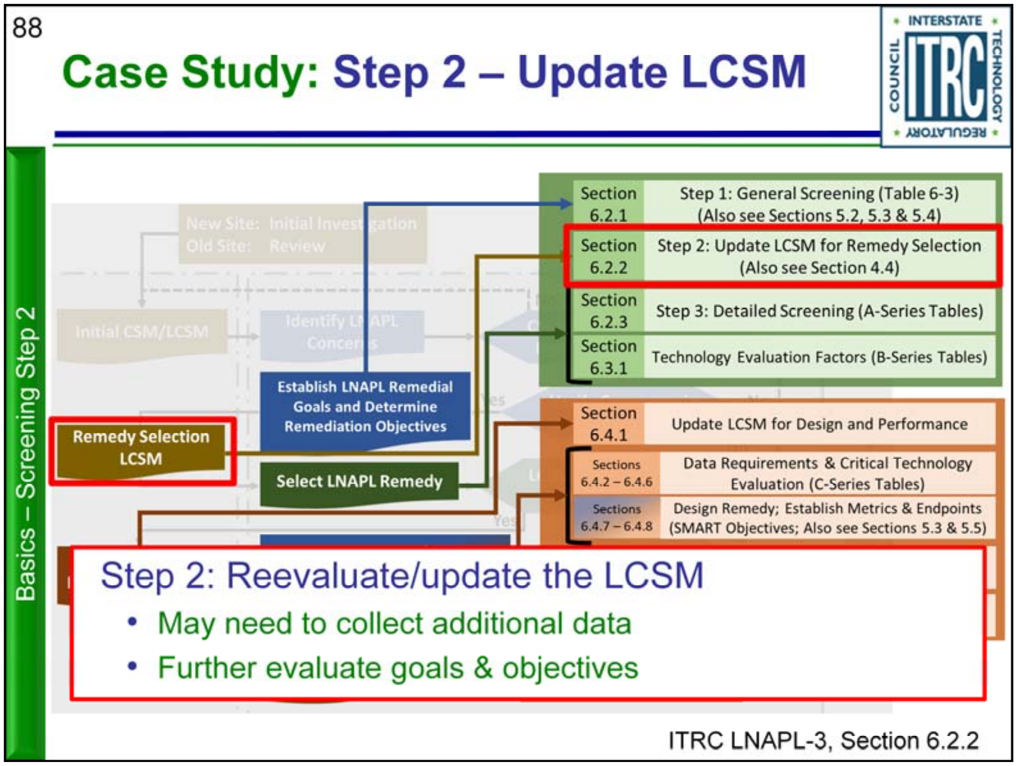
ITRC LNAPL-3, Section 6.2.1

[Consultant]

Even though the full list of geologic factors and detailed information can be found in the A-series Tables in Appendix A, Table 6-3 summarizes three factors **[CLICK]** for each of the technologies listed, providing an additional screening of the technologies. The geologic factors on Table 6-3 include:

- geology – whether the soils at the site are fine or coarse grained;
- the impacted zone – is LNAPL in the saturated or unsaturated zone;
- and the LNAPL type – whether you have low volatility and solubility or high volatility and solubility.

Since our site was mainly fine grained, **[CLICK]** we were able to eliminate skimming and total liquid extraction since these technologies are most successful when applied to sites with coarse grained soils.

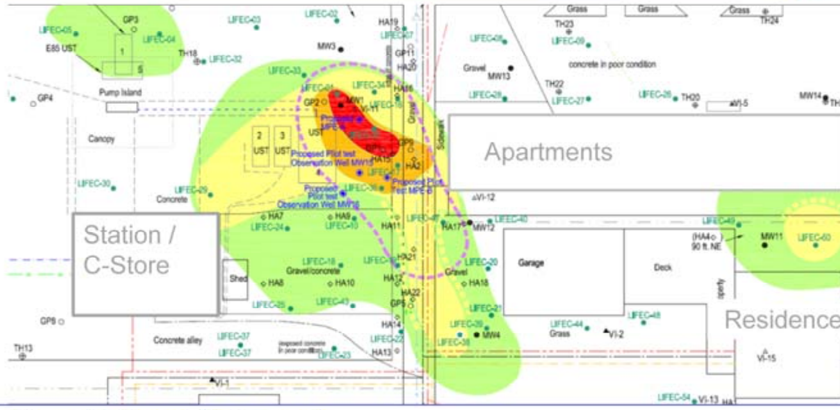


[Regulator]

It sounds like you made a good decision to eliminate skimming and total liquid extraction. I'm assuming you reevaluated your LCSM at this stage. We certainly don't want to get too far ahead of ourselves and doing this adds an extra layer of comfort to ensure the protection of human health and the environment. So this is the next step in the technology screening process. Was your LCSM thorough enough to move forward with the three remaining remediation technologies in your list?

Case Study: Step 2 – Update LCSM

Case Study – Step 2



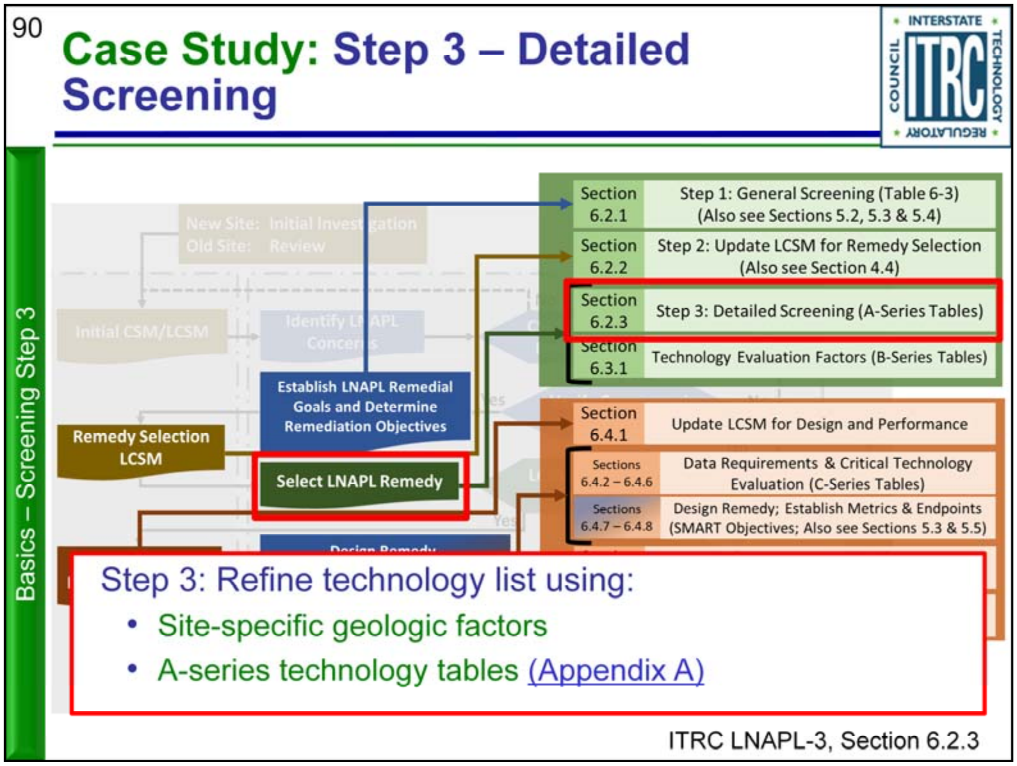
No additional field work:

