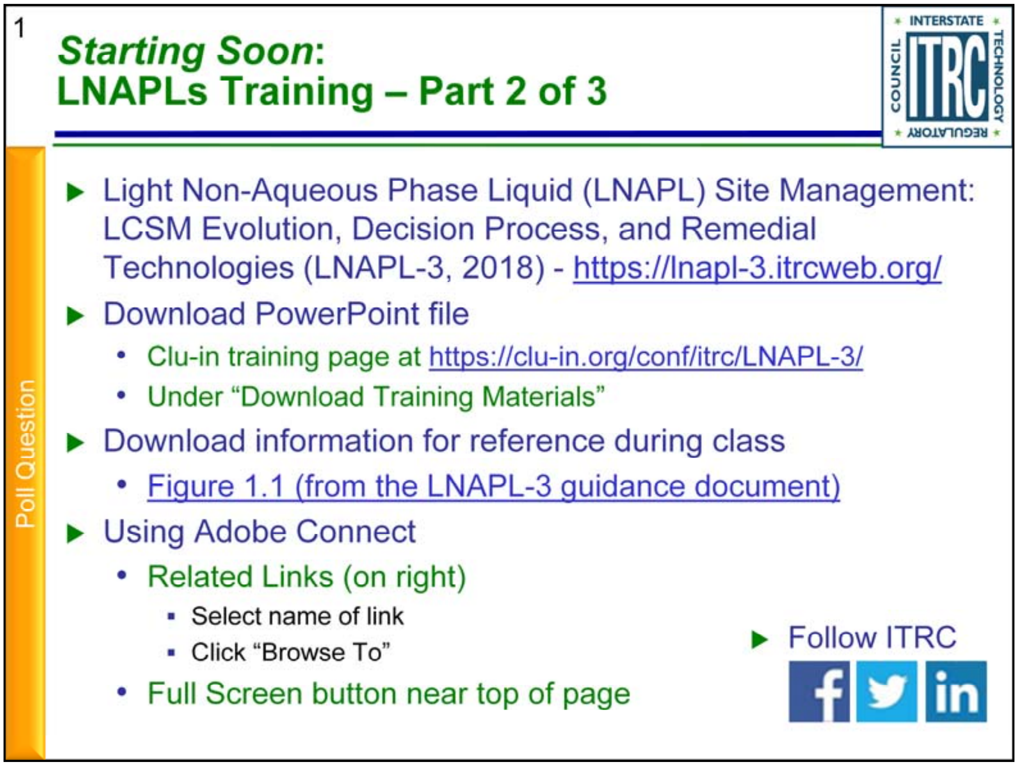


The projects I work on are limited by: (choose the best answer)

A. Budget constraints, there is sufficient time and technical understanding how goals could be achieved

B. Technical constraints, site characteristics (fine grained soil, depth to impacts, bedrock) limit effectiveness of technologies and ability to reduce impacts

C. Time constraints, there is a time driver which limits the available approaches to addressing concerns achieving goals

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.

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

Training Co-Sponsored by: US EPA Technology Innovation and Field Services Division (TIFSD) (www.clu-in.org)

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

3

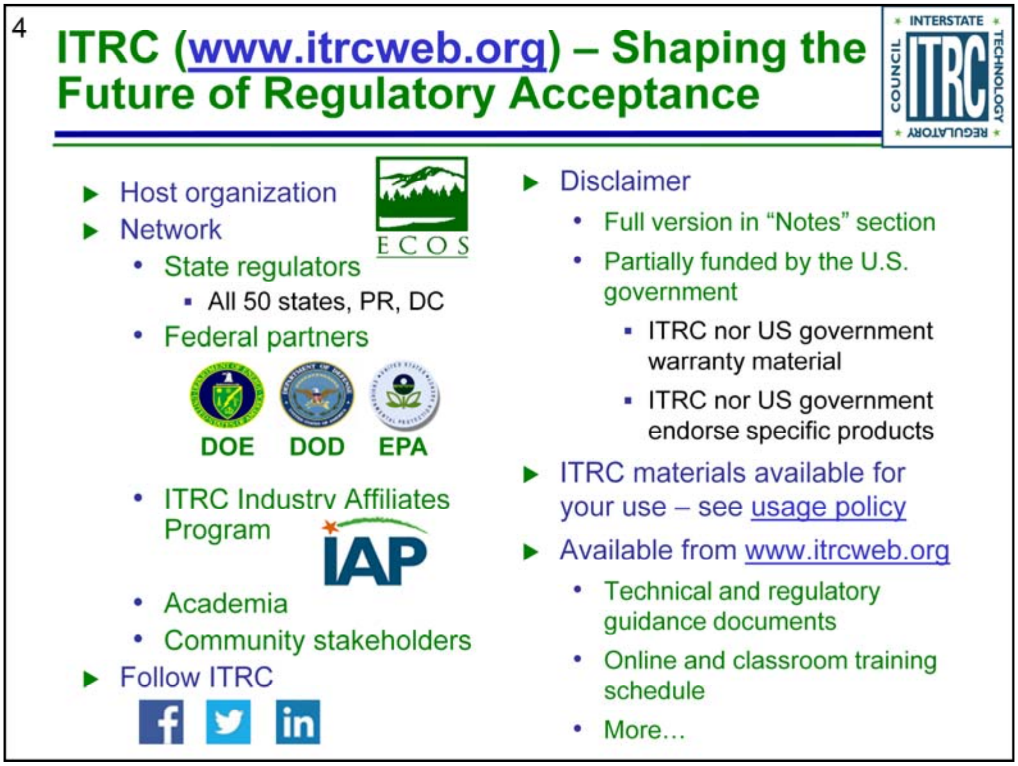
Housekeeping

- Course time is 2¼ hours
- This event is being recorded
- Trainers control slides
  - **Want to control your own slides?** You can download presentation file on Clu-in training page
- Questions and feedback
  - **Throughout training:** type in the “Q & A” box
  - **At Q&A breaks:** unmute your phone with #6 to ask out loud
  - **At end of class:** Feedback form available from last slide
    - **Need confirmation of your participation today?** Fill out the feedback form and check box for confirmation email and certificate

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

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Meet the ITRC LNAPL Trainers – Part 2

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https://clu-in.org/conf/itrc/LNAPL-3/

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.

Andrew Kirkman is the lead LNAPL Technical Specialist for BP America located in Naperville, IL. Andrew joined BP in 2012 and currently supports LNAPL related site remediation, educational advocacy and research efforts. Previously, was the Global LNAPL Technical lead for AECOM Environment. Andrew worked as a consultant at AECOM for 14 years. Andrew focused on characterization and remediation of railroad, manufactured gas plant tie treatment facilities petroleum terminals and refineries in North America as well as Thailand, Indonesia, Australia, New Zealand, Brazil, Europe and United Arab Emirates. Andrew has led and participated in multiple industry advocacy efforts related to LNAPL, these include: 1) chairing the ASTM task group that created the standard for estimation of LNAPL transmissivity and the task group that is revising the ASTM Standard guidance document related to LNAPL Conceptual Site Models and Remediation Strategies; 2) generating publications for Applied NAPL Science Review, American Petroleum Institute, and Groundwater Monitoring and Remediation and; 3) presenting training sessions and technical discussions at regulatory agencies, conferences and for industry on topics such as use of NAPL transmissivity, LNAPL baildown tests, core analyses and laser induced fluorescence technology and improved LNAPL conceptual site models.

Eric M. Nichols , PE, is a principal at Substrata LLC in Newfields, New Hampshire. He has characterized and remediated contaminated sites since 1985. Eric founded Substrata LLC in 2014. Previously, he worked for ARCADIS and LFR from 1996-2014, and for Weiss Associates from 1985-1995. Eric serves as a technical resource for LNAPL and petroleum characterization, remediation, natural source zone depletion, vapor intrusion, and litigation support. Eric has taught short courses for several organizations, including the U.S. Environmental Protection Agency, the National Ground Water Association, the American Society for Testing and Materials, the New England Interstate Water Pollution Control Commission, the American Petroleum Institute, and the University of California Extension. Eric has contributed to ITRC documents and training since 1998 as a member and trainer for the Fuel Oxygenates Team, the LNAPL Team, and the Petroleum Vapor Intrusion Team. Eric has received Industry Appreciation Awards for his service on ITRC teams. Eric earned a bachelor's degree in Civil Engineering from the University of California, Berkeley, in 1982 and a master’s degree in Civil Engineering from the Massachusetts Institute of Technology in 1985. He is a licensed professional engineer in California.

Jon Smith is a Technical Leader with AECOM, located in Southfield, Michigan. Jon has worked in environmental site investigation and remediation since 2003, specializing in characterization and remediation of sites with nonaqueous phase liquids (NAPLs). His experience includes the planning and execution of site investigations using a diverse set of characterization and data evaluation techniques, development of conceptual site models, assessment of NAPL mobility and recoverability, evaluation of natural source zone depletion (NSZD), and remediation technology screening and implementation. Jon has helped lead applied field research projects on LNAPL tracer testing, LNAPL transmissivity measurement, NSZD, and in situ bioremediation. He has provided technical training on NAPLs to several regulatory agencies within the U.S. and Canada and has served as a technical leader on NAPL projects in the U.S., Canada, Europe, Australia, and Western Asia. Jon earned a bachelor's degree in geology from Michigan State University in East Lansing, Michigan in 2002.

6

Your Online LNAPL Resource

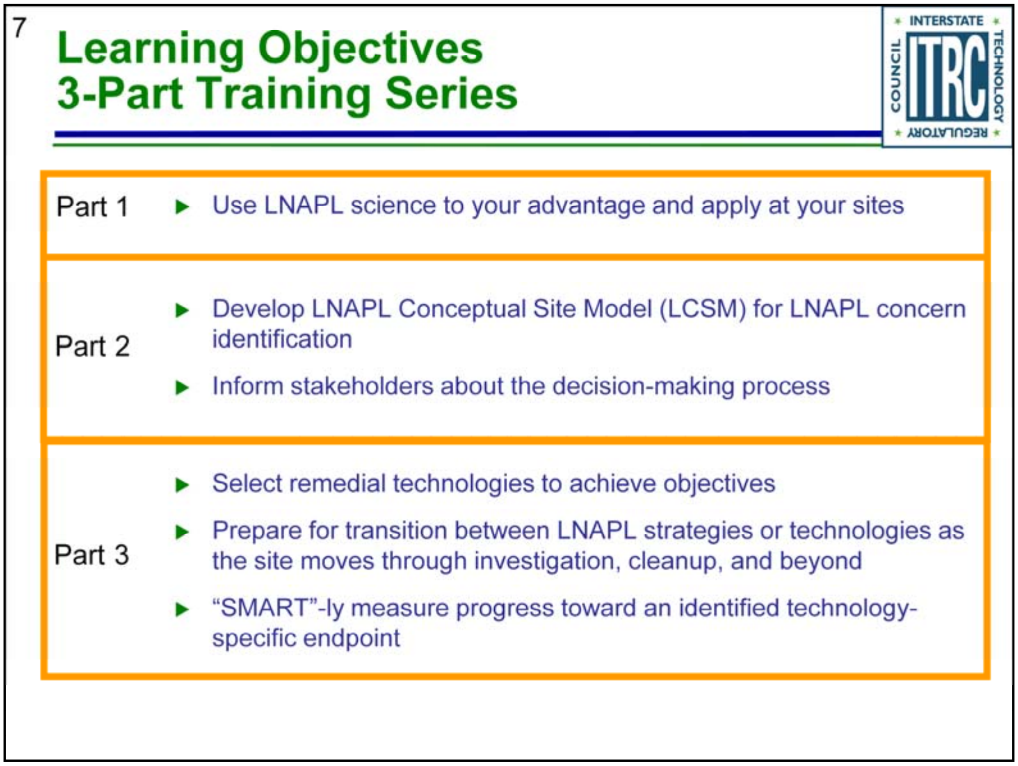
https://lnapl-3.itrcweb.org/

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

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

We want to remind you to visit the ITRC web site to view and use the updated, web-based document. Here is what’s new about LNAPL-3 (4 items listed at bottom of slide).

This guidance can be used for any LNAPL site regardless of size and site use.



Learning objectives for this 3-part series.

Part 1 – listed on slide

Part 2

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 (next week)

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.

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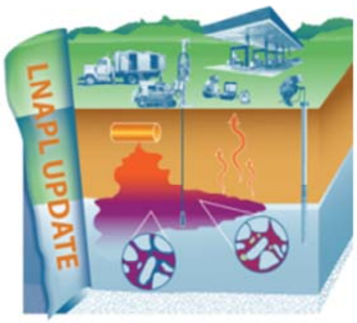
LNAPL Part 1 Summary

LNAPL Science: Key to Improving Decision-making



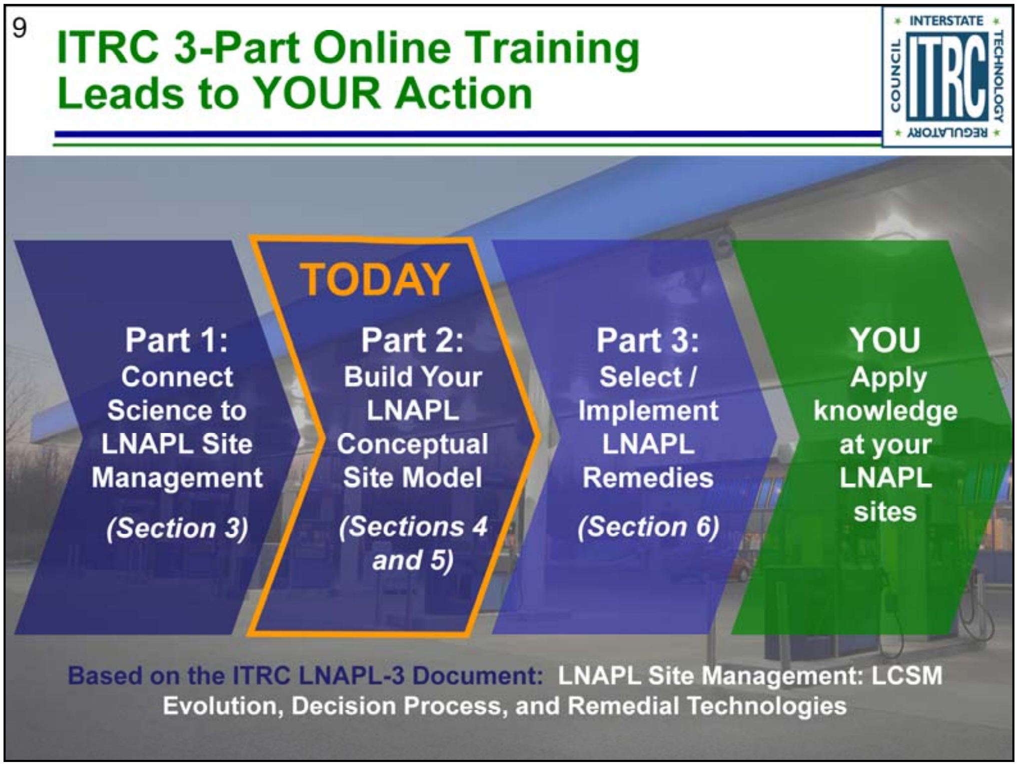
- Use LNAPL science to your advantage and apply at your sites

It is important to use LNAPL science and apply it to make good decisions

The main take away from Part 1 of our 3-part series is that our knowledge and understanding of LNAPL behavior has evolved. We should all use that knowledge to improve our decision-making at release sites. Key points last week were:

- LNAPL in wells does not mean 100% saturation (dispel pancake)
- LNAPL may be present in the subsurface even if not in MWs
- LNAPL creates Saturation vs. Composition concerns
- Apparent LNAPL Thickness challenges:
  - LNAPL in well does not mean it is migrating
  - Transmissivity is a better indicator of recoverability than thickness
- Stable LNAPL bodies can still result in sheens or long-term compositional concerns
- Biological processes play a large role in LNAPL depletion. These have not been appreciated until recently.

CLICK! And reiterate.



Our 3-part training series focuses on helping you:

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

This training will be incomplete unless <u>YOU</u> (**CLICK**) apply this information. After this training our expectation is that you will use ITRC science-based resources to improve decision making at your LNAPL sites (and for you regulators and other government agency staff, look at ways you can incorporate ITRC states guidance into your own guidance).

Today (**CLICK**) in Part 2, we ask: Do you know where the LNAPL is and how to address LNAPL concerns?

LNAPL Part 2 Agenda

LNAPL Online Training Part 2

- Discuss the evolution of the LCSM
  - Concerns
  - Remedy Selection
  - Remedy Performance (Covered in Part 3)

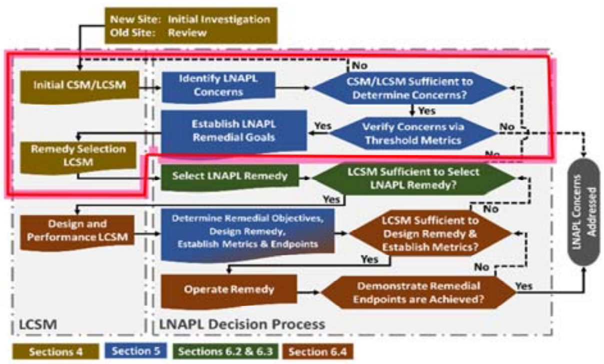


Figure 4-1, LNAPL-3

- Relate the LCSM to Site Strategy
  - Identification and Classification of Concerns
  - Establishing Remedial Goals to Address Concerns
  - Development of Remediation Objectives

In relation to the process flow diagram in the LNAPL document, this is the section we will covering today.

Today we will

1. Show how to develop an LNAPL conceptual site model and how that empowers you to make LNAPL remediation and management decisions
   - Discuss key LNAPL and site data for the model
   - When and why those data may be important
   - How to effectively organize the data into an LCSM
2. Discuss how to relate LNAPL concerns by selecting appropriate goals and objectives, choosing applicable remedies, and assigning remedial performance metrics and endpoints to those objectives

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Poll Question

Poll the Group

- The projects I work on are limited by: (choose the best answer)
  A. Budget constraints, there is sufficient time and technical understanding how goals could be achieved
  B. Technical constraints, site characteristics (fine grained soil, depth to impacts, bedrock) limit effectiveness of technologies and ability to reduce impacts
  C. Time constraints, there is a time driver which limits the available approaches to addressing concerns achieving goals

No associated notes.