- LIF data already collected at the site
- LNAPL source below the water table
- Low permeability soils at the site

[Consultant]

Section 4.4 of the LNAPL Guidance has key questions for developing the Remedy Selection LCSM, which range from general topics to more LNAPL specific topics. Some questions focus on the source, such as "where is it" and "how is it distributed above and below the water table", and includes others such as, "what's achievable for a given technology".

After reviewing these topics, we determined that we did not have to collect any additional field data to move forward; we had already completed two LIF investigations in addition to other investigations, and we had the data we needed. Some of the elements of the LCSM that were important for remedy selection included…knowing the permeability was low and that the source was submerged below the water table.



[Regulator]

Ok. Now Step 3 of the selection process would be to screen the remaining possible technologies from Step 1 using geologic factors and the A-series tables in Appendix A. Were you able to narrow down your list of three technologies based on additional site geologic factors?

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Case Study: Step 3 - Geologic Screening

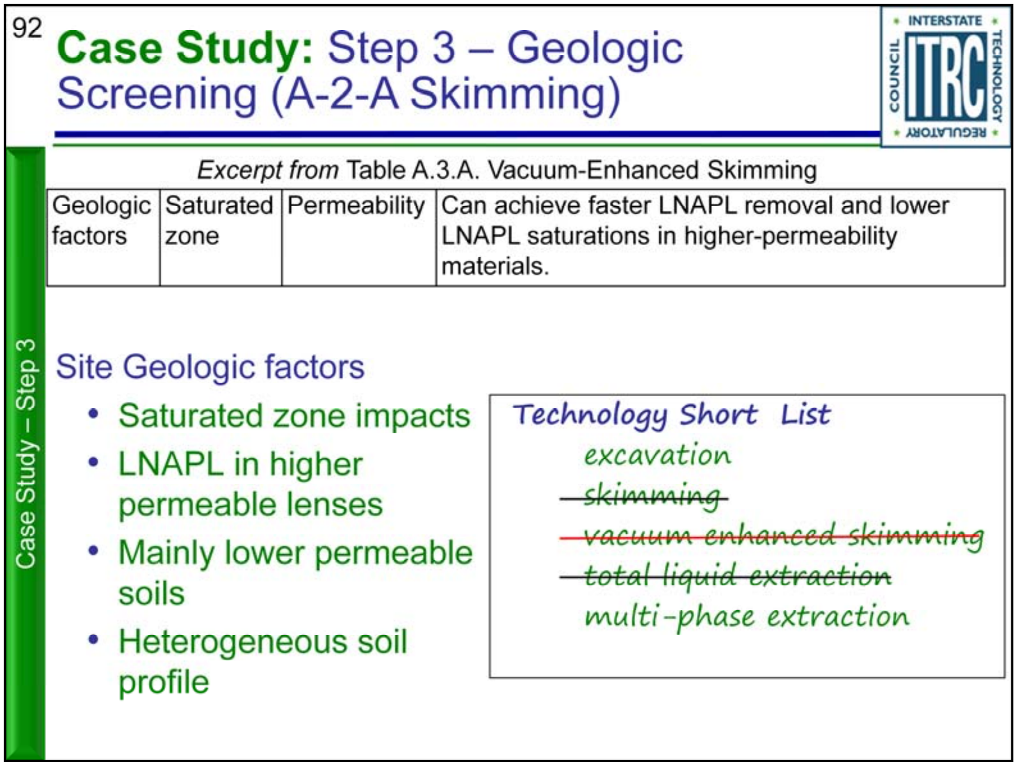
Basics – A-series Table

Table A-3.A. Vacuum-enhanced skimming

Technology	Vacuum-enhanced skimming	LNAPL & vapor are the fluids removed. LNAPL drawdown and vacuum induce an..	
Remediation process	Physical mass recovery	Yes (primary)	1.Skimming removes liquid LNAPL from saturated zone and perched LNAPL zones. 2. Induced vacuum extracts LNAPL vapors from…
	Phase change	Yes (secondary)	The induced vacuum volatilizes and evaporates the LNAPL.
	In situ destruction	Yes (secondary)	Infiltration of oxygenated air from the surface enhances in situ aerobic
	Stabilization/ binding	No	
Objective applicability	LNAPL saturation	Yes	Vacuum-enhanced skimming reduces LNAPL saturations.
	LNAPL composition	Yes	Vacuum-enhanced skimming reduces the volatile constituent fraction
Applicable LNAPL type	All LNAPL types, although better suited to less viscous LNAPLs (e.g., gasoline, kerosene).		
Geologic factors	Unsaturated zone	Permeability	More effective in higher-permeability materials where vapor flow is…
		Grain size	More applicable to sands and gravels but can also be applied in…
		Heterogeneity	In heterogeneous soils, vacuum extracts LNAPL from preferential…
		Consolidation	Not typically a factor.
	Saturated zone	Permeability	Can achieve faster LNAPL removal and lower LNAPL saturations in higher-permeability materials.
		Grain size	More applicable to sands and gravels but can also be applied in silts and clays.
		Heterogeneity	Fractured bedrock and heterogeneous soils will induce preferential flow. More applicable to perched LNAPL and unconfined LNAPL…
		Consolidation	Not typically a factor.

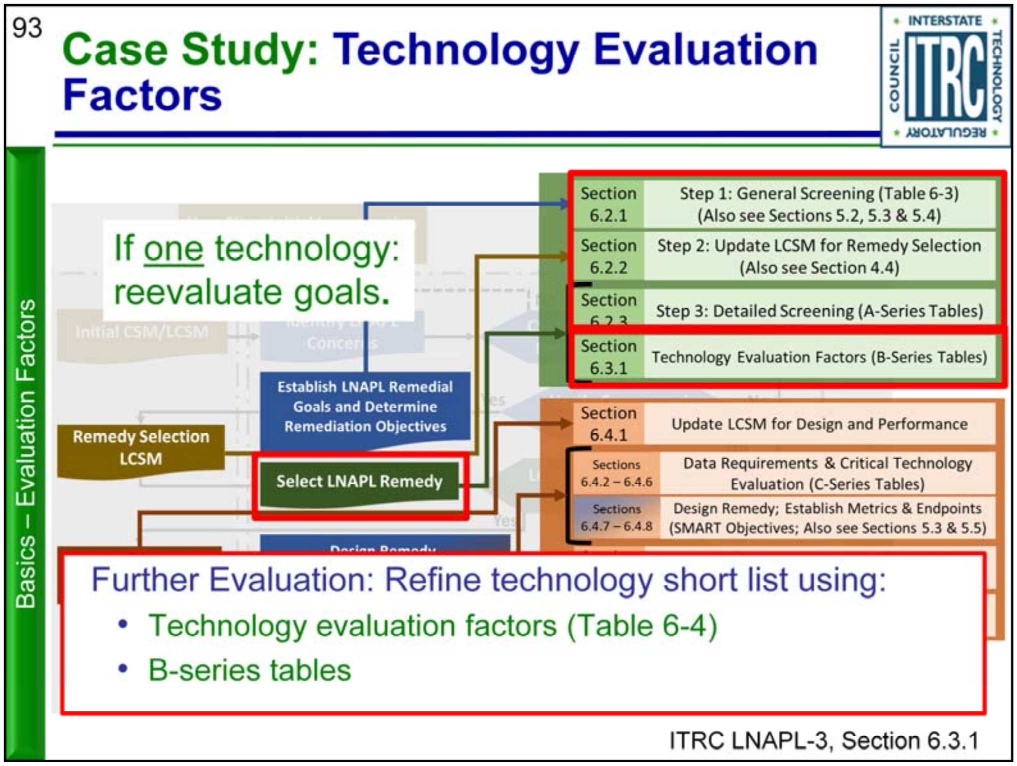
[Consultant]

Those tables were helpful. In addition to geologic factors, the A-series tables have some general information about the technologies. For example, here's the A-series table for vacuum-enhanced skimming. The top is condensed here for easier reading, but you can see there is a **[CLICK]** description of the technology, the remediation process, objective applicability and applicable LNAPL type. **[CLICK]** Geologic factors are at the bottom and include information for both **[CLICK]** the unsaturated and saturated zones, including **[CLICK]** permeability, grain size, heterogeneity and consolidation for both zones. In particular, the information about saturated zone permeability was beneficial to our screening process.



[Consultant]

The permeability description told us that vacuum enhanced skimming would be more successful in higher permeability soils. Although LNAPL at the site is in higher permeable lenses, most of the site has lower permeability soil. **[CLICK]** Based on this, we determined that vacuum enhanced skimming was not a good fit for this site. We repeated this geologic screening for the other two technologies on the short list and decided they were both applicable to this site. So after the preliminary screening process, we had 2 technologies remaining in our short list.



[Regulator]

If only one technology had been left after the preliminary screening process, you would have needed to reevaluate site goals or objectives. If you still had only one technology, this next evaluation **[CLICK]** might be used to identify any “show stopper” concerns before moving forward with that technology. This step involves further evaluation of the technologies remaining in your short list using evaluation factors on Table 6-4 and the B-series tables.

Case Study: Table 6-4 Evaluation Factors

Basics – Evaluation Factors

- Remedial time frame
- Safety
- Waste stream generation and management
- Community concerns
- Environmental factors
- Site restrictions
- LNAPL body size
- Cost
- Other

- Review factors
- Rank top 4-6 factors
- Review “B-series” tables

[Regulator]

Here are the nine evaluation factors included in Table 6-4. The next step in the process involves reviewing these evaluation factors and ranking the top 4-6 of these based on your site considerations, then using the B-series tables to compare the technologies.

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Case Study: Table 6-4 Evaluation Factors

Basics – Evaluation Factors

Example from Table 6-4. Evaluation Factors

Site Restrictions	**Defined**	Physical, logistical or legal obstacles to system deployment at the site (e.g., building locations, high-traffic areas, small property size, noise ordinances…or nearby sensitive receptors, such as schools, day cares, hospitals, etc.)
	Impact	Site restrictions and limitations impact the implementation of some technologies more than others, due to equipment size, degree of surface disruption, etc. At sites with more potential physical, logistical, or legal site restrictions, the physically larger, more “disruptive” technologies may be less feasible to implement.

[Regulator]

Here’s an example from Table 6-4 for Site Restrictions. Table 6.4 defines each evaluation factor and gives general examples of possible impacts to selecting a technology. What evaluation factors were important for this site?

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Case Study: Evaluation Factors

Case Study – Evaluation Factors

- Remedial Time Frame
  - Priority cleanup site by regulatory agency
- Site restrictions
  - No sewer connections
  - No 3-phase power nearby
  - Many underground utilities
- Waste Stream Management
  - Cannot handle large waste water volume
- Safety
  - Small site
  - Active gas station
  - Adjacent to highway & residential area/apartments

[Consultant]

We decided these four factors were the most important for this site…remedial time frame, safety, waste stream generation and management, and site restrictions, with this priority.

Remedial time frame **[CLICK]** was the most important factor and needed to be short, because the regulatory agency had placed the site on the priority cleanup list. **[CLICK]** Site restrictions included no sewer connections, no 3-phase power nearby, and many underground utilities. **[CLICK]**

Waste stream management was a factor because this would be necessary for any of the technologies being considered. Vapors and noise mitigation were doable, but the site could not easily handle a large volume of waste water. **[CLICK]** Safety was a concern because the site is small, it's an active station, and it's located near a highway and residential area, so there's also foot traffic.

Case Study: B-Series Table – Excavation

Technology:	Excavation	
Site Restrictions	Concern	High
	Discussion	Disruptive technology. Physical space, and logistical demands significant. Often excavation is infeasible due to site improvements, buildings, structures, roads, etc. Due to the use of large, heavy equipment and the need…

Photo: WCEC

[Regulator]

The B-series Table in Appendix A gives specific impacts of each of the nine evaluation factors for each remedial technology. In this example for excavation, we see that site restrictions is a high concern **[CLICK]**, and there's a discussion giving details to consider.