Welcome to Progression Beyond Infinity

LCSM Evolution

- The LCSM is continually updated, but each update represents a focus specific to that project phase

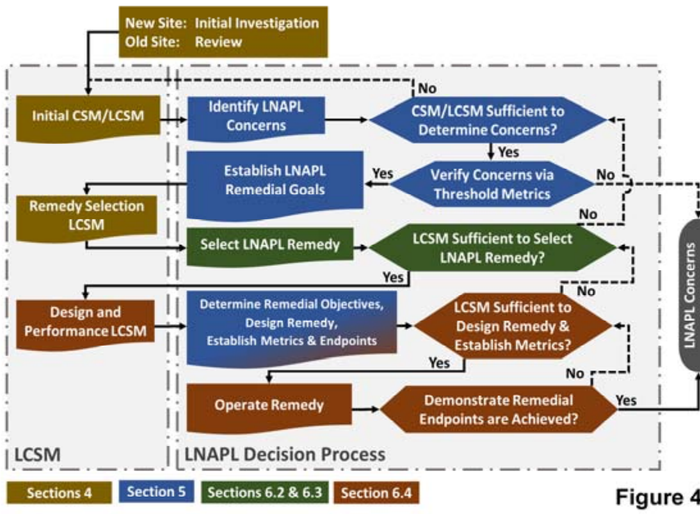
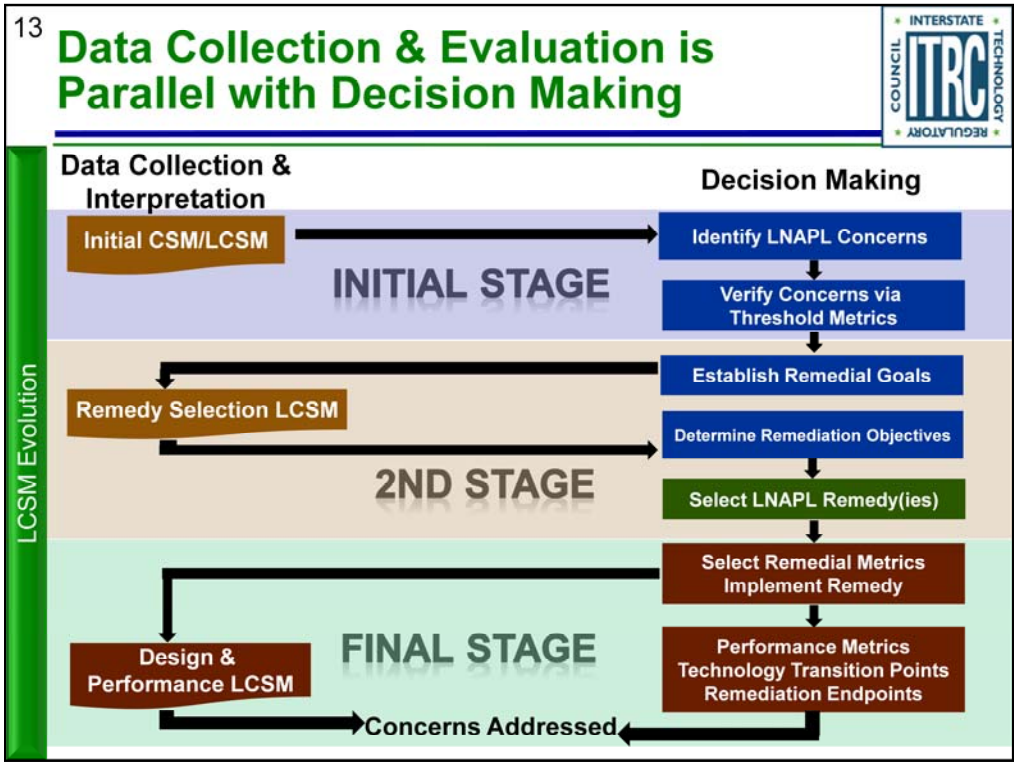


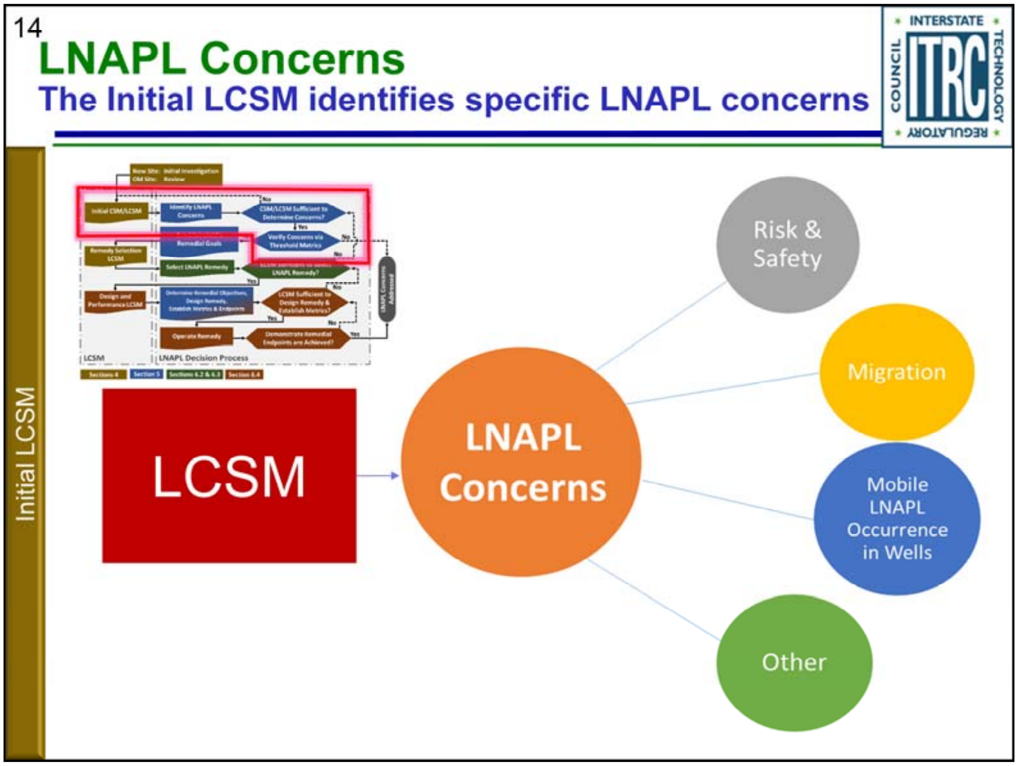
Figure 4-1, LNAPL-3

No associated notes.



Further highlight the parallel between the decision making and the data collection

Although we have broken these out they are really in Parallel. The decision making process and the LCSM will both be discussed today, but it is worthwhile to keep this figure in mind.



LCSM informs and identifies LNAPL concerns

Stakeholder engagement – chapter 2

15

Initial LCSM

Initial LCSM

- Overall, the Concerns portion of the LCSM are typically well developed and mature
- Recent improvements in this area include
  - ITRC's Petroleum Vapor Intrusion guidance and online training
    - Screening distances (ITRC, 2015)
  - Natural Source Zone Depletion
  - Plume stability & NSZD (Part 1)
  - LNAPL transmissivity to improve understanding of recoverability as related to maximum extent practicable
  - Sheens – Related Appendix in LNAPL Update document
- Ongoing Development
  - TPH guidance is being updated
- Recommended completeness test for Initial LCSM
  - LCSM should be able to inform a series of typical questions
  - Amount of detail for a given question is decided by asking "is there sufficient understanding to enable **Decision Making**?"

Define what the concerns LCSM is, what is the intent, the final decision made based on it, what is characterized as part of it.

NSZD – Natural Source Zone Depletion

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What is Needed for the Initial LCSM Consistently Needed or Possibly Needed?

Initial LCSM

- Receptors – NEED to understand where they are relative to plume
- Extent of impacts – NEED to understand if receptors are affected
- Migration – NEED to understand if existing impact extent will change
- LNAPL Occurrence in wells – Regulatory driven NEED
- Hydraulic Conductivity – Typically not needed to evaluate Concerns. Site Specific – for Concerns and Often Needed in Remediation
- Distribution of LNAPL and dissolved/vapor within the extent of Impacts – Typically not needed to evaluate concerns, Site Specific – for Concerns and Often Needed in Remediation

Point out that if sufficient information is in hand to know that excavation is decided upon or no remediation is needed, then continued testing is not worthwhile.

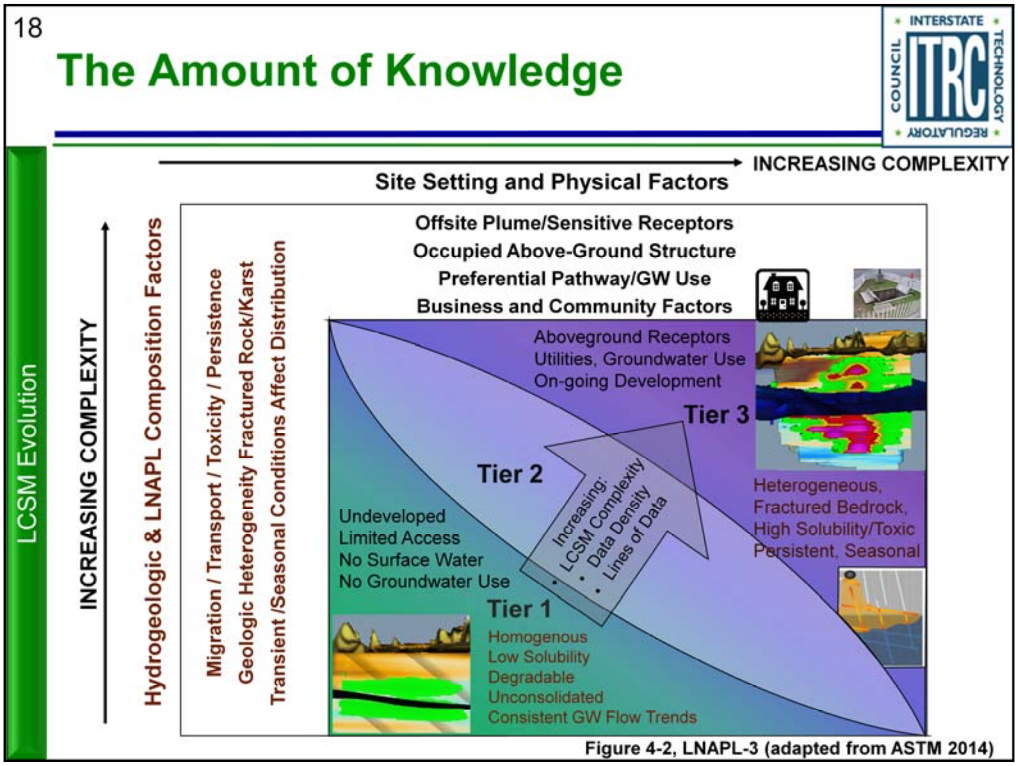
The Concerns LCSM Litmus Test

Initial LCSM

- The questions provided:
  - Are typical of multiple guidance (ASTM, CRCcare, IPECA, EPA)
  - Encourage a systematic framework to develop an LCSM
  - Encourage a systematic thought process to help confirm the completeness of the LCSM
  - Only apply to the Initial LCSM & may not be sufficient to select a remedy

1. Is current and future land use known?
2. Does the potential for preferential pathways exist?
3. How does stratigraphy relate to affecting impacts and potential migration?
4. Is the source and extent of the LNAPL known?
5. Are dissolved or vapor issues expected based on LNAPL composition?
6. Are dissolved or vapor plumes characterized?
7. Do soil or groundwater concentrations exceed criteria?
8. Are exposure pathways complete or incomplete?
9. Is the LNAPL body stable?
10. Is the mobile LNAPL hydrogeologic condition known?

No associated notes.



No associated notes.

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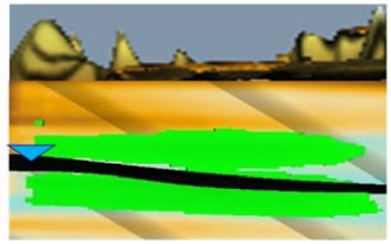
Tier 1 vs. Tier 3

Tier 1 Retail – Diesel in Sand

- 10 – 15 feet to Water-table
- Dissolved plume contained onsite (MNA)
- Mobile LNAPL in wells – T_n 1.0 ft^2/day
- LNAPL is not under any buildings
- Release occurred 10+ years ago

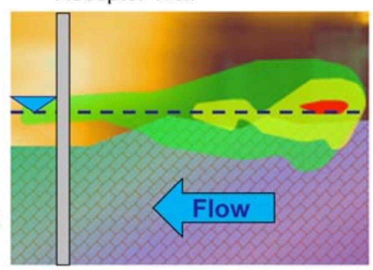
- Well Defined Remedial Concerns
- No risk, Tn above but close to 0.8 ft^2/day



Tier 3 Retail – Gasoline Interbedded Soil Over Bedrock

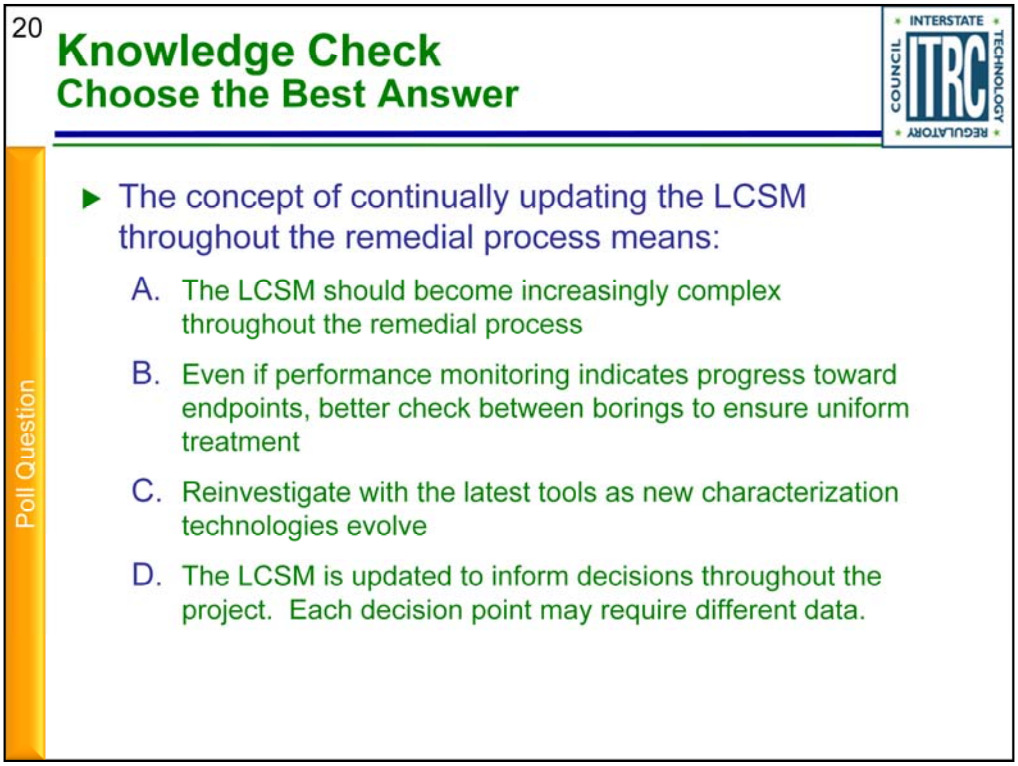
- Water- Table 15-20 ft. depth
- Fractured bedrock at ~25 ft depth,
- Down gradient receptors - 30 year old bedrock screened wells exhibit impacts
- LNAPL is off-site in unconsolidated soil
- What are remaining questions for the LCSM?
  - Likely requires nest well pairs (unconsolidated bedrock) for dissolved delineation

Receptor Well



Note the light brown on the right of the Tier 3 is a sand, yes its not in the description because soil type changes off-site but on-site borings don’t tell us that.

Example Remaining Questions : Where is LNAPL?, Is all LNAPL sourcing the impacts to wells or only the portion in bedrock or portion in shallow sand? Is dissolved phase through poor surface completion or bedrock aquifer



We asked you a question at the start of our presentation

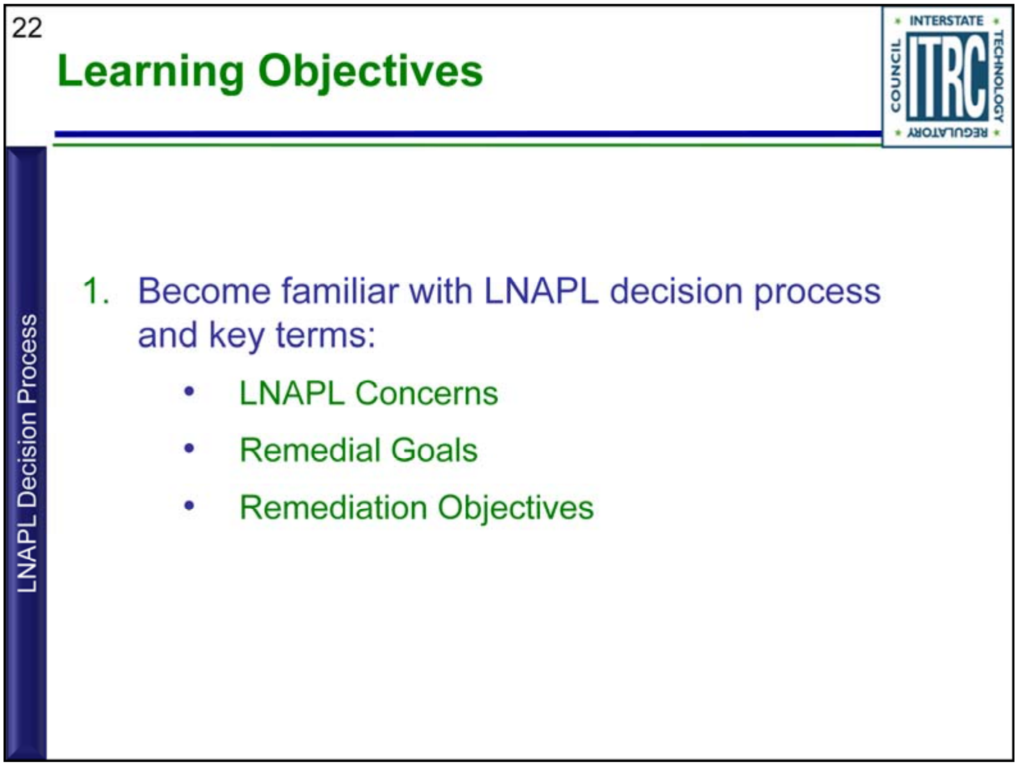
21

Summary
Initial LCSM and The Decision

Initial LCSM

- Is there sufficient information for a given question to support identification of Concerns?
- Is additional site characterization required for evaluating the Concerns LCSM?
  - Initial characterization activities may go beyond collecting data for concerns
  - Combining mobilizations for concerns and remedial selection characterization may improve efficiency at sites where remediation is already known to be needed
  - Collecting remedial-technology-focused characterization data at more complex sites may result in incomplete data collection, or less efficient data collection

No associated notes.