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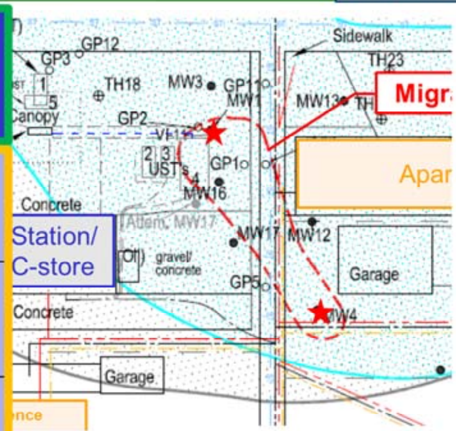
Case Study: Evaluation Factor Screening

Case Study – Evaluation Factors

Evaluation Factors	Excavation (A-1.B)	Multi-Phase Extraction (A-5.B)
Remedial Time Frame	Low	Moderate
Site Restrictions	*High*	Moderate
Waste Stream Management	*Moderate to High*	Moderate
Safety	Moderate	Moderate

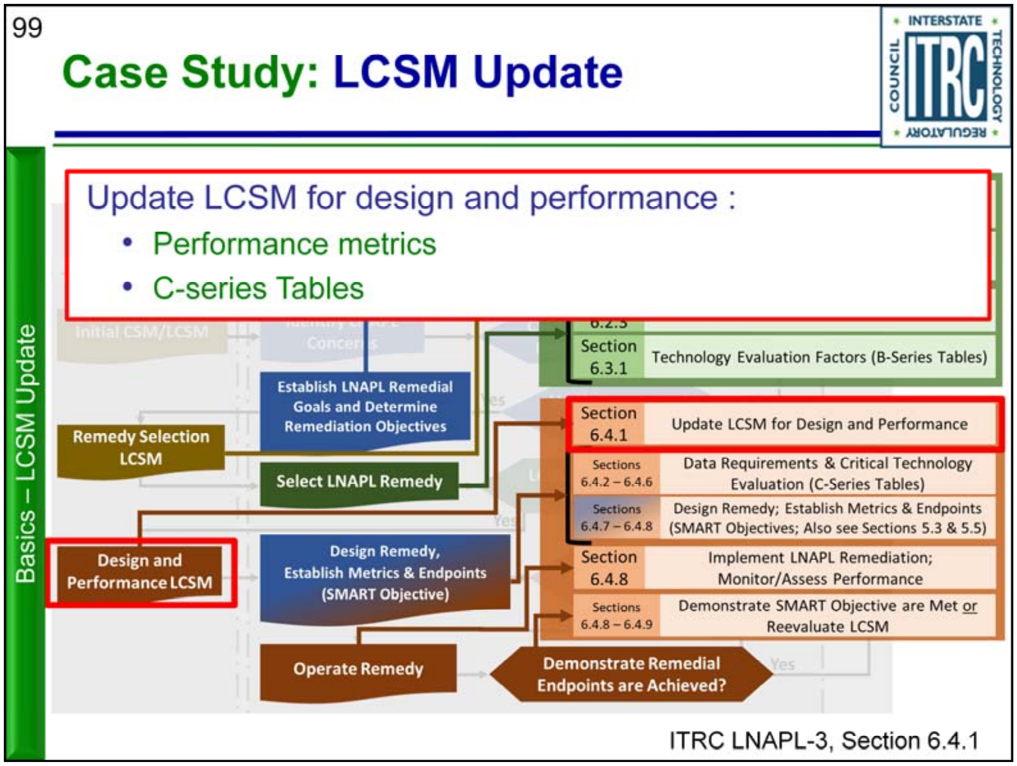


- Small site
- Active tank basin
- Apartment building
- Alley with utilities
- Offsite garage

[Consultant]

We created a table to compare the evaluation factors for the two technologies still being considered. The four evaluation factors are on the left side and our two remaining technologies are along the top. We then referred to the B-series tables to add the concern level for each factor.

We started **[CLICK]** by noting the high concerns, which were for site restrictions and waste stream management. This site was heavy in infrastructure in the area of concern such as the active tank basin, apartment building, the alley with utility corridor and an offsite garage. So even though the remedial time frame for excavation was low **[CLICK]**, which was a priority, there were too many high concerns **[CLICK],** so excavation was eliminated. There were no high concerns for MPE, so **[CLICK]** it was retained for further consideration.



[Regulator]

The next step is to review the LCSM based on the design and performance metrics provided in the C-series Tables for the technologies that are still being considered. The LCSM for a site must include knowledge related to these metrics if the technology is to be employed at the site.

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Case Study: Design and Performance LCSM Update

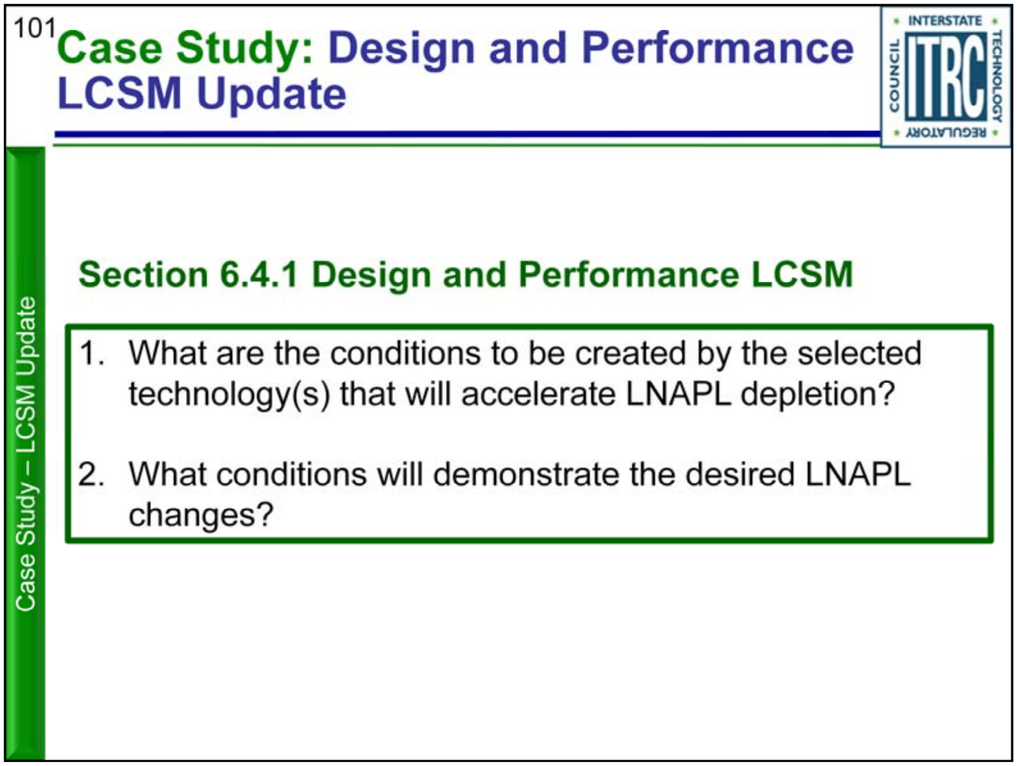
Basics – LCSM Update

Table A-5-C Technical implementation considerations for MPE

Full-scale design	Number of extraction wells	Determine number of required MPE wells necessary to achieve adequate zone of LNAPL recovery...
	Conveyance piping	Determine locations, lengths, materials for all horizontal conveyance piping to/from MPE wells...
	GW ROC	Establish groundwater ROI/ROC for different groundwater pumping rates. For continuous...
	LNAPL ROC	Establish LNAPL ROI/ROC for different LNAPL...
Performance metrics	GW and LNAPL recovery rates and volumes	Basic system performance monitoring
	Cumulative GW/ LNAPL recovery	
	LNAPL recovery cost metric	Cost per gallon of LNAPL recovered

[Regulator]

Let's look at an example of the design and performance metrics from the C-series Table for MPE. Examples of design metrics include number of extraction wells and conveyance piping. Examples of performance metrics include GW and LNAPL recovery rates and volumes. Information related to these data requirements and metrics should be part of the LCSM since these will need to be part of the full-scale design and then measured to show MPE was successful. Was it necessary for you to update your LCSM for MPE to still be considered?