Now that we have been oriented to the LCSM, let's take a closer look at the overall LNAPL decision process and some key concepts and terms. The information we're about to cover comes from Chapter 5 in our guidance document.

Here is the first learning objective for this portion of today's training.

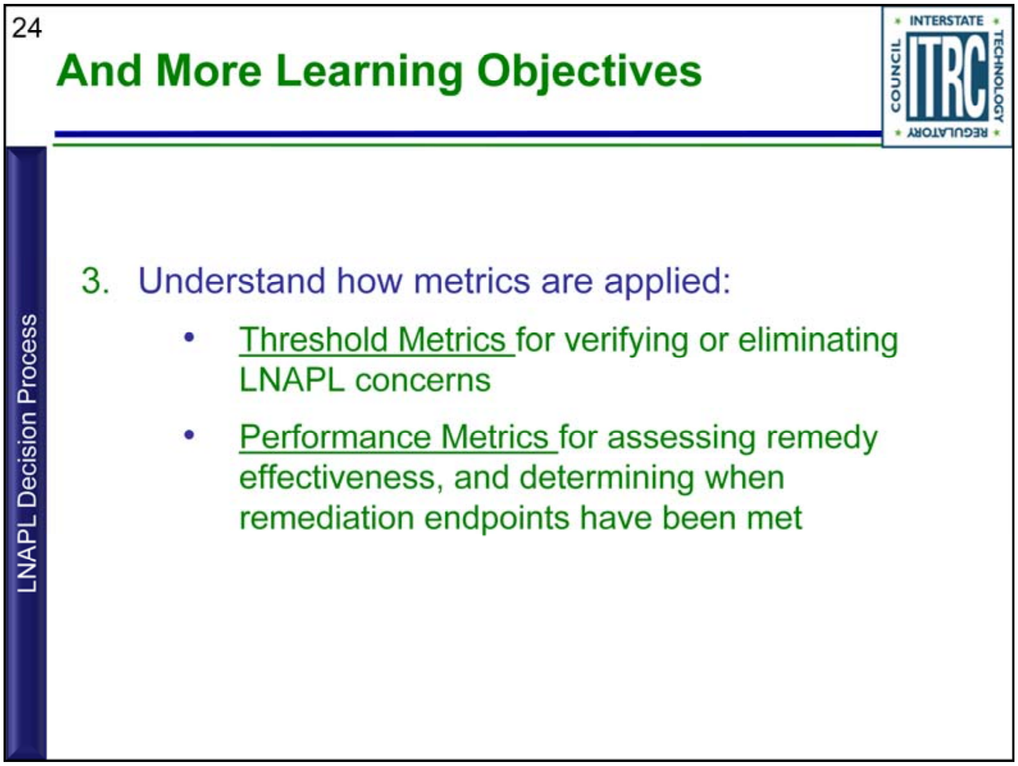
More Learning Objectives

LNAPL Decision Process

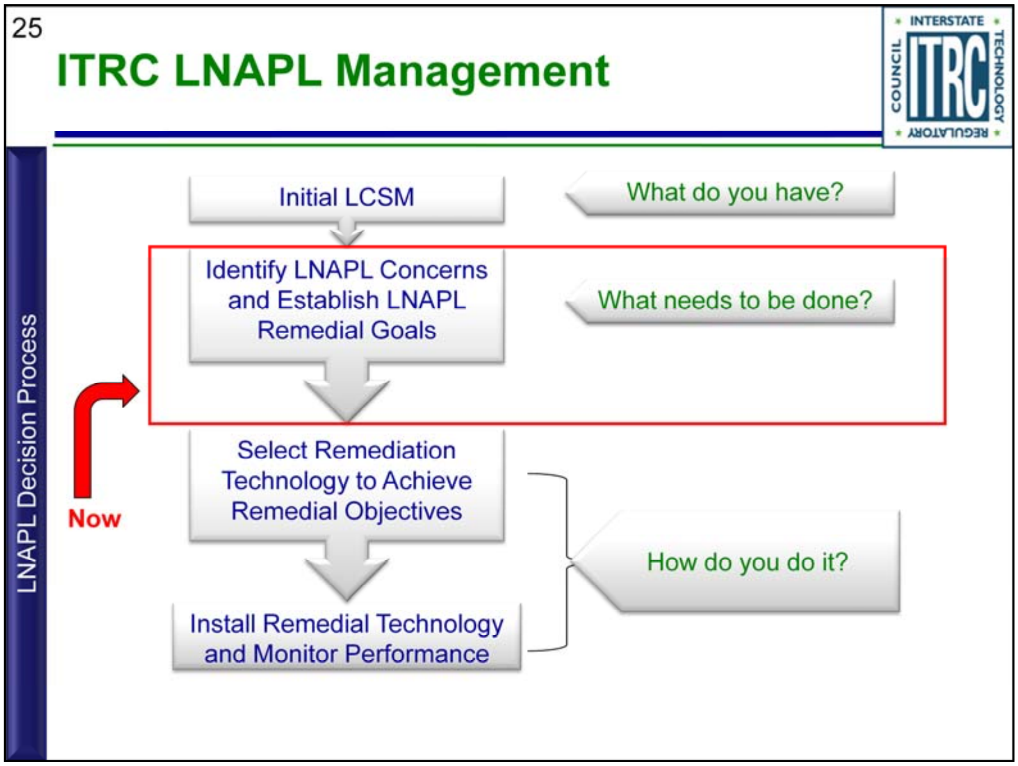
2. Understand three classes of LNAPL remediation objectives:
    - Mass Recovery
    - Phase Change
    - Mass Control

   To apply ITRC framework for LNAPL remedial technology selection

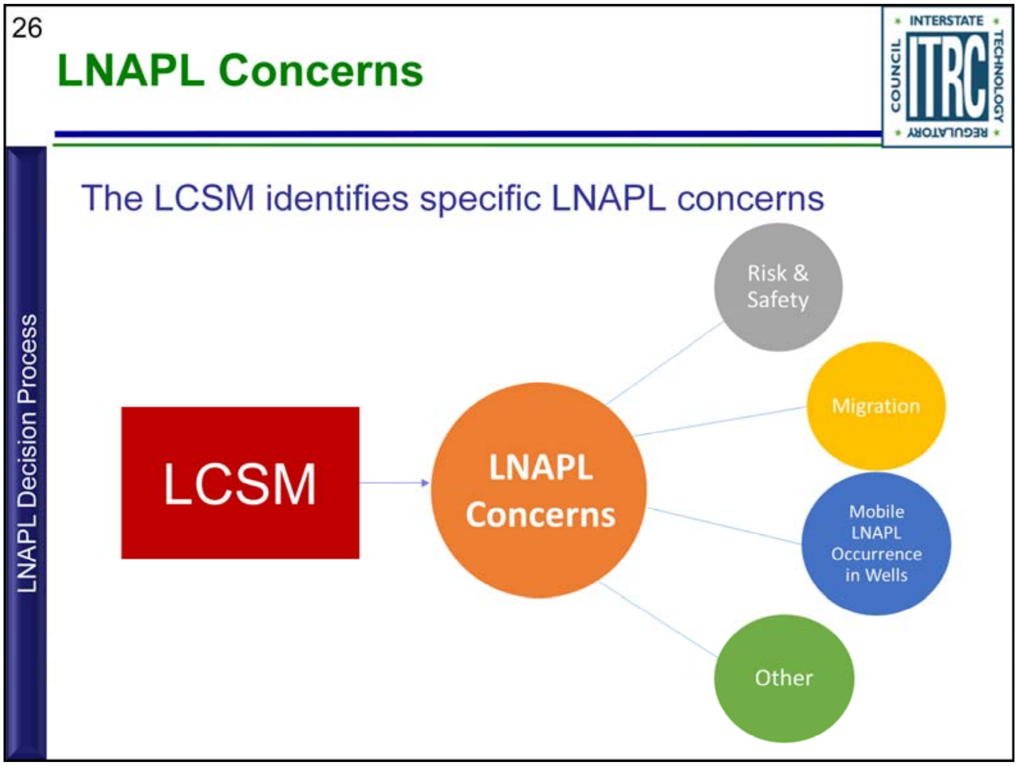
The second learning objective is to...



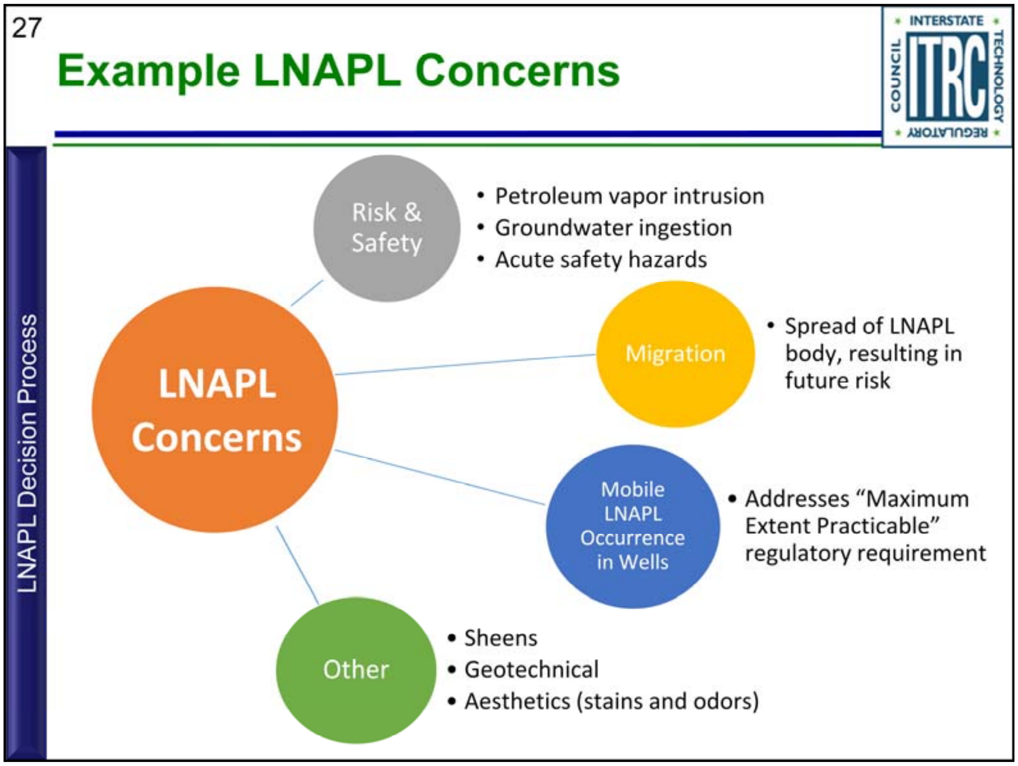
A third outcome



What we will be covering in this module.

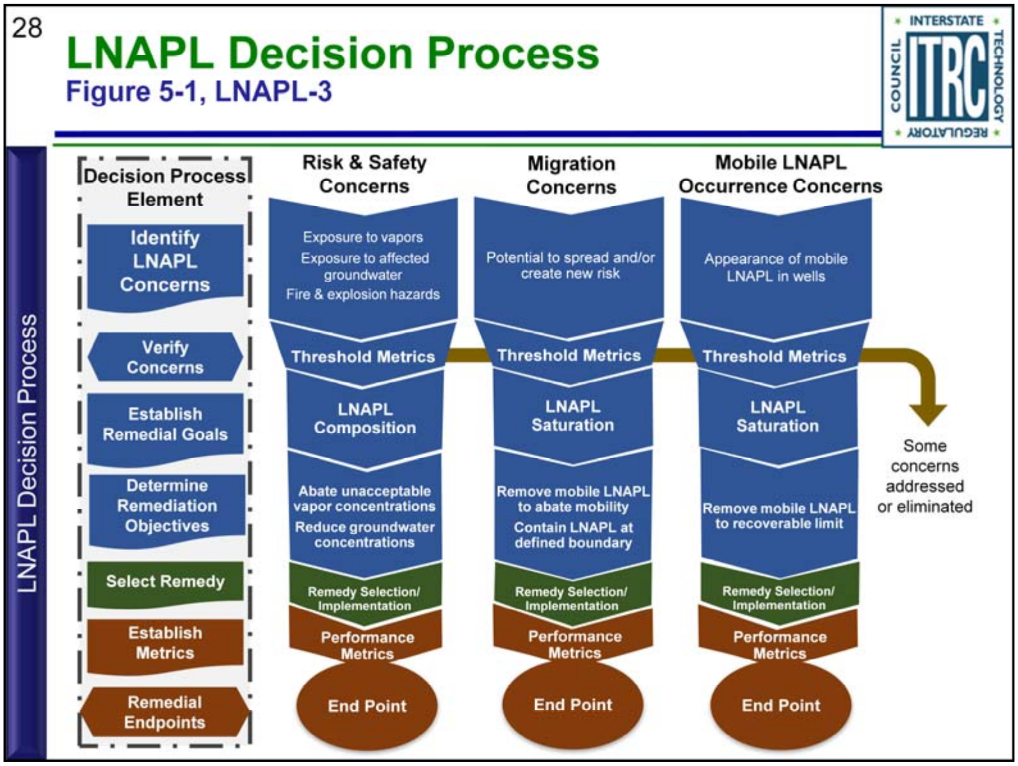


LCSM informs and identifies LNAPL concerns



Some specific examples of each type of LNAPL concern

Stakeholder engagement – refer to Chapter 2



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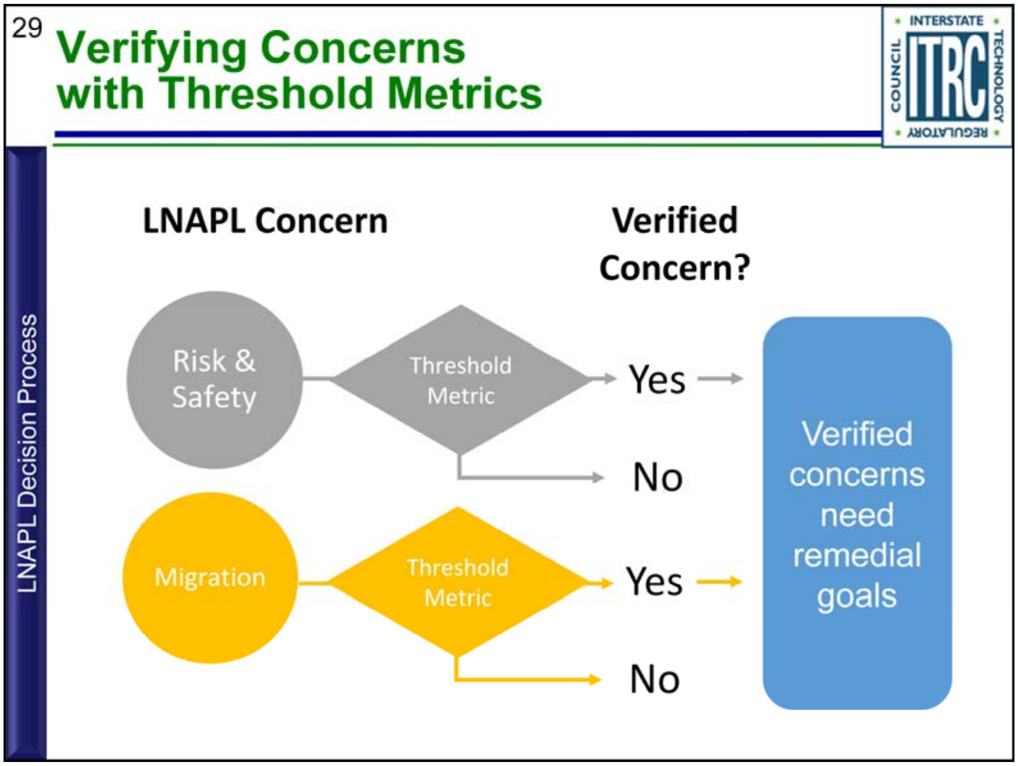


This “off-ramp” allows some concerns to be addressed without the need for remedial action. Example: if ingestion of GW at a supply well is a risk concern, then a comparison of in-hand data to drinking water standards, and an evaluation of dissolved plume stability, may show that the concern can be addressed without the need for further remedial action.

Knowledge Check

Poll Question

Which statement is true?

An LNAPL concern…

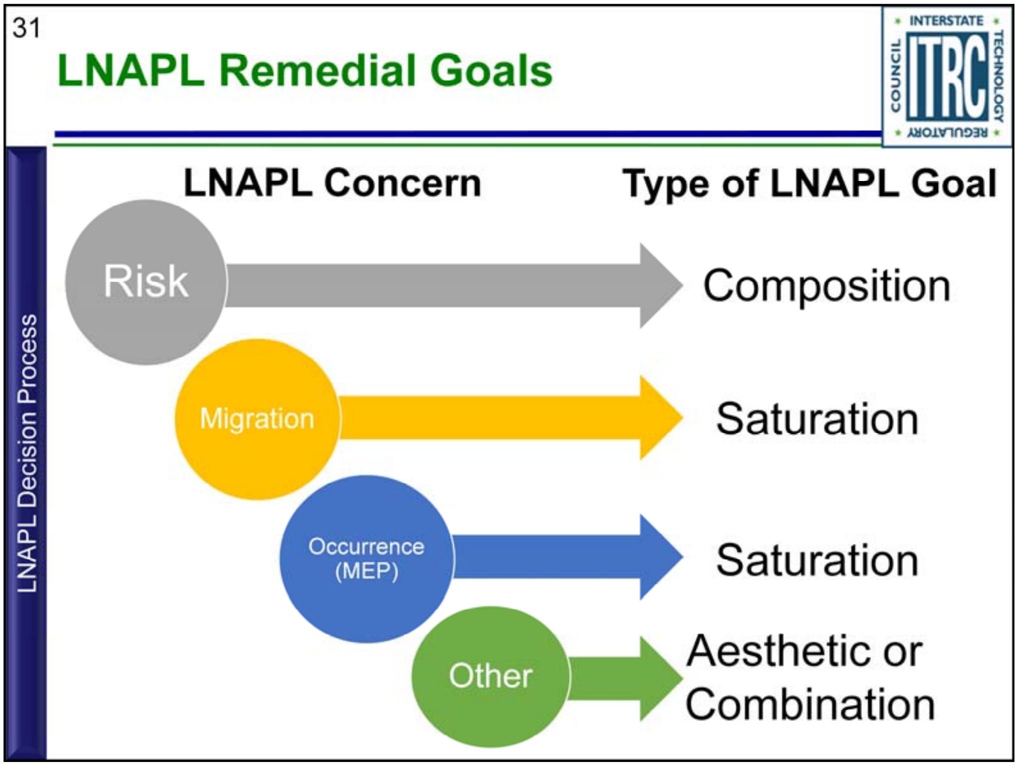
A. Does not need to be identified before remedial action occurs

B. May sometimes be addressed by testing against a threshold metric

C. Is nothing to worry about

D. Can only be addressed through remedial action

No associated notes.



Goals translate an LNAPL concern into a measurable LNAPL condition.

Each concern may have its own goal. Sometimes multiple concerns may share a common goal.

(For brevity, only Composition and Saturation examples are carried forward in the next slides)

More on goals in the next slide…

Remedial Goal vs. Remediation Objectives

LNAPL Decision Process

LNAPL Remedial Goal:

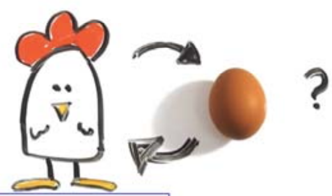
the desired change in LNAPL conditions

- Aspirational… envisioning a future state
- Established before choosing remedy

LNAPL Remediation Objectives:

the actions and desired outcomes that need to occur using the chosen technology

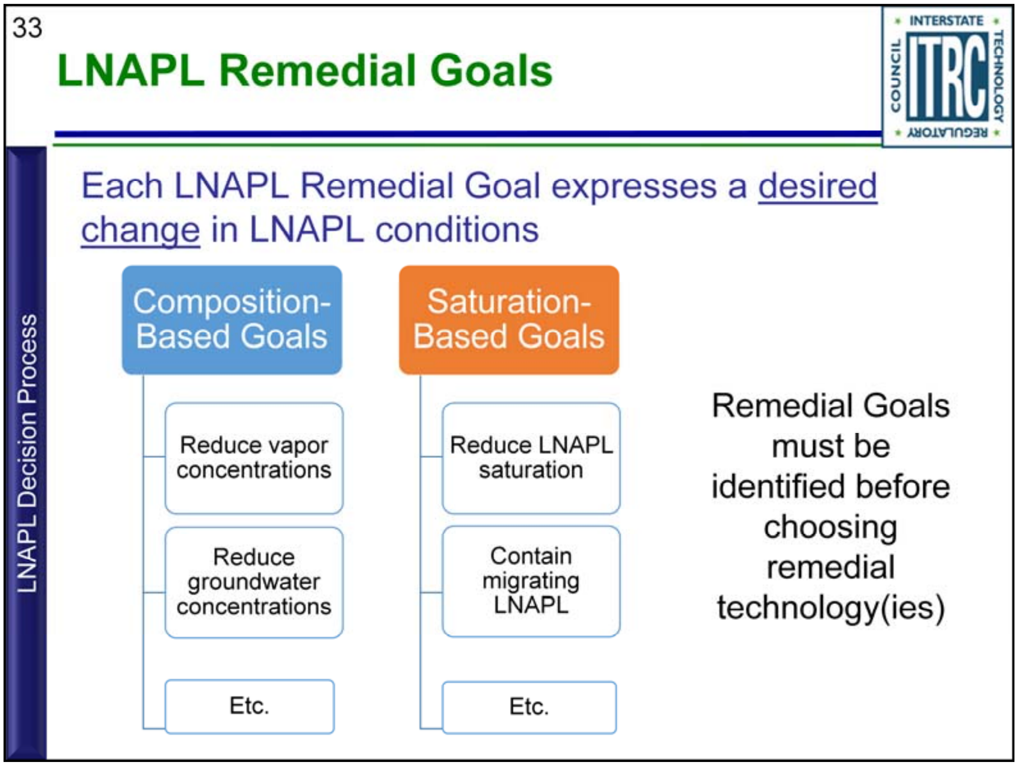
- Tactical… how to get to the goal
- Determined in parallel with remedy selection



These definitions are the *opposite* of what they were in the previous ITRC LNAPL Guide

A goal states, in general terms, the measurable change that you seek in the LNAPL condition.

Both graphics tagged with creative commons license



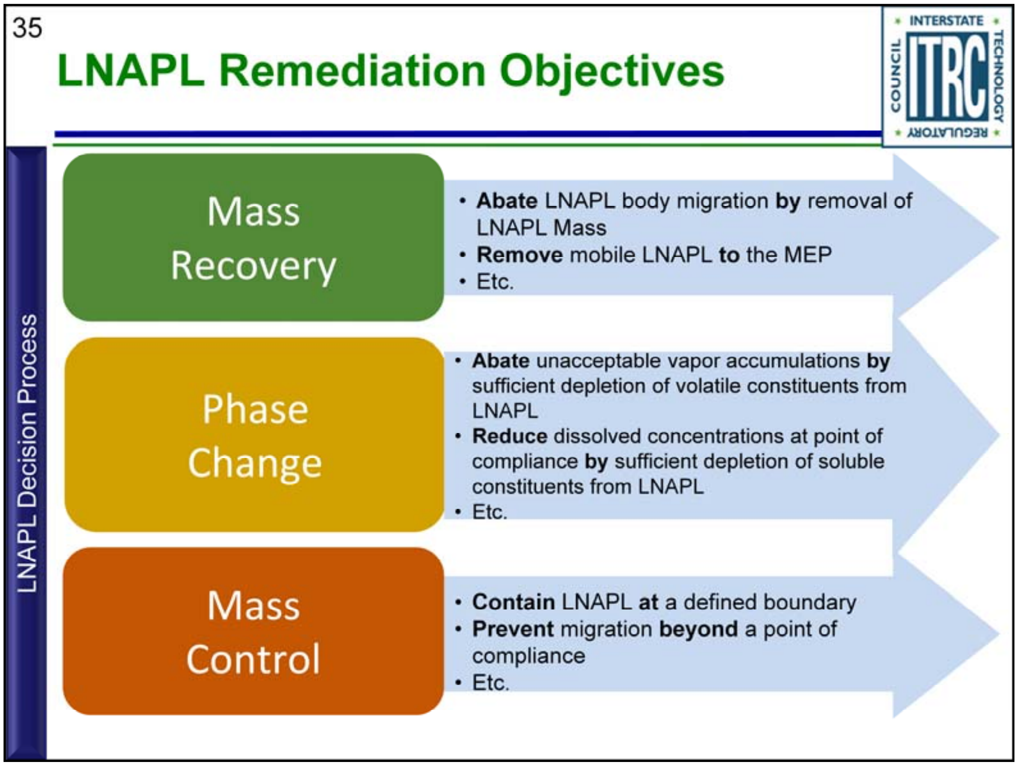
A goal states, in general terms, the measurable change that you seek in the LNAPL condition. At this stage, you have enough information to start the process of selecting a remedial strategy. You can't pick a remedy until you know what it needs to achieve!

LNAPL Remediation Objectives

LNAPL Decision Process

- LNAPL remediation objectives describe how the goal will be accomplished by the selected technology(ies)
- Remediation objectives state the actions and desired outcomes that need to occur using the chosen technology
- Combined with the agreed-upon endpoint and performance metrics, the remediation objectives becomes SMART
    - SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based

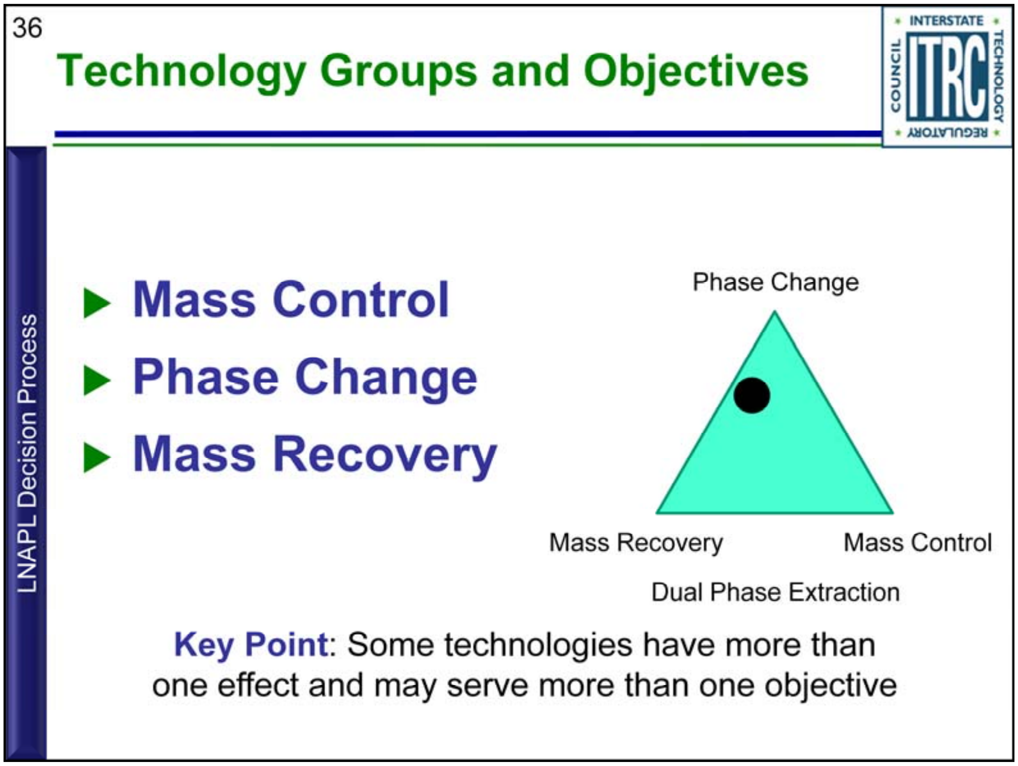
SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based



We categorize remedial technologies by the primary remedial mechanism that each employs.

The choice of technology – and remedial mechanism -- can influence how the objectives are expressed.
An objectives statement typically includes an active word such as : “stop,” “abate”, “control,” “change,” “remove” or “recover.”

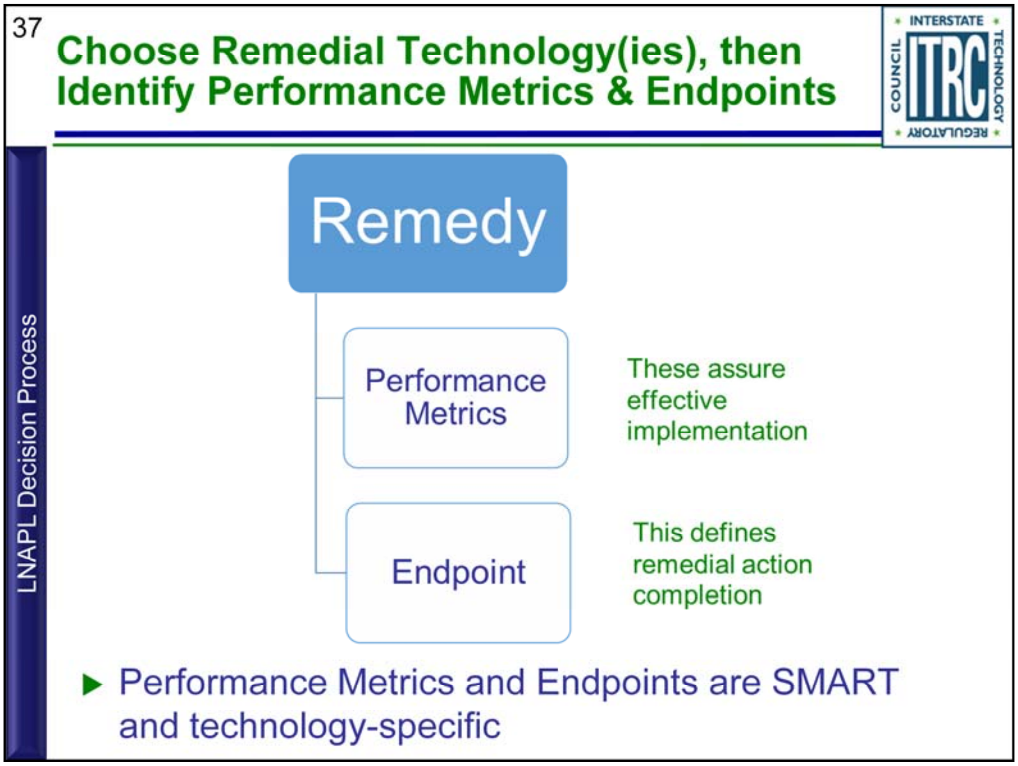
NSZD can work across all three categories of objectives.



This slide shows the first cut of how to think about technologies. What do they do? In the tech reg, this is also referred to as the "primary mechanism" 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 (triangular) diagram.

Example: Dual-phase extraction volatilizes, extracts, and biodegrades LNAPL, so it has both mass recovery and phase change mechanisms



The remedy needs to be capable of meeting the identified LNAPL remedial objectives. Then it needs performance metrics to assure that it is implemented effectively. It also needs an endpoint to know when it has done its job.

Rather than “trying something to see what happens” this process identifies what is expected to happen, and what to expect when you are done.

SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based

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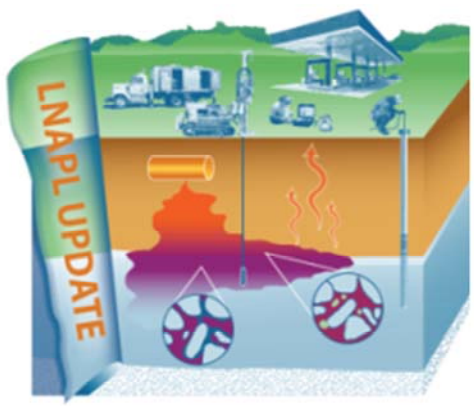
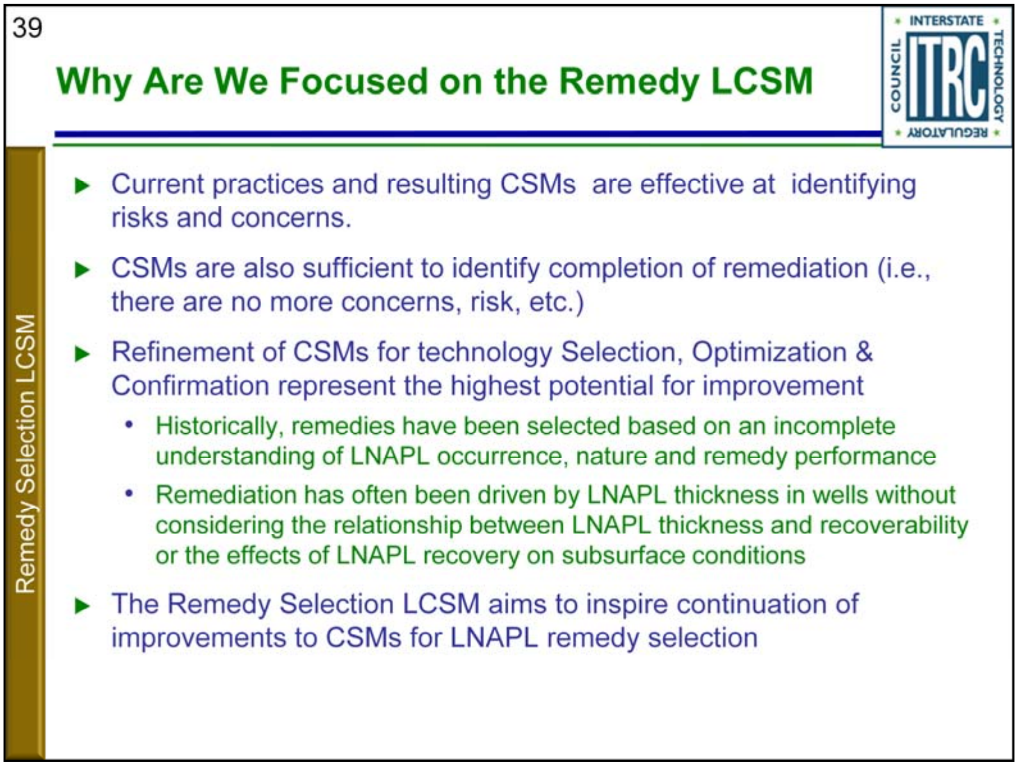
Q&A Break

Follow ITRC



- 1st Question and Answer Break

No associated notes.



Discuss how in past years, the concerns at a given site have not readily changed whether its dissolved phase concentrations, PVI, MEP. However understanding the efficacy of remedial technologies to achieve various goals has changed. Pump and treat and LNAPL recovery are not going to restore aquifer conditions. LNAPL in wells is generally not the largest source of LNAPL. Correctly directing your focus means weighing additional lines of evidence to establish an effective remedial approach.

Remedy Selection Needs Improvement
This Starts with the LCSM

Remedy Selection LCSM

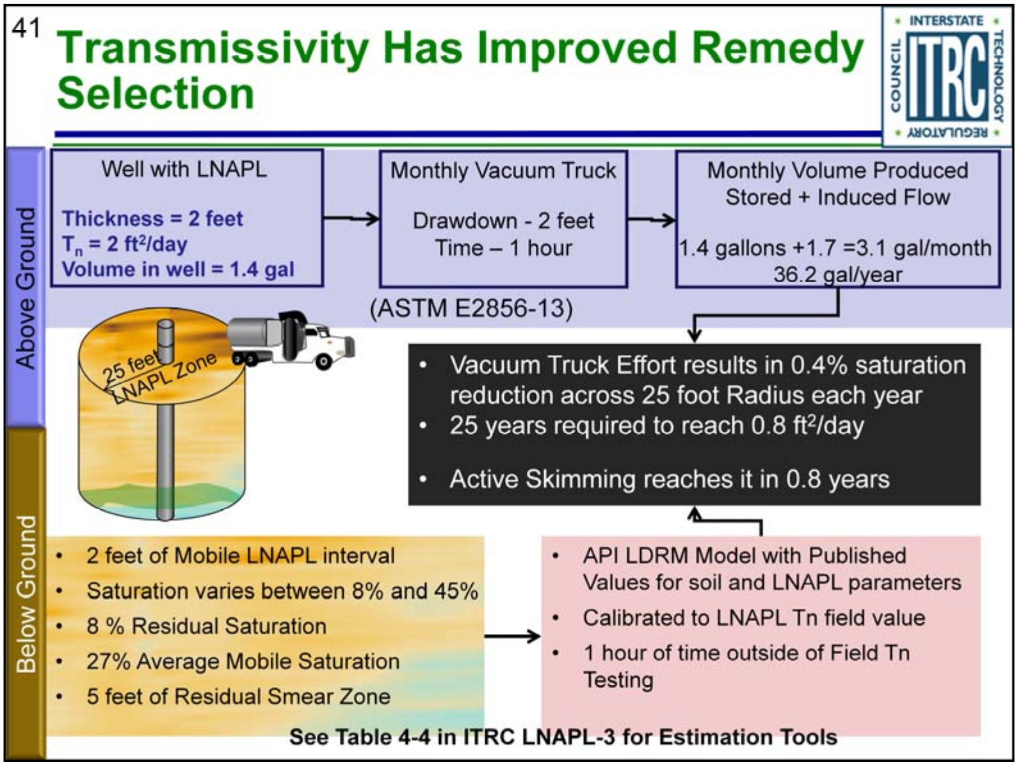
- Our concerns are known,
- We know the Remedial Technology Types
- Ok, move ahead with remediation?!? Give it a shot?