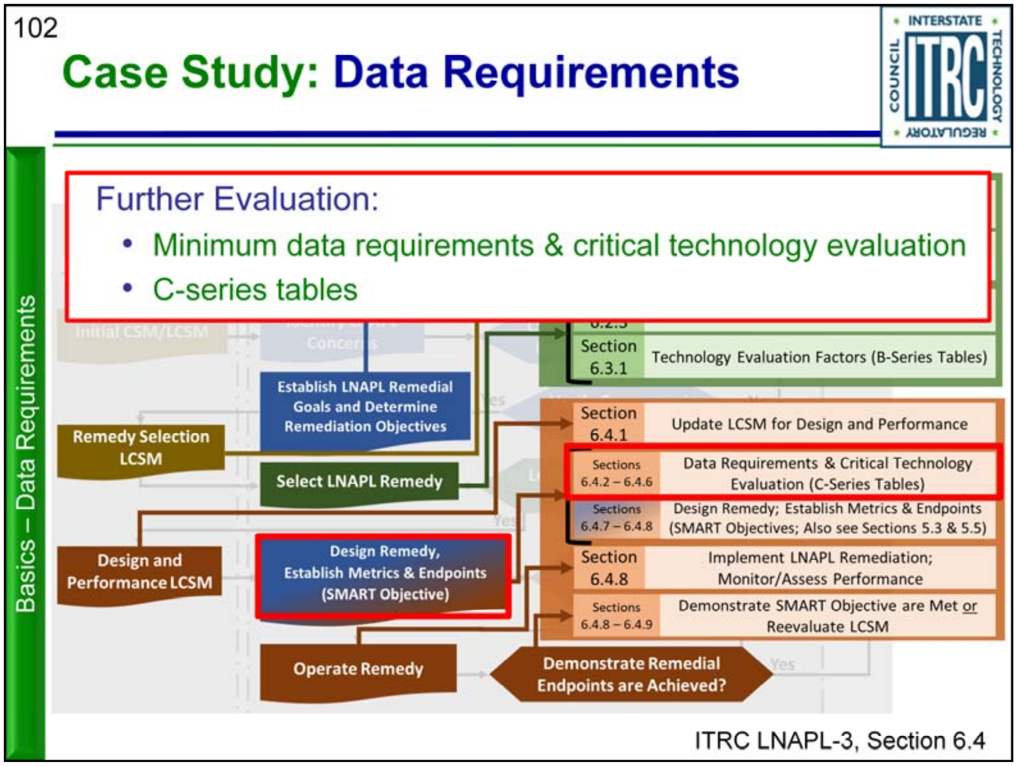
[Consultant]

This was a good time to refer to the design and performance LCSM questions in Section 6.4.1 to help us review our LCSM. *By answering these questions, the metrics and endpoints will be on their way to SMART.*

1. What are the conditions… Lowering the water table was one condition.

2. What conditions will demonstrate… Considering our endpoints for technology implementation was important here. In this case, our endpoints included reduced LNAPL occurrence and declining groundwater concentrations.

We had a lot of site information at this point that was necessary for implementation, such as depth to the bottom of NAPL zone, that was the target for dewatering. However, we did need to update our LCSM with information such as the ROI of dewatering and vacuum extraction.



[Regulator]

The next step in the process is to review the minimum data requirements and the critical technology evaluation needed for any remaining technologies using the C-series tables in Appendix A.

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Section 6 – Minimum Data Requirements and Critical Considerations For Technology Evaluation

Basics – Data Requirements

Table A-5-C. Technical implementation considerations for MPE

Data requirements	Site-Specific data for technology evaluation	Hydraulic conductivity/transmissivity; LNAPL conductivity/transmissivity; LNAPL characteristics, power availability…
	Bench-scale testing	N/A
	Pilot-scale testing	GW and LNAPL ROC; GW and LNAPL recovery rate, volume & influent concentrations; vacuum and flow…
	Full-scale design	Number of extraction wells; conveyance piping; GW and LNAPL ROC; and LNAPL emulsification issues.
	Performance metrics	GW/LNAPL recovery rates and volumes; system uptime vs downtime; cumulative GW/LNAPL recovery…

- Determine minimum data requirements
- Further evaluate considering critical technology evaluation
- If no technology can be determined, reevaluate the objectives or goals.

[Regulator] Here's an example of the C-series Table for multi-phase extraction. **[CLICK]** Examples of minimum data requirements for MPE include determining hydraulic conductivity and transmissivity, LNAPL conductivity and transmissivity, and LNAPL characteristics. Critical technology evaluation information **[CLICK]** includes necessary bench tests and pilot tests. All of this information can be considered to further evaluate the technologies. **[CLICK]** If no technology is left after further evaluation, the objectives and goals should be reevaluated.

For this case study we're discussing, there was only 1 technology left prior to reviewing the C-series table, MPE. What did you do at this point?