- LNAPL in Well
- No Migration

Vacuum- Truck It Out

- Insufficient data often exists at end of concerns LCSM to choose a remedy that will achieve remedial goals

No associated notes.



Message is Why are we not doing this for other mechanisms. Tn has allowed for improved Estimates for Recovery performance. We need to move in that direction for remaining mechanisms of remediation.

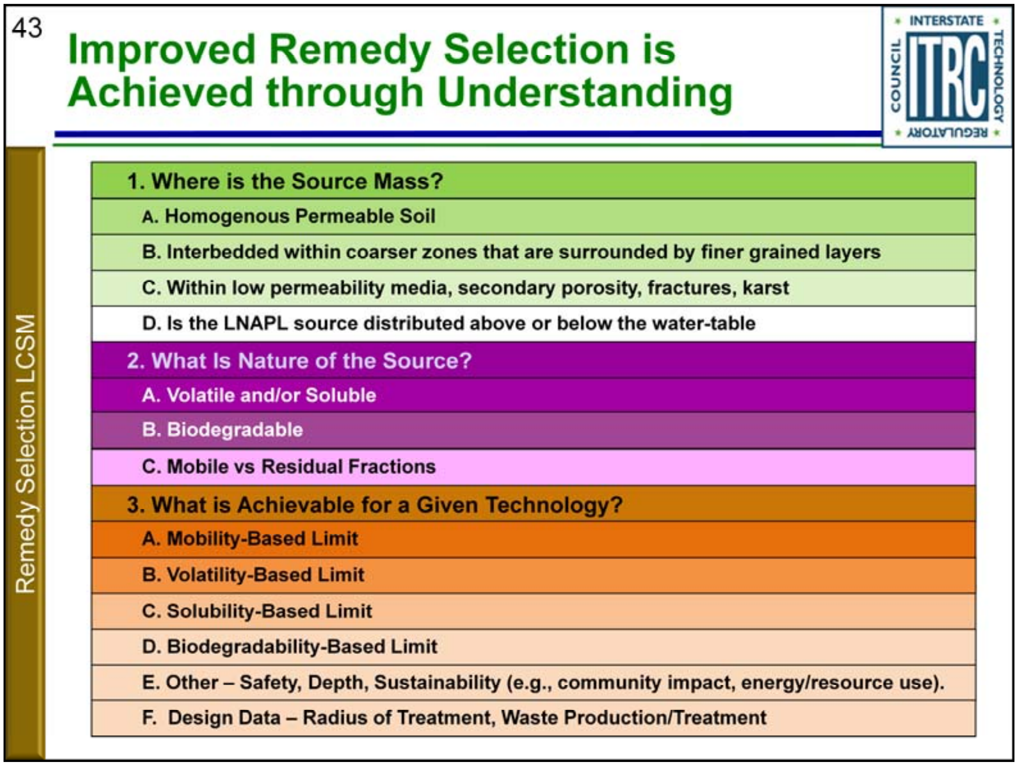
We have tools to do this for multiple mechanisms

Remedy Selection Should be Informed by the LCSM not just the Concern

Remedy Selection LCSM

- The concern associated with a gauged LNAPL thickness or a dissolved phase concentration does not indicate how to eliminate it
- This Section will identify approaches to answer
  - Where remediation needs to target
  - Which remedial mechanisms may be effective
  - Improved quantification of these mechanisms prior to implementing a technology

The concerns alone do not inform the remedial selection, gauged thickness does not mean recovery will be effective. We are going to discuss approaches to better inform remedy decisions. This essentially becomes a remedy selection LCSM



Each Layer build upon the previous question, this is less true for the concerns question but not absent from those either.

Discuss that this is the goal of the LCSM or the thinking behind it. Including these aspects into an LCSM improves decision making relative to the remedy selection. As we go through this section we will discuss some of the methods to evaluate these topics. This slide and the next provide the big picture and the details are forth coming.

Improved remedy selection is achieved through Understanding

1. LNAPL Distribution relative to
    a) Soil layers
    b) Water-table
2. Nature of the Source
    a) Recoverability, volatility, biodegradability
    b) Residual vs mobile LNAPL fractions
3. Understanding technical limitations of a technology
    a) These are technology and Site Specific

Remedy Selection LCSM Questions

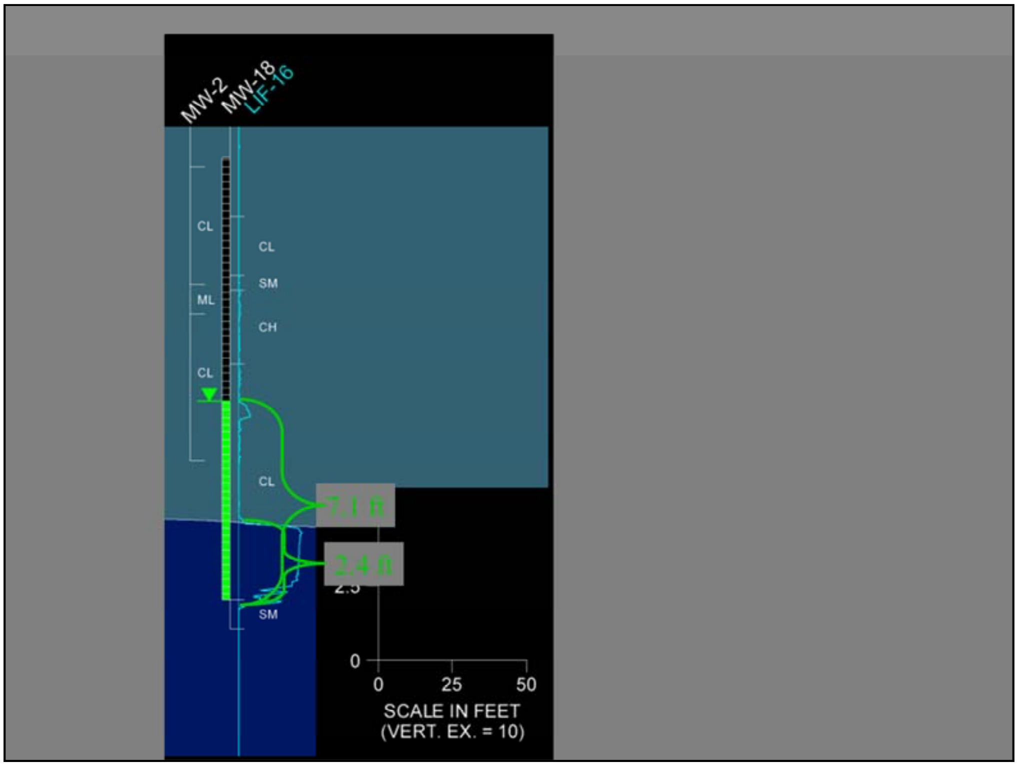
Remedy Selection LCSM

1. Where is the Source Mass?

- Identifies where to target remediation
- Identifies Physical factors/limitations to consider for impacted soil
  - Soil Permeability
  - Depth - absolute and relative to water table
- References (See Tables 4.2 in the ITRC LNAPL-3 Document for additional Tools)

Brief Discussion of Tools is Next

Characterization can be qualitative e.g., Tier 1 or more quantitative, higher resolution Tier 2-3



Go To 3D model and Discuss Bullets, We know can focus the recovery to the areas with the highest potential fro mobile recovery (courtesy of Andrew Kirkman)

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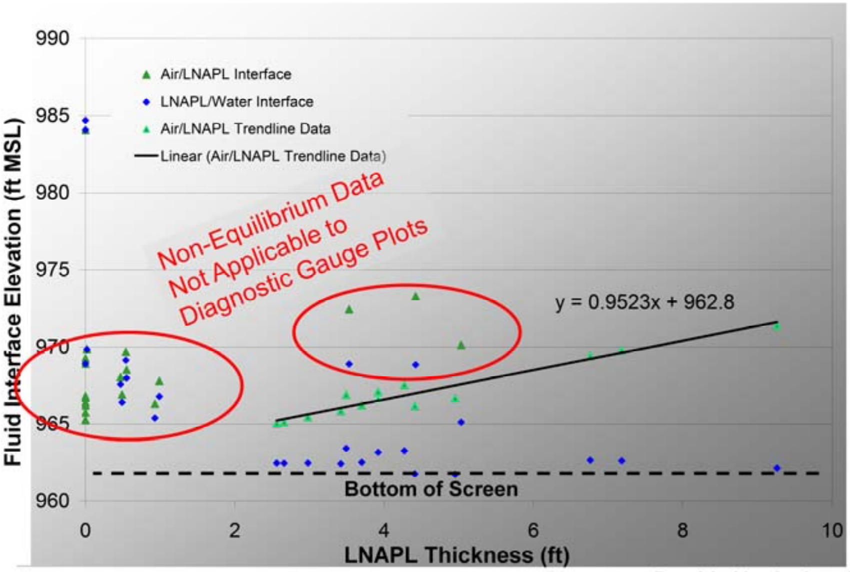
Diagnostic Gauge Plots Utilize Equilibrium Fluid Levels to Inform

Remedy Selection LCSM: Where is Source Mass



Provided by Andrew Kirkman

No associated notes.

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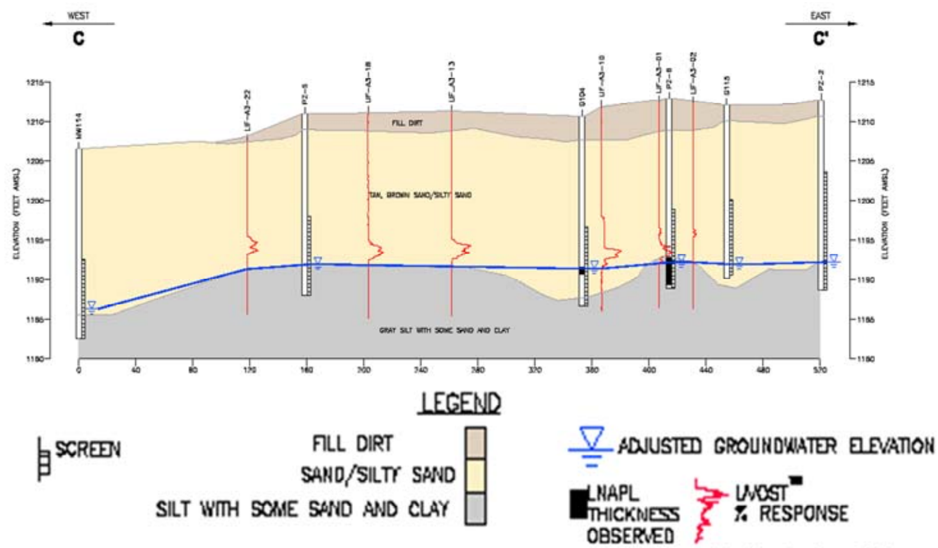
Where is the LNAPL?

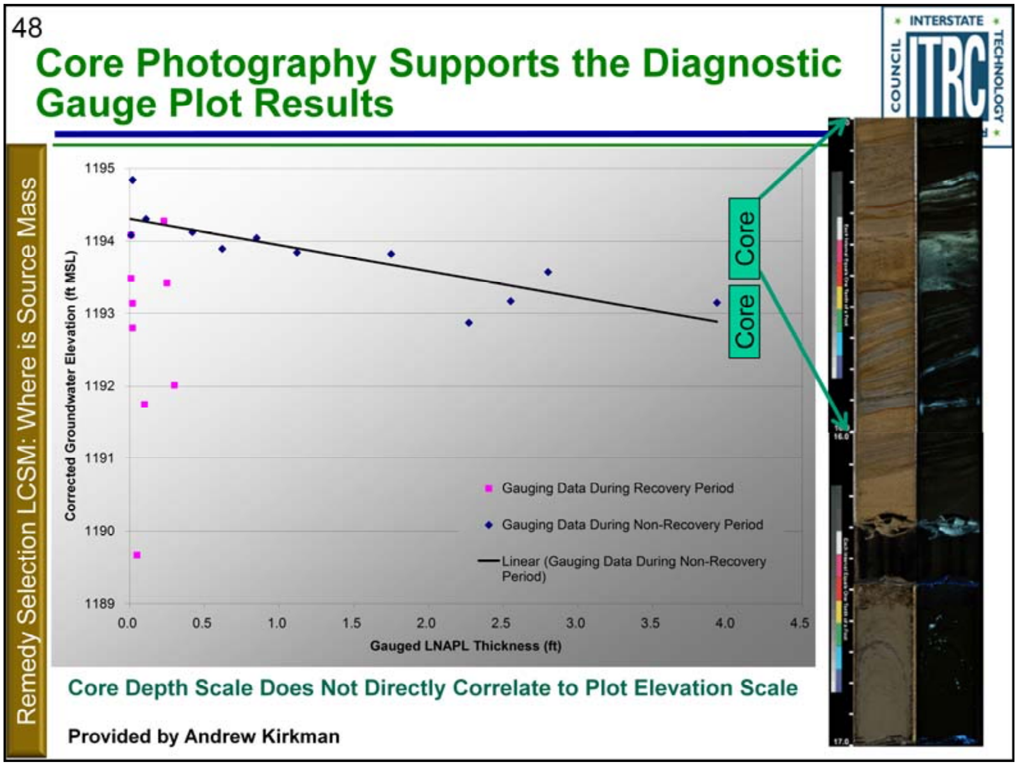
Above or Below the Water-table

Remedy Selection LCSM: Where is Source Mass



Provided by Andrew Kirkman

No associated notes.



If the remedial driver is MEP, perhaps this helps identify why 2-4 foot thickness might be in a well but low recovery, transmissivity is observed. If the remedial driver is dissolved phase risk, then this might help target remedial activities.

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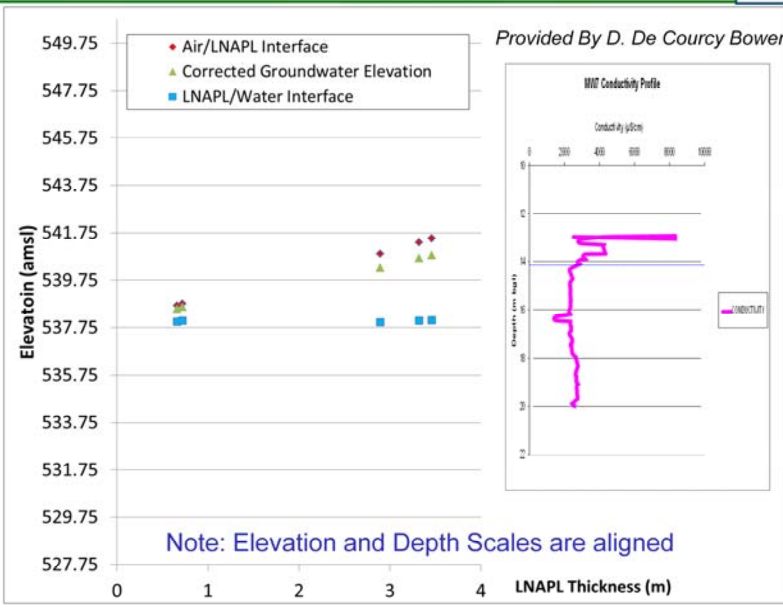
Diagnostic Gauge Plots
Bedrock Application

Remedy Selection LCSM: Where is Source Mass



Gauging data is useful, Gauging data not over time but plotted as a diagnostic gauge plot combined with subsurface geologic characterization is even more useful.

Summary For Where is The Source

Characterization Data

- Soil Characterization
  - Soil Boring Logs
  - Cone penetrometer tool
  - Hydraulic profiling tool
  - Core photographs
- Fluid Elevation Vs Soil Data
  - Diagnostic Gauge Plots
  - Cross-sections
  - Hydrographs with geology
  - Baildown tests

Remedial Application

- Identifies where injection/ gradient driven technologies will target
- Identifies hydrogeologic condition of mobile LNAPL and the elevation
  - Vacuum has limited effect on confined LNAPL
  - Water Drawdown has limited effect on perched LNAPL

See Geology/Hydrogeology & LNAPL Delineation in Table 4-2 of LNAPL-3

Note that Injection could be ISCO, Air Sparging, perhaps Injected media. Gradient driven technologies include, LNAPL recovery, Soil Vapor extraction, surfactant flushing

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Summary For Where is The Source

Remedy Selection LCSM: Where is Source Mass

Characterization Data

- LNAPL Source Distribution
  - Head space (GRO Range)
  - Shake Tests
  - TPH analysis for soil
  - Laser Induced Fluorescence
  - Membrane Interface Tool
  - Core photographs
  - LNAPL transmissivity map

  (Combine with Soil Profile Data)
- Geophysical Data
  - See Bedrock Appendix &
  - ITRC Fractured Rock Guide

Remedial Application

- Identifies where injection/ gradient driven technologies will target
- Identifies vertical intervals of fractures

  (Combine with LNAPL Source Distribution Data)

Note that Injection could be ISCO, Air Sparging, perhaps Injected media. Gradient driven technologies include, LNAPL recovery, Soil Vapor extraction, surfactant flushing

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Remedy Selection LCSM Questions

Remedy Selection LCSM: Nature of the Source

1. Where is the Source Mass?

- Identifies where to target remediation
- Identifies Physical factors/limitation to consider for impacted soil
  - Soil Permeability
  - Depth - absolute and relative to water table

2. What Is Nature of the Source?

- Identifies factors/limitation related to the LNAPL
  - Volatile, residual, mobile, biodegradable
- Table 4.2 in ITRC LNAPL update Document includes methods under
  - LNAPL Chemical /Physical Properties
  - LNAPL Recoverability
  - Natural Degradation Processes

Intense Discussion of Tools is Next

Characterization can be qualitative e.g., Tier 1 or more quantitative, higher resolution Tier 2-3

Is it Volatile

LNAPL composition tools

Headspace results

PVI Concern

Is It Biodegradable?

Fuel type knowledge

GC analysis

NSZD data

What is the Residual vs Mobile Fraction

Transmissivity 0.1 to 0.8 ft2/day – empirical

Residual smear zone vs mobile interval - can be qualitative or quantitative

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Key Points

What is the Nature of the Source

Poll Question

- The LCSM needs metrics to indicate relative efficacy of different remedial mechanisms
  - LNAPL transmissivity indicates recovery efficacy
  - Composition can help evaluate the biodegradability and vapor removal mechanisms
  - Soil gas and headspace readings are also indicative of relative volatility

Poll - Class Understanding of Transmissivity

What is your understanding of Transmissivity?

A. Understand its use and have applied on sites

B. Understand its use but not much experience

C. Know little about it

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Characterize the Site for Metrics Related to Remedial Mechanisms

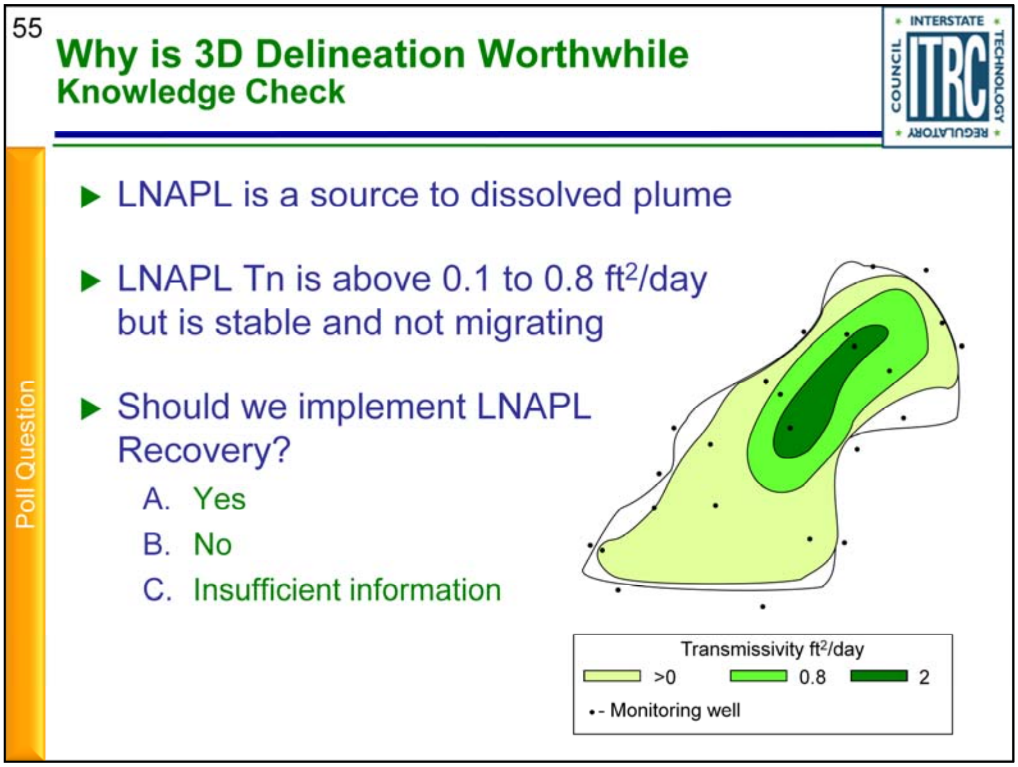
Remedy Selection LCSM: Nature of the Source

Remedial Mechanism	Characterization Data
• LNAPL Recoverability	• LNAPL Transmissivity • Mobile vs Residual
• Vapor Extraction	• Vapor Pressure
• Air Sparging	• LNAPL Composition
• Biodegradation ▪ Biovent ▪ BioSparge ▪ NSZD	• Compound Specific Biodegradation Rate • CO_2 Efflux / NSZD data • Respiration Rate

The Remedy Selection LCSM uses characterization data to indicate relative remedial effectiveness

Train Module #3 will take these remedial mechanisms and describe each technology in more detail & how these mechanisms may overlap

Note that, unless remediation is needed why would we characterize these as part of the concerns, Tn perhaps but biodegradation or NSZD rate probably not. This is why there is a remedy LCSM and a Concerns LCSM. While many of these aspect overlap with Concerns, not all do and the degree to which they might be characterized doesn't as well.



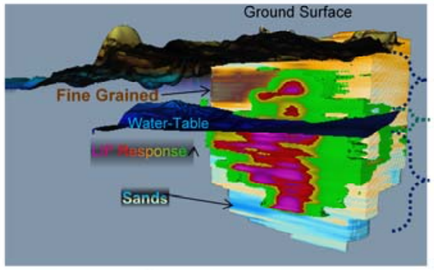
Should we implement LNAPL Recovery?

A. Yes

B. No

C. Insufficient information

Fraction of Mobile vs Residual Hydrocarbon



- The 1-2 feet of mobile LNAPL Mass **<<** 90 feet of residual vadose and saturated impacts
- What about
  - 0.2 foot of mobile LNAPL? ⟺ 4 feet of residual LNAPL?
  - Data such as TPH or saturation in mobile interval and above and below the water-table can indicate relative fractions
  - Models such as the LDRM model by API can also help evaluate
  - Consider seasonality of water-table fluctuations on LNAPL

While the is an example of a large LNAPL release the principles are the same for smaller LNAPL releases. E.g. a smaller release may result in 0.2 feet of thickness and a 10 foot smear zone. Where the relative difference in mobile interval and smear zone are not as dramatic other tools may be important and knowing the difference is still important for remedial strategy.

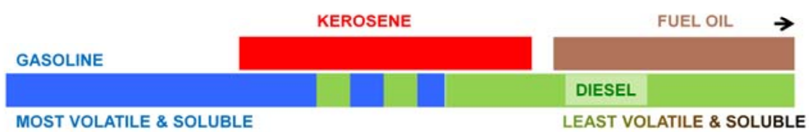
Empirical Method
Mobile vs Residual Fractions

- 2009 ITRC LNAPL guidance on LNAPL Transmissivity
  - Several sites were closed or given no further action based on
    - Asymptotic recovery or demonstrations that recovery would not benefit source reduction
    - Stable LNAPL bodies
    - No risk to receptors
  - These sites exhibited LNAPL transmissivity values between 0.1 and 0.8 ft^2/day
  - This range is a good indicator where further recovery may not be practicable and residual LNAPL dominates the source
  - LNAPL Transmissivity Information
    - ITRC Updated LNAPL-3 Appendix for Overview
    - Test Methods and Analysis – See ASTM E2856-13
    - Data Analysis – See API LNAPL Transmissivity Workbook (API.org)

No associated notes.

Composition and Volatility

- Table 3-2 provides indicators with gasoline in mind (e.g., PID readings >500 ppmv)
- Composition can be known based on facility operations
  - e.g., Retail with Gasoline only
- Composition can also be analyzed for with LNAPL samples
  - LNAPL analyzed by GC/FID method – provides a good understanding and is similar in layout to the bar chart below



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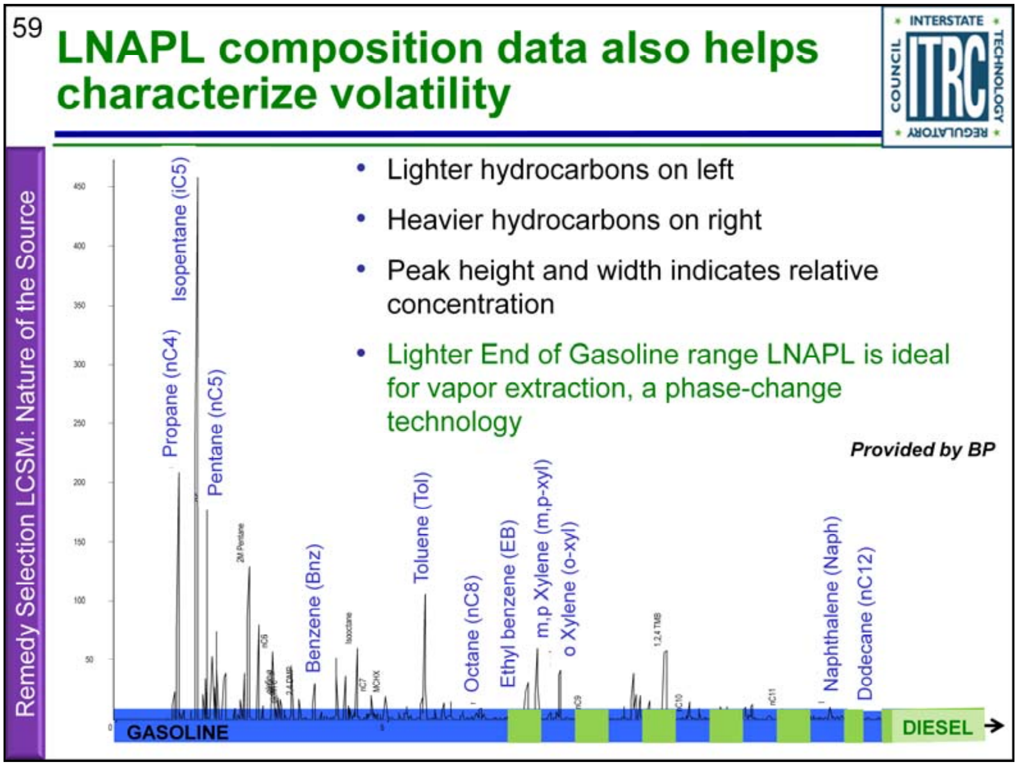
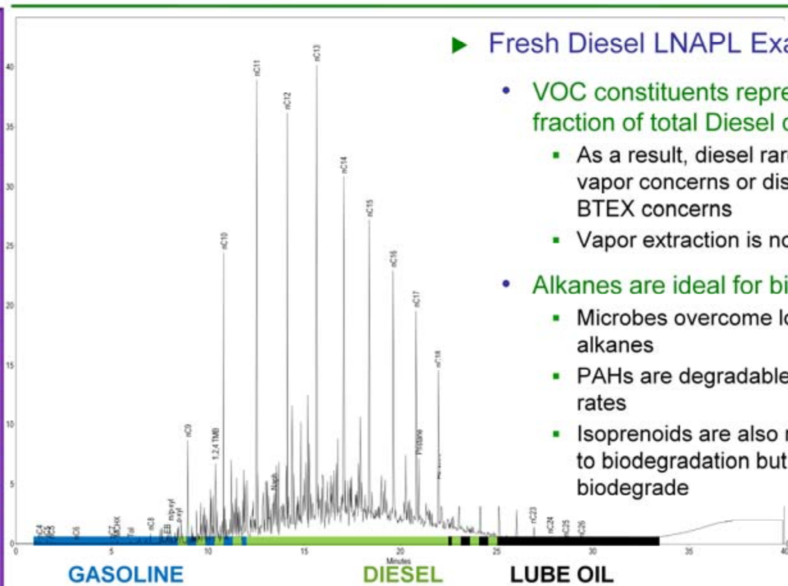


Explain that a chromatogram presents the relative mole fraction of individual hydrocarbon constituents. The smaller hydrocarbons are to the left and as we move right the hydrocarbon compounds increase in size/molecular weight.

Discuss that Chromatograms may hold a large amount of detail. We are primarily looking at ranges of what is present to help select the best remedy. This chromatogram presents the gasoline range fraction of LNAPL. When a Chromatograms has a higher proportion of peaks in the light end of gasoline range the volatilization mechanism can be effective given the correct geologic conditions. We cut of the Diesel range of this hydrocarbon.

Low Volatility LNAPL



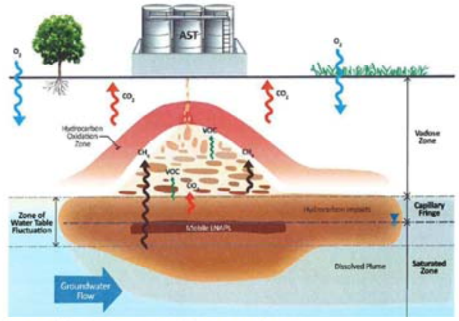
- Fresh Diesel LNAPL Example
  - VOC constituents represent a tiny fraction of total Diesel composition
    - As a result, diesel rarely generates vapor concerns or dissolved phase BTEX concerns
    - Vapor extraction is not effective
  - Alkanes are ideal for biodegradation
    - Microbes overcome low solubility of alkanes
    - PAHs are degradable but at lower rates
    - Isoprenoids are also more resistant to biodegradation but still biodegrade

Provided by BP

No associated notes.

Natural Source Zone Depletion
A Baseline for Biodegradation

- Represents a Conceptualization and Quantification of biodegradation processes in the subsurface
  - Includes aerobic and anaerobic
- Highlights that Microbes Are Ubiquitous and remain active in the same pores as LNAPL
- Can address a large range in hydrocarbon composition
- Rate varies based on composition

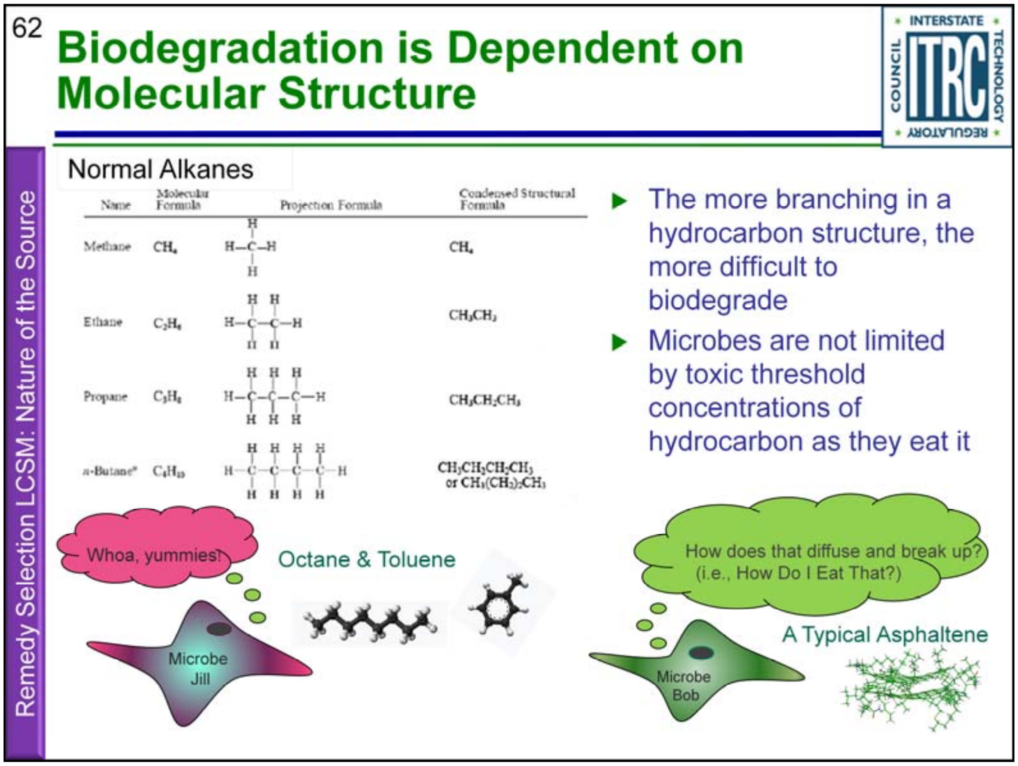


- Current methods quantify the majority of degradation using thermal, CO_2 efflux, or soil gas methods

API, 2017

Note that this is discussed more as a leading and lagging metric in Part 3

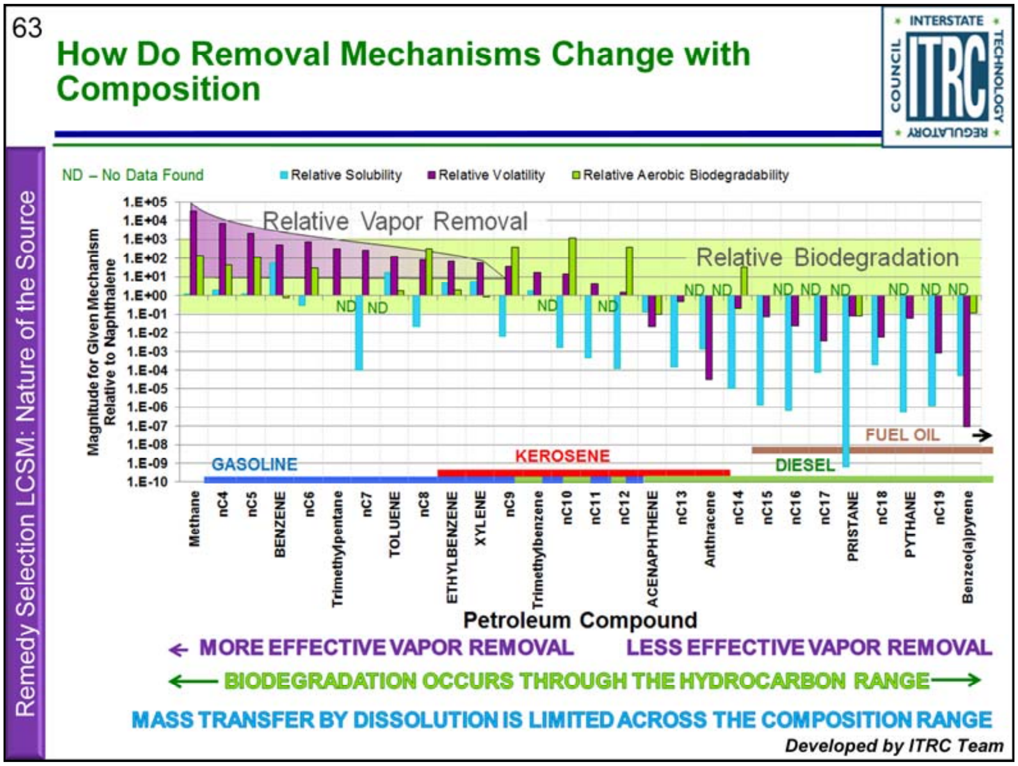
Also why are we focused on biodegradation, Other remedial metrics, indicators, e.g., volatility, Tn are more mature. There is less awareness of the biodegradation performance than other mechanisms.



We’ve discussed one aspect to understand the nature of the source mobile vs residual fraction, Now we are going more towards the chemical side or compositional nature of the source.

We will discuss biodegradation and vapor aspects as related to remedial mechanisms

Glucose, can be a straight chain carbon molecule with hydrogen and OH groups. It’s the most basic substrate for us. I look at alkane hydrocarbons similar for microbes when considering hydrocarbon degradation. More complicated structures have less net energy due to more difficult bonds to break, lower hydrogen molecules resulting in lower energy yield.



Doesn't have to be soluble to be biodegradable

Vapor limit is in gasoline to kerosene transition

This is a graph of vapor pressure – black line and biodegradation rates – purple line

The biodegradation rate constant values are not in the same units as vapor pressure and the absolute values are not comparable. What is comparable is how these values change with hydrocarbon constituent.