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Case Study: Implementation Consideration

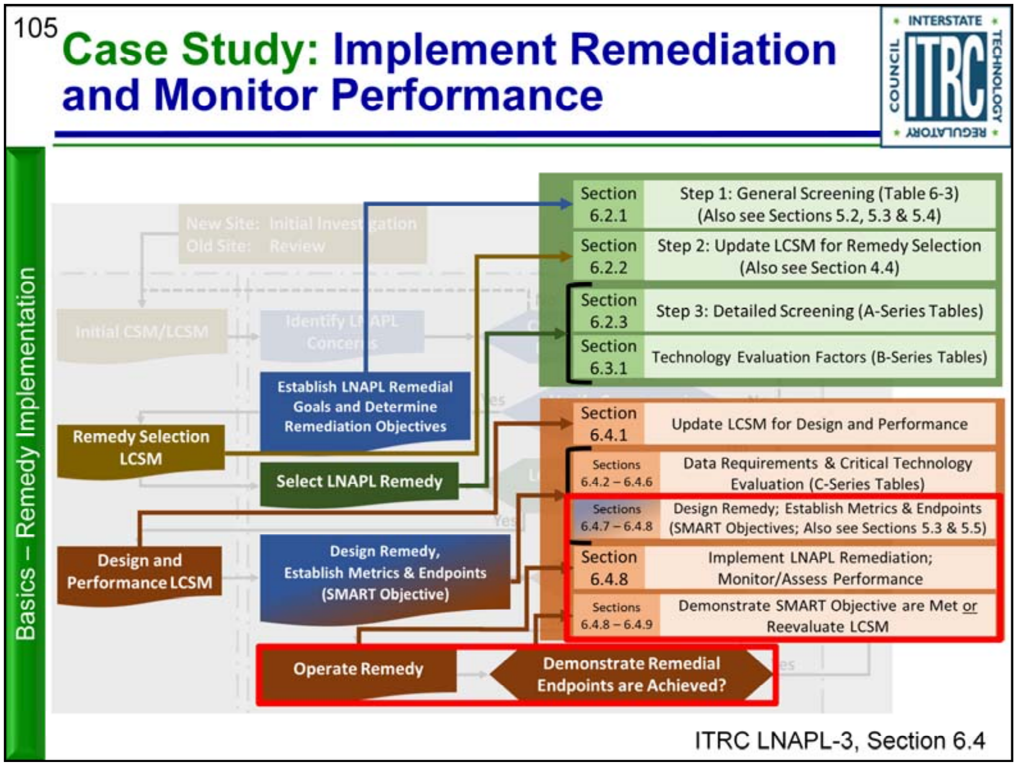
Case Study – Pilot Test

	Multi-Phase Extraction (A-5.C)
Site Specific Data for Technology Evaluation	Hydraulic conductivity/ transmissivity, LNAPL conductivity/ transmissivity, power availability
Pilot Testing	GW & LNAPL radius of influence (ROI), recovery rates
Full-Scale Design	Number of extraction wells, conveyance piping

Photo: WCEC

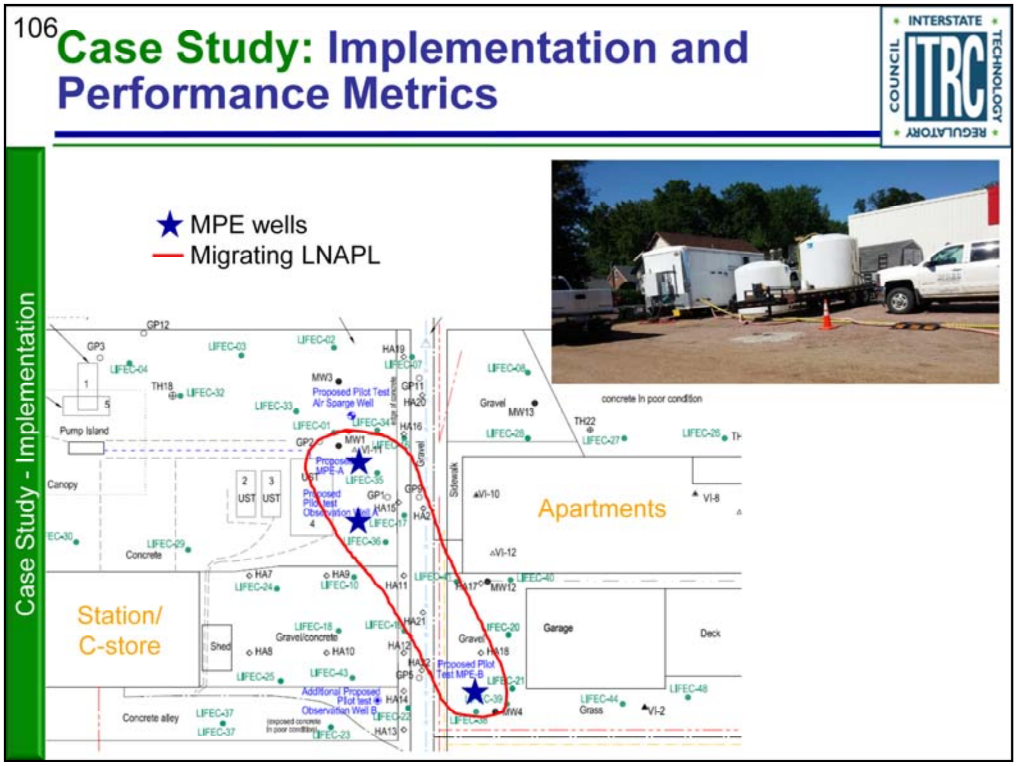
[Consultant]

Next, we conducted a pilot test to gather additional data as shown in MPE's C-series Table and to update our LCSM. This included determining ROI and recovery rates, which would also indicate how well MPE would work at the site and the number of wells needed. We had to work with the city to have 3-phase power installed for the pilot test, but this did show that MPE should be successful at this site.



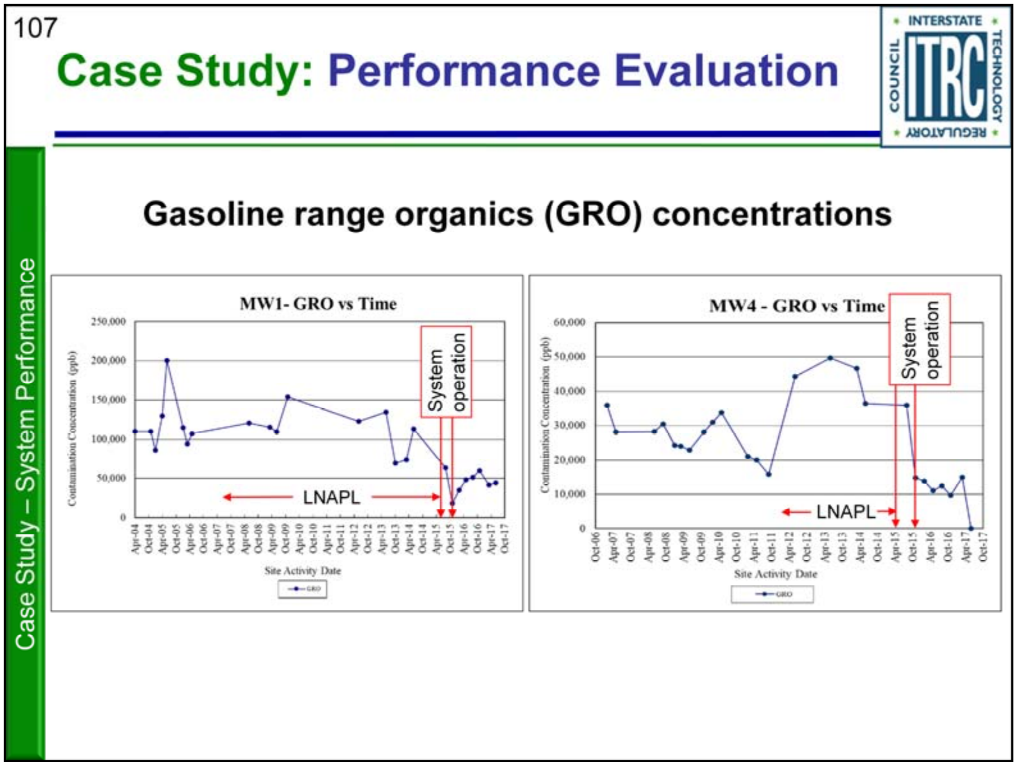
[Regulator]