The x-axis represents LNAPL types, gasoline, Kerosene, diesel as well as individual components of these mixtures

Example Technology Parameters
Improving the LCSM for Remedy Selection

Remedy Selection LCSM: Nature of the Source

- LNAPL Transmissivity is a good example of a predictive metric that can be characterized without Pilot testing
- Parameters that can be quantified to allow initial technology performance estimates/comparisons

- General Remediation
  - Soil Type/Permeability/Hydraulic Conductivity
- LNAPL Recovery
  - LNAPL Transmissivity, Decline curve data from existing recovery data
  - Mobile vs Residual
- Bioremediation
  - Passive
  - Bioventing
  - Biosparge
  - Phytoremediation
  - → NSZD Rate or Respiration Test
  - → LNAPL Composition
  - → Macro & Micro Soil Nutrients
- Soil Vapor Extraction / Air Sparging
  - LNAPL Characterization for volatile fraction and constituent fractions
  - Pilot Test

No associated notes.

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Example Technology Parameters
Improving the LCSM for Remedy Selection

Remedy Selection LCSM: Nature of the Source

- ISCO, Carbon Injection, other injection technologies
  - 3D Delineation of source zone to be treated
  - Soil Permeability/Hydraulic Conductivity
  - LNAPL Composition
  - Bench/Pilot Scale Testing
- Surfactant
  - 3D Delineation of Source Zone
  - LNAPL Physical Properties
  - Soil Permeability/Hydraulic Conductivity
  - Bench/Pilot Scale Testing
- Thermal
  - 3D Delineation of Source Zone
  - LNAPL Physical Properties
  - Bench/Pilot Scale Testing

No associated notes.

Estimating the Performance of Potential Remedies

- While mobile LNAPL may exist, alternate mechanisms may still be more effective at Source Remediation
- Remedial Mechanisms can evaluate individual constituent removal vs bulk LNAPL removal
- Biodegradation may outperform other mechanisms
  - Confirm the composition and weathering during LCSM development
- Sufficient science exists today to compare expected performance rates
- Go review USEPA, ASTM, API, Army Corps of Engineers, scientific literature, and unit conversion references to quantify performance expectations

No associated notes.

Remedy Selection LCSM Questions

Remedy Selection LCSM

1. Where is the Source Mass?

- Identifies where to target remediation
- Identifies Physical factors/limitation to consider for impacted soil
  - Soil Permeability
  - Depth - absolute and relative to water table

2. What Is Nature of the Source?

- Identifies factors/limitation related to the LNAPL
  - Volatile, residual, mobile, biodegradable
- More advanced characterization can occur (See Table 4.2)

3. What is Achievable for a Given Technology?

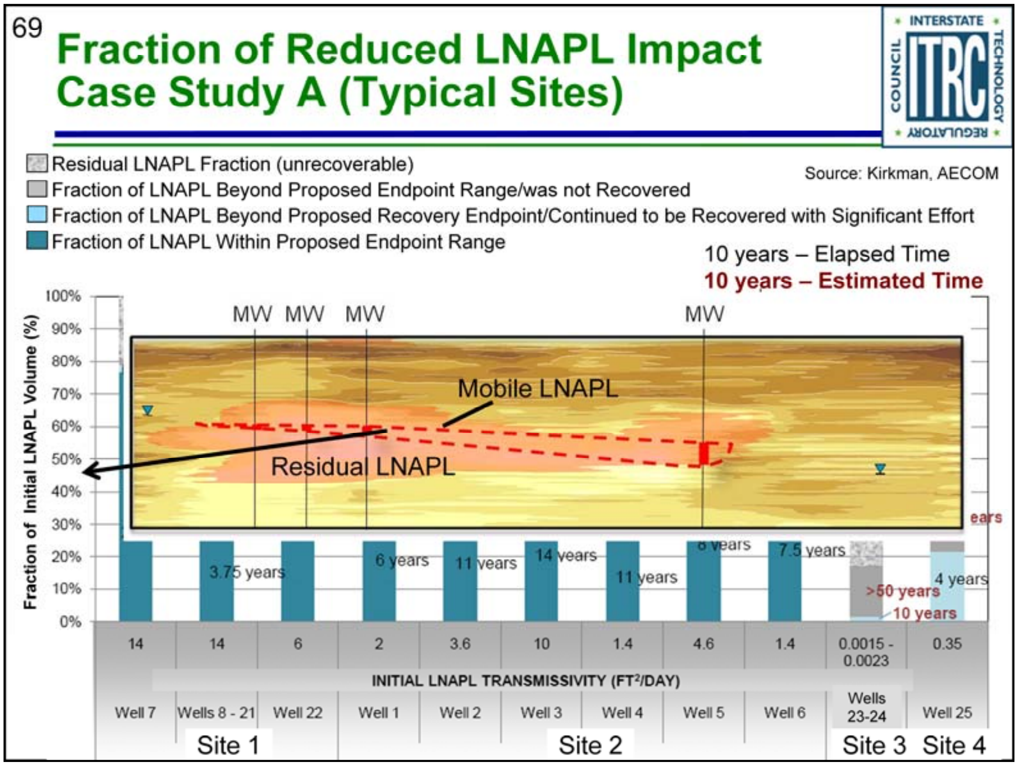
- Utilizes the past 2 questions (Site Specific) and the characteristics of a given technology to define
  - **Site Specific** Remedial effectiveness, cost, waste, impact to current land usage, safety and other feasibility study like considerations
- Utilize ITRC Appendix Tables and External Technology Specific References (See Tables 4.3 & 4.4, ITRC Update Document)

Characterization can be qualitative e.g., Tier 1 or more quantitative, higher resolution Tier 2-3

Empirical Method
Mobile vs Residual Fractions

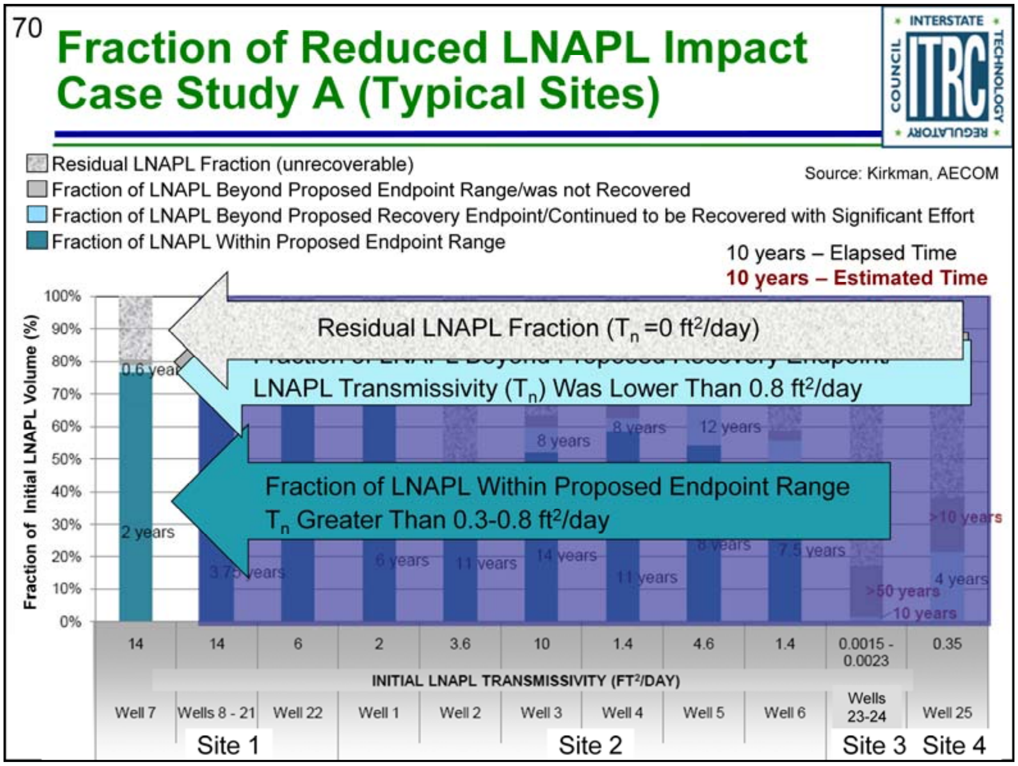
- These data represent
  - 4 sites Ranging from 400 ft./day to 0.3 ft./day hydraulic conductivity
    - Site 1 - 400 ft/day sand and gravel
    - Site 2 – 30 ft/day sand overlain by fine grained silts and clays
    - Site three – 0.3 ft/day sandy silt
    - Site 4 – 0.03 ft/day silty sand
  - Fraction of LNAPL recovered above 0.3 to 0.8 ft^2/day is provided, along with remaining residual and mobile

No associated notes.



Mobile interval is for sites 1 and 2. Sites 3 and 4 utilized entire smear zone to estimate residual and mobile fractions

Sites 1 and 2 utilized Decline curve analysis and core analyses. Sites 3 and 4 utilized multiple TPH soil samples and recovery data.



No associated notes.

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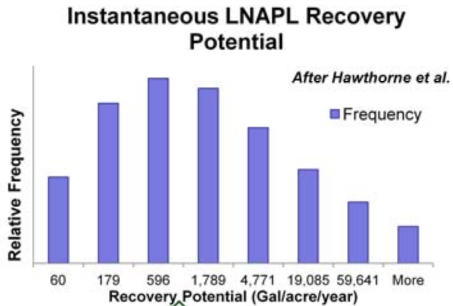
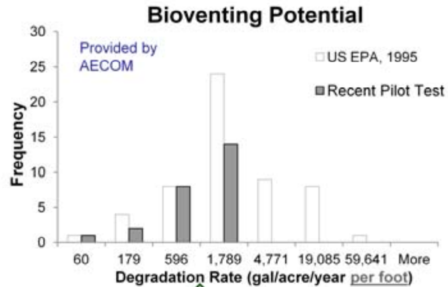
Fraction of Reduced LNAPL Impact Case Study A (Typical Sites)

No associated notes.

Why Do LCSMs quantify recoverability (Tn) and not Enhanced Biodegradation Potential?

Remedy Selection LCSM: Technically Achievable



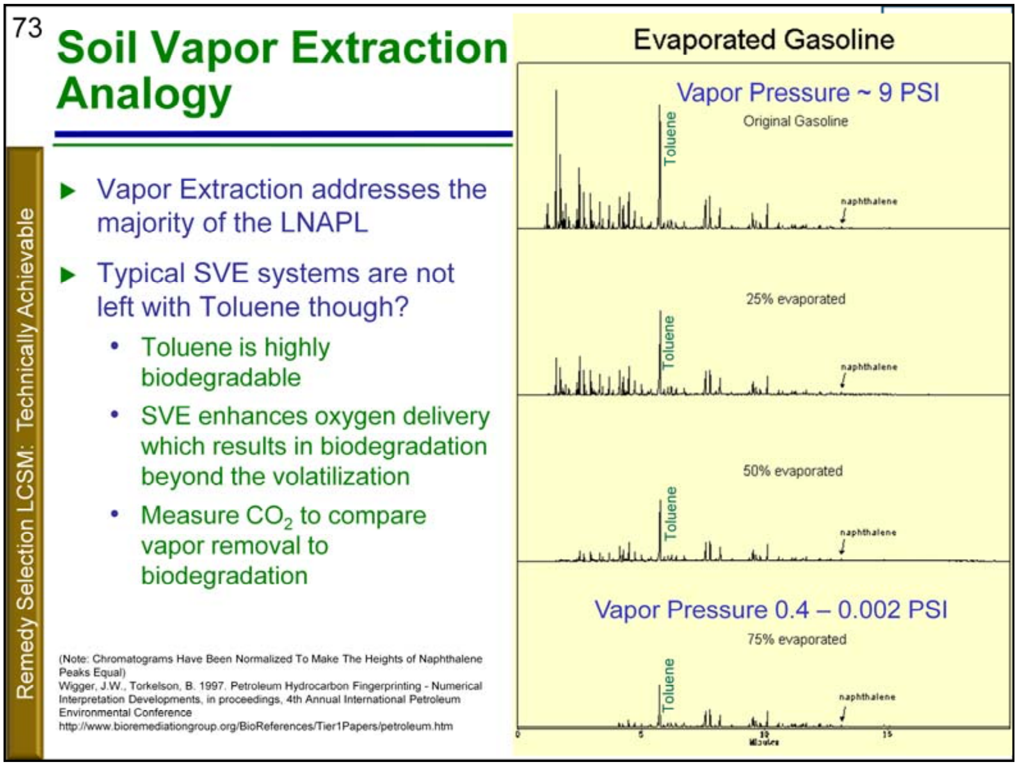


← **Average Removal Rates** →

- Average INITIAL LNAPL recovery rate ~ Average Bioventing rate FOR 1 FOOT OF SOIL TREATMENT
- Microbes are not limited by concentration of LNAPL (i.e., too toxic)
- Limited by nutrients, water content, composition of LNAPL

Data Sources Represent API Tn Database & AFCEE Bioventing Database

No associated notes.

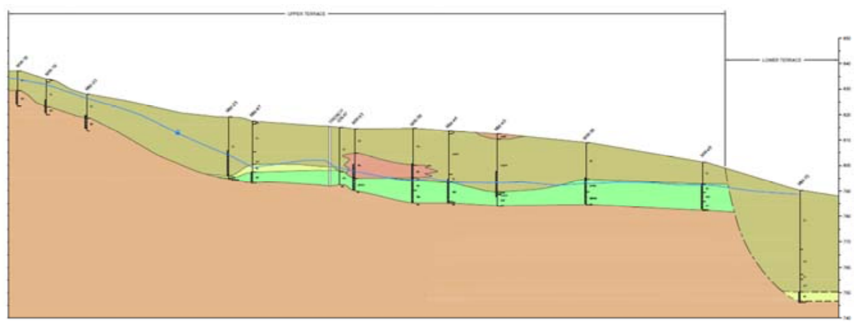


Describe volatilization and phase change process. Discuss how benzene dissolved concentrations would decrease and over all GRO would decrease because less soluble compounds remain. Ask is the toluene mass increasing or concentration? Ask with SVE is volatilization the only mechanism

Challenge thinking about left over mass, no benzene, no risk, so now what?

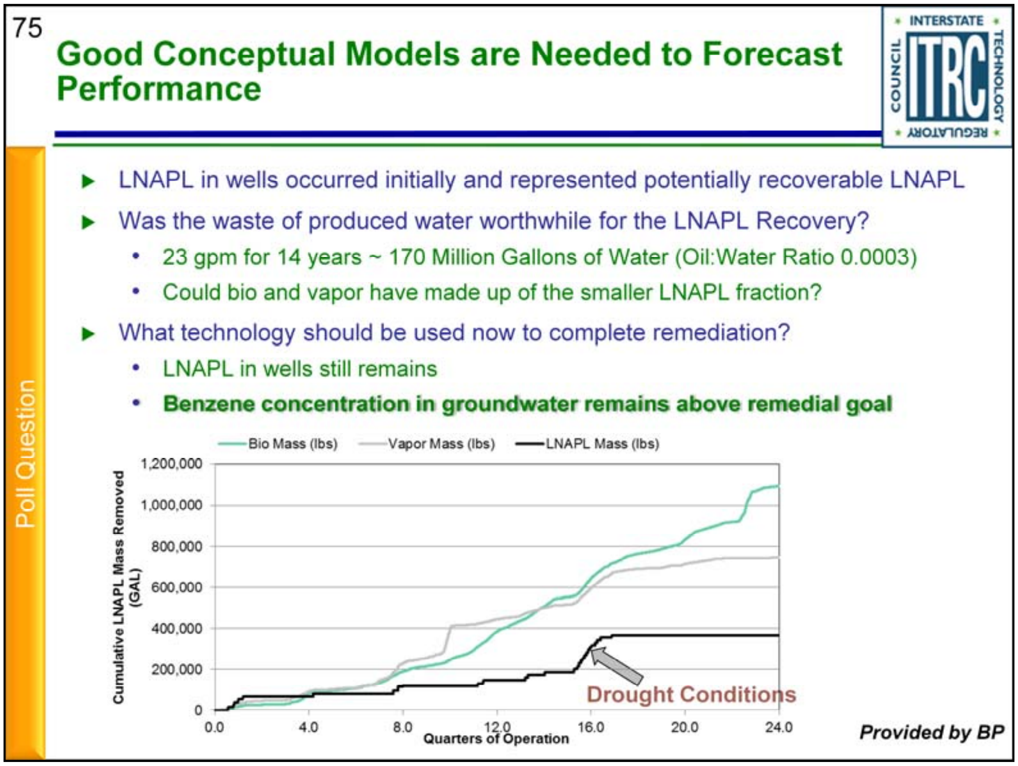
Why Performance Estimates Are Important

- Site – MPE within Terraced and Channelized Deposits
- Multi-phase extraction system to address historical gasoline release
- Water-table fluctuations affect all remedial mechanisms



Provided by BP

No associated notes.



LNAPL Transmissivity was not quantified to decide if LNAPL Recovery should be implemented, thickness was

Poll – Knowledge Check

What technology should be used now to complete remediation?

- LNAPL Recovery
- Bioremediation
- Vapor
- Surfactant
- ISCO

Site Specific Limits of Technology

- Site Limits of Technology Combine the inherent Technical Limits with Site Considerations
  - Sites with existing systems can utilize remedial performance data when selecting alternate remedies
    - Decline curve analysis
    - Sustainability analysis including waste generation, economic, Community
  - The waste stream treatment of a given technology represents a higher level of cost/effort/risk than alternate remedial mechanisms that achieve a similar or higher level of effectiveness
    - An operating industrial facility may be able to treat water more easily than a retail station
    - Why utilize propane to oxidize 100 ppm vapor when biodegradation dominates?
  - Source zone is inaccessible due to source relative to infrastructure or other physical obstacles

No associated notes.

Technically Achievable
Tiered Approach is Applicable

- Higher Tier Sites may benefit from quantified metrics for comparing technology performance estimates
- Analytical or other Modelling Tools May Benefit Technology Performance
  - Use of these tools encourages higher resolution data collection
  - Quantification of Parameters
    - Often several of the Parameters can be looked-up or calibrated based on a few site specific parameters
  - Table 4-4 In the guidance provides references to existing analytical calculation methods, tools and/or models for various remedial mechanisms
  - Moving in this direction will encourage development of additional tools to further inform performance expectations

No associated notes.

Unit Conversion Challenges

- Few technologies utilize similar performance metrics / units
  - LNAPL Recovery – GPD, $/Gal, LNAPL-Water Recovery Ratio
  - Vapor – lbs./hr., $/lb.
  - ISCO – ?? $/lb., change in dissolved phase / source mass, it's a contact sport
  - NSZD – gal/acre/year
- Need to find a similar unit for comparison
  - Gal/Acre/year useful for Mass Removal
  - $/lb. removed is frequently used
  - Pounds of CO_2 produced per Pound of Contaminant Removed
  - Constituent specific mass removal rates for vapor or dissolved plumes may be required
  - Risk to Workers (Remediation or active facility)
  - Risk Reduction to Community

Discuss why Change in GW concentrations isn't enough

A lack of change in GW concentration doesn't indicate why a given technology didn't work, was it contact issues, is the rate too low. It is one metric but perhaps needs to be supplemented.

Technically Achievable
What is it?... Examples Include

Remedial Mechanism

- LNAPL Recoverability
- Volatilization
  - Air Sparging
  - Soil Vapor Extraction
- Biodegradation
  - Biovent
  - BioSparge
  - NSZD
  - Phytoremediation
- Injection
  - ISCO
  - Carbon

Technically Achievable / Limit

- LNAPL Recoverability
  - LNAPL Transmissivity - 0.1 to 0.8 ft^2/day
- Volatilization
  - Vapor Pressure 10-100X less than Gasoline (i.e., 0.9 – 0.09 psi)
  - Biodegradation dominates
- Biodegradation
  - Rate of degradation too low to achieve remedial goal in timeframe
  - Soil texture limits oxygen delivery
- Injection
  - Soil texture limits delivery of oxidant/other media

No associated notes.

Knowledge Check
Enter Yes or No for each question

Poll Question

- Sheen on Creek, LNAPL in well nearby, LNAPL transmissivity is < 0.05 ft^2/day
  - Should recovery be considered? (Y/N)
  - Is recovery likely to be the final remedy? (Y/N)
  - What else could be done to improve remedy selection?
    - A. We are good to install a final remedy
    - B. Improve vertical and horizontal resolution of impacts and soil type
    - C. Quantify Biodegradation Rate
    - D. Estimate Volatile Fraction of LNAPL in place
    - E. Confirm Sheen LNAPL originates from impacts in well

Should recovery be considered? (Y/N)

Is the recovery Final or Interim measure? (Y/N)

What else could be done to improve remedy selection?

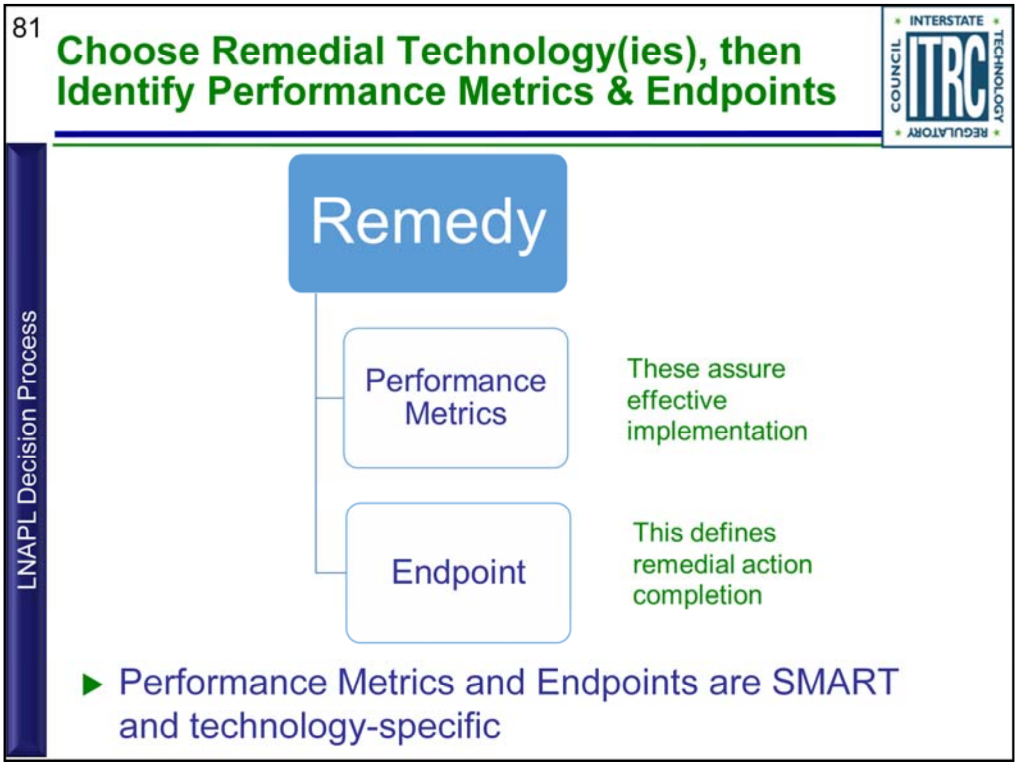
A. We are good to install a final remedy

B. Improve vertical and horizontal resolution of impacts and soil type

C. Quantify Biodegradation Rate

D. Estimate Volatile Fraction of LNAPL in place

E. Confirm Sheen LNAPL originates from impacts in well

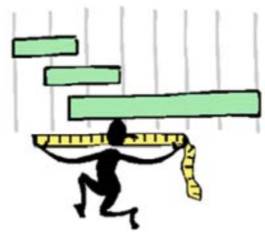


Now that we've covered the remedy selection phase of the LSCM, let's return to the LNAPL decision process. You seen this slide already. Recall that the selected remedy needs to be capable of meeting the established LNAPL remedial goals and remediation objectives. The remedy also needs performance metrics to assure that it is being implemented effectively. It also needs an endpoint to know when it has done its job.

SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based

Performance Metrics

- Technology-specific!
- Verifies that remedy is being effectively implemented
- Allows for mid-course corrections
- Tracks progress toward endpoint
- Example performance metric for bioventing:
  - Maintain a specified minimum oxygen content in a targeted region of LNAPL-affected soil (to deplete LNAPL mass by aerobic biodegradation)



The remedy needs to be capable of meeting the identified LNAPL remedial objectives. Then it needs performance metrics to assure that it is implemented effectively. It also needs an endpoint to know when it has done its job.

[example with numeric metric(s)]

Clip art source: http://clipart-library.com/metrics-cliparts.html

Endpoints

LNAPL Decision Process

- Also technology-specific!
- Defined as:
  - LNAPL concern has been addressed, OR
  - Practicable limit of the technology

- If technology reaches its practicable limit before LNAPL concern is abated, then the endpoint marks the transition to the next technology in the treatment train

The remedy needs an endpoint to know when it has done its job.

Example of a endpoint: Dissolved risk concern about benzene -> LNAPL composition goal –> phase change mechanism -> SVE remedy. Endpoint is when dissolved concentrations are reduced to risk-based or regulatory limits at points of compliance.

Transitions should be expected and planned, based on expected performance of technology… not a disappointment or a surprise.

Clip art source: http://www.clker.com/clipart-treasure-map-1.html

Knowledge Check

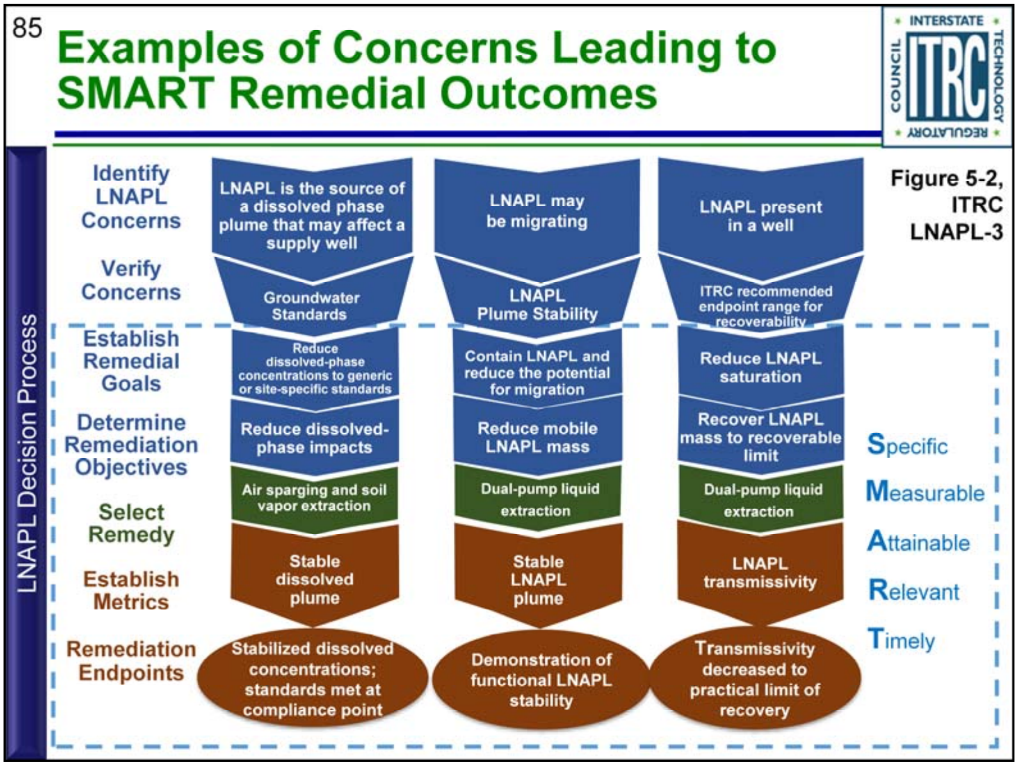
Poll Question

Which statement is true?

Remedial Performance Metrics and Endpoints…

A. Are optional
B. Are the same for every technology
C. Are technology-specific and site-specific

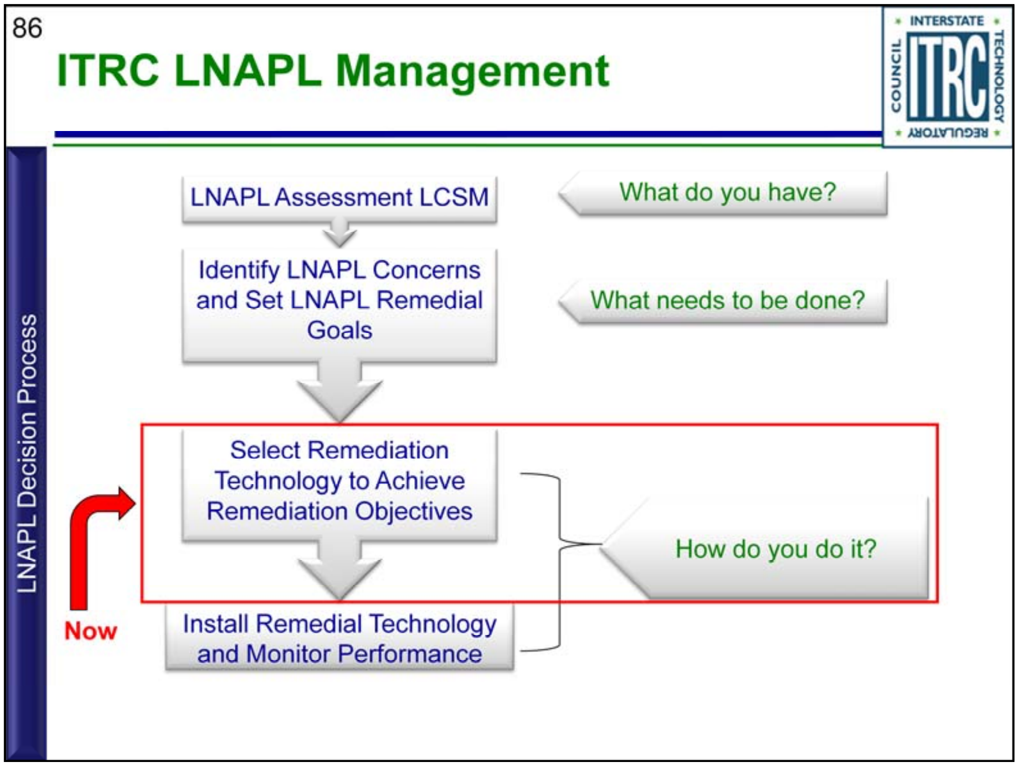
No associated notes.



Putting it all together, we get this.

SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based

Reiterate that metrics and endpoints should rely on multiple converging lines of evidence



What will be covered in upcoming third training module.

LNAPL Remedial Technology Screening Process for Verified Concerns

LNAPL Decision Process

- Step 1 – Screen technologies on the remedial goals
- Step 2 – Screen technologies on site geological factors and LNAPL characteristics
- Step 3 – Comparative analysis
- Step 4 – Identify critical data needs
- Step 5 – Select technology(ies) address concern(s)

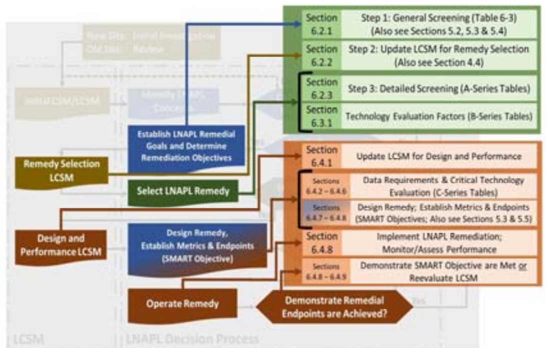
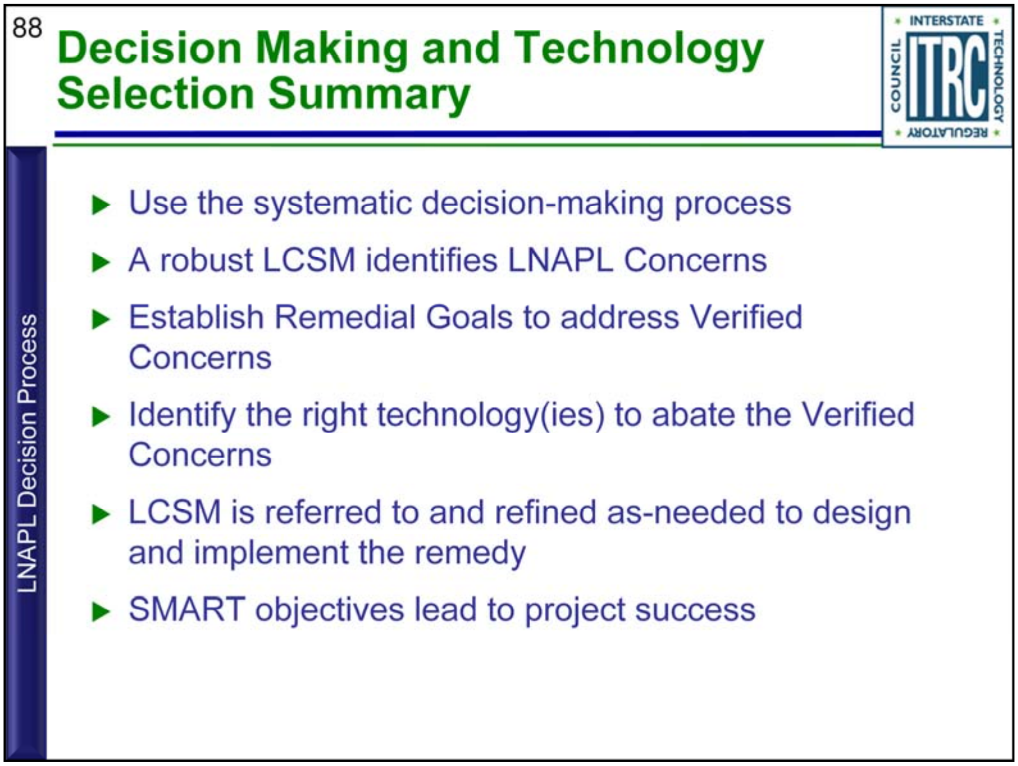


Figure 6-1, ITRC LNAPL-3

The Remedy Selection and Design LCSM is further developed & updated during these steps

These are the major topics and concepts covered the next module

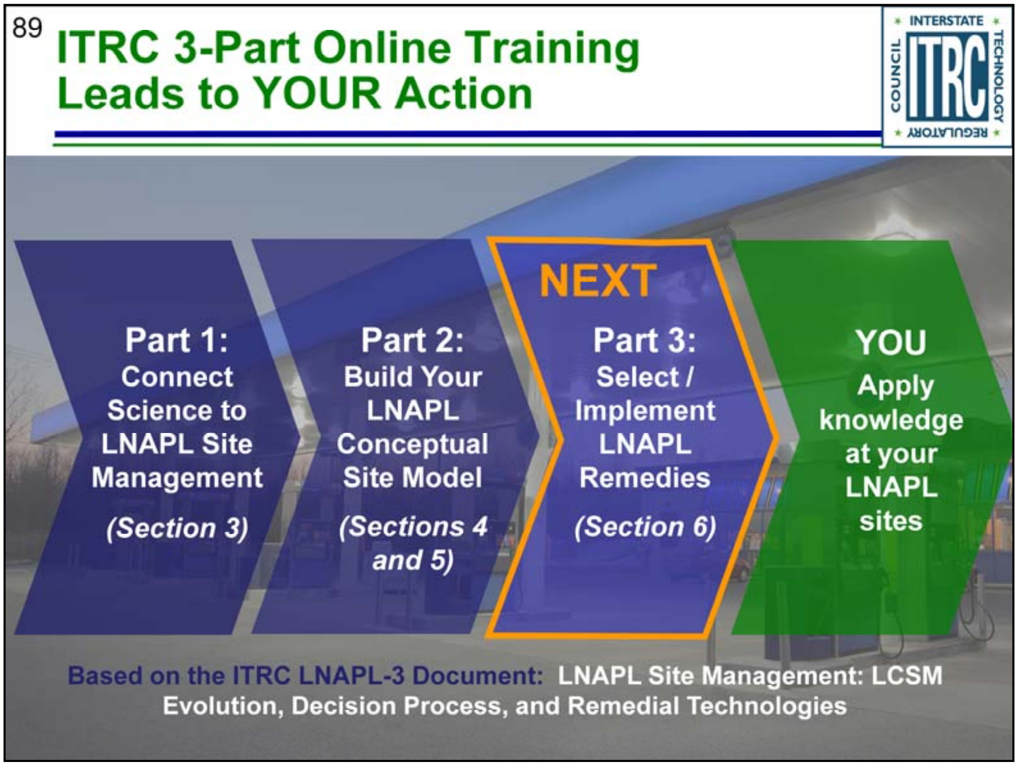
Good opportunity to reiterate LCSM update theme. You are getting data to: a. complete a step in the decision process and b. to update/confirm your LCSM.



What have we covered?

SMART = Specific, Measurable, Attainable (or agreed-upon), Realistic (or relevant), Time-based

Tie whole presentation together more… identify points made in all presentation



We are near the end of Part 2 of training to use ITRC's new LNAPL document.

(CLICK) Next week in Part 3, we will

- Discuss remedial technology groups
- Introduce specific remedial technologies
- Provide a framework for technology selection
- Introduce tools to screen the technologies for use
- Introduce performance metrics to optimize your efforts and decide when to stop and/or use another technology
- Use a case study to demonstrate the use of these tools