Before implementing a technology, this Guidance recommends establishing SMART objectives and performance metrics. This Guidance recommended starting to think about this end process when reviewing and updating the LCSM for design and performance. It's also important to monitor the remediation technology and constantly assess performance during implementation and then to demonstrate that the objectives are met. How were you going to determine performance and success at your site?



[Consultant]

Before we implemented MPE, we knew system sampling would be necessary to monitor system performance. To show that objectives had been met, metrics were established including decline curve analysis and groundwater contaminant concentration decline. Since the site was small, the LNAPL body was relatively small and time was of the essence for cleanup, we decided to run a mobile MPE system instead of installing a full-scale MPE system. We knew the best option for discharge water was to treat it and discharge to a nearby storm drain, so an NPDES permit would need to be obtained. We also knew we would not be remediating all of the LNAPL at the site, so our treatment train would include natural source zone depletion (NSZD) to treat LNAPL contamination remaining at the site.



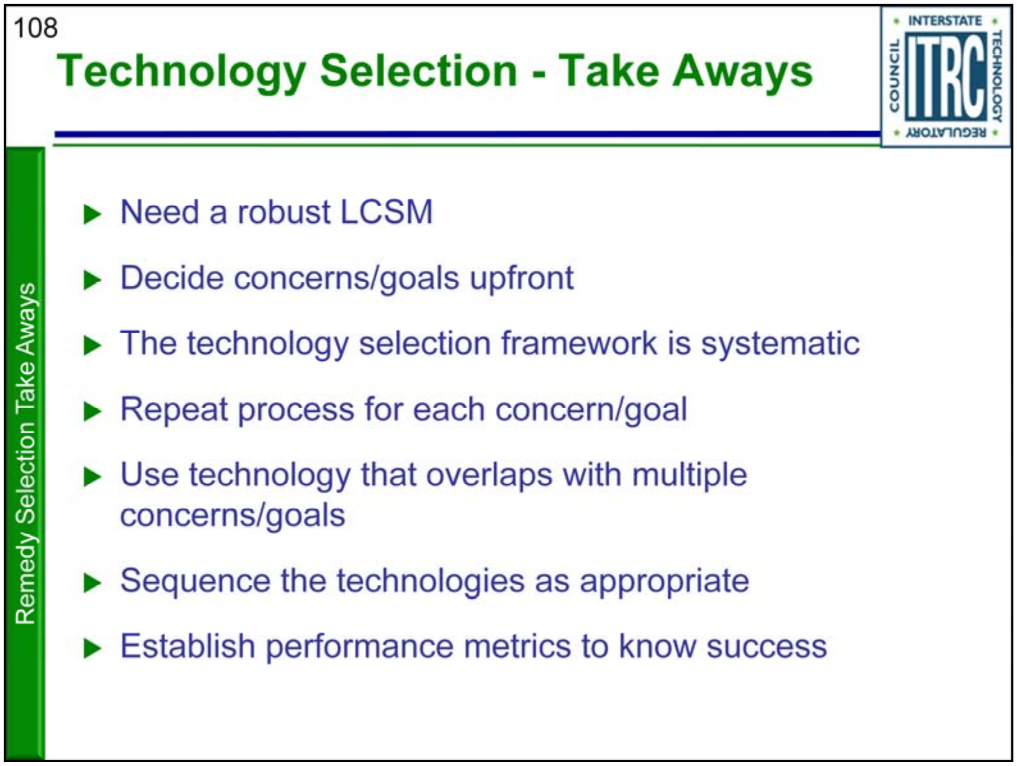
[Consultant]

Once operation began, we conducted monthly system site visits so we could monitor system performance and collect system operation samples. LNAPL was no longer observed in MW1 or MW4, which is one of the endpoints we set prior to implementation.

The graph shows how dissolved phase GRO contamination increased after LNAPL had migrated to the well. Once decline curve analysis indicated the system was no longer removing contamination efficiently, the system was shut down. After system shutdown, groundwater monitoring continued for 2 years, which showed a decrease in dissolved-phase GRO concentrations and the regulatory agency closed the site.

[Regulator]

Thanks for running through the case study and showing how the LNAPL guidance document can be applied at a real site.



[Regulator]
Here are the Take Aways from the Technology Selection Process:

- Need a robust LCSM
- Decide concerns/goals upfront
- The technology selection framework is systematic
- Repeat process for each concern/goal
- Use technology that overlaps with multiple concerns/goals
- Sequence the technologies as appropriate
- Establish performance metrics to know success

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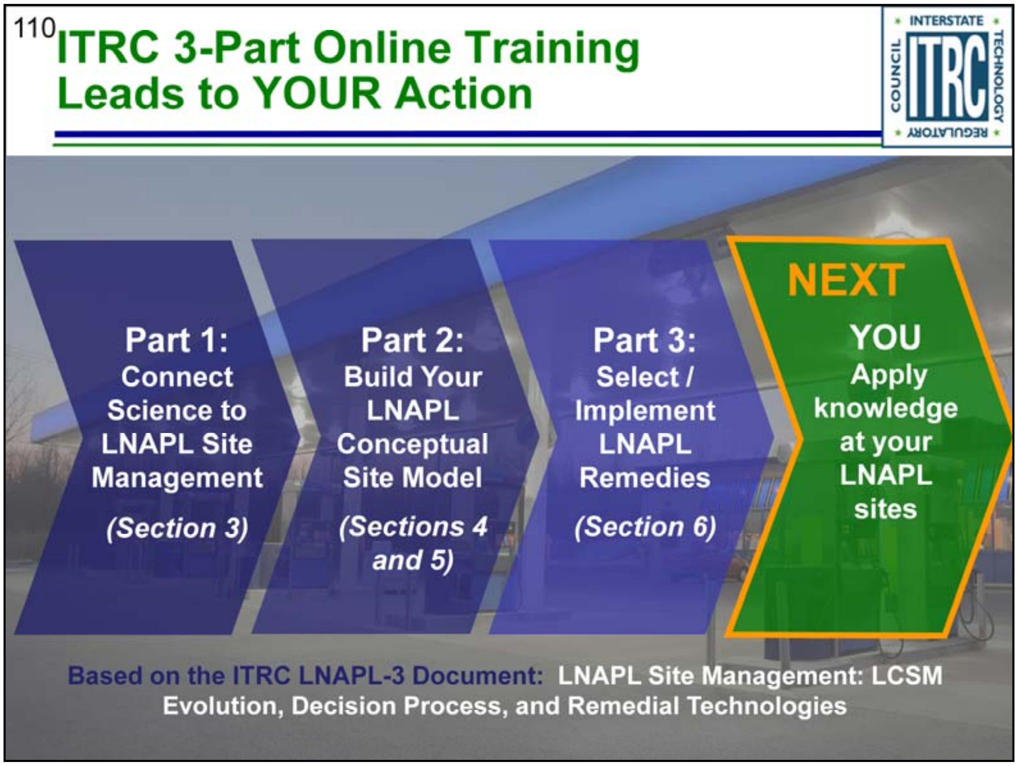
Knowledge Check

Poll Question

- During the technology remediation selection process, when should the LCSM be reevaluated? (Chose all that apply.)
  - A. An LCSM should be developed prior to starting the remedy selection process
  - B. During the preliminary screening process
  - C. After further screening with the evaluation factors
  - D. After remediation, if unsuccessful

[Regulator]



Part 1: An Improved Understanding of LNAPL Behavior in the Subsurface - Connecting the Science to Managing Sites

- Explains how LNAPL behaves in the subsurface
- Examines what controls their behavior
- Explains what LNAPL data can tell you about the LNAPL and site conditions
- Relevant and practical examples are used to illustrate key concepts

Part 1 explains how LNAPLs behave in the subsurface and examines what controls their behavior. Part 1 also explains what LNAPL data can tell you about the LNAPL and site conditions. Relevant and practical examples are used to illustrate key concepts.

Part 2: LNAPL Conceptual Site Models and Remedial Decision Framework - Do you know where the LNAPL is and how to address LNAPL concerns?

- Addresses LNAPL conceptual site model (LCSM) development and the overall framework for making LNAPL remediation and management decisions
    - Discusses key LNAPL and site data
    - When and why those data may be important
    - How to effectively organize the data into an LCSM
- Discusses how to resolve LNAPL concerns by selecting appropriate goals and objectives, choosing applicable technologies, and assigning remedial performance metrics and endpoints
- Concludes with a special focus on LNAPL Transmissivity and how it may be used to improve LNAPL decision making

Part 2 addresses LNAPL conceptual site model (LCSM) development as well as the overall framework for making LNAPL remediation and management decisions. Part 2:
discusses key LNAPL and site data
when and why those data may be important, and
how to effectively organize the data into an LCSM.

Part 2 also discusses how to resolve LNAPL concerns by selecting appropriate goals and objectives, choosing applicable technologies, and assigning remedial performance metrics and endpoints. Part 2 concludes with a special focus on LNAPL Transmissivity and how it may be used to improve LNAPL decision making.

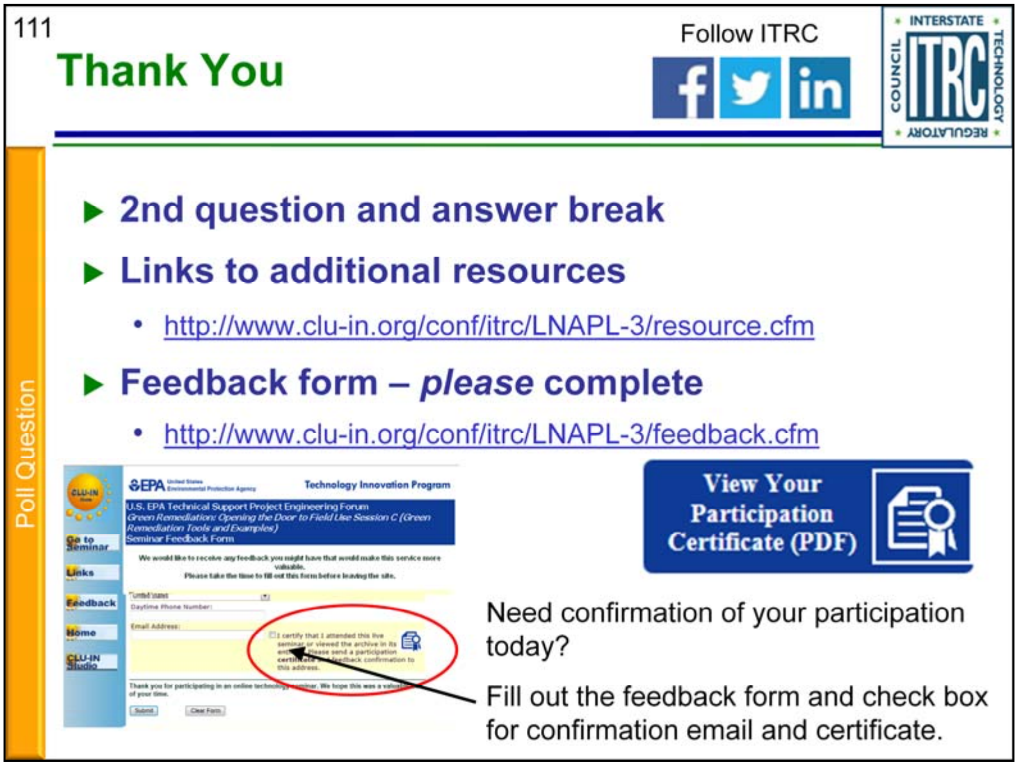
Part 3: Using LNAPL Science, the LCSM, and LNAPL Goals to Select an LNAPL Remedial Technology

- Fosters informed remedial technology selection and appropriate technology application. Part 3:
    - Discusses remedial technology groups
    - Introduces specific remedial technologies
    - Provides a framework for technology selection
    - Introduces a series of tools to screen the several remedial technologies addressed in the updated ITRC document
- A case study demonstrates the use of these tools for remedial technology selection, implementation, and demonstration of successful remediation

Part 3 of the training fosters informed remedial technology selection and appropriate technology application. Part 3:

- discusses remedial technology groups,
- introduces specific remedial technologies,
- provides a framework for technology selection, and
- introduces a series of tools to screen the several remedial technologies addressed in the updated ITRC document.

A case study demonstrates the use of these tools for remedial technology selection, implementation, and demonstration of successful remediation.



Links to additional resources:
http://www.clu-in.org/conf/itrc/LNAPL-3/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/LNAPL-3/feedback.cfm

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

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓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

✓Sponsor ITRC's technical team and other activities

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects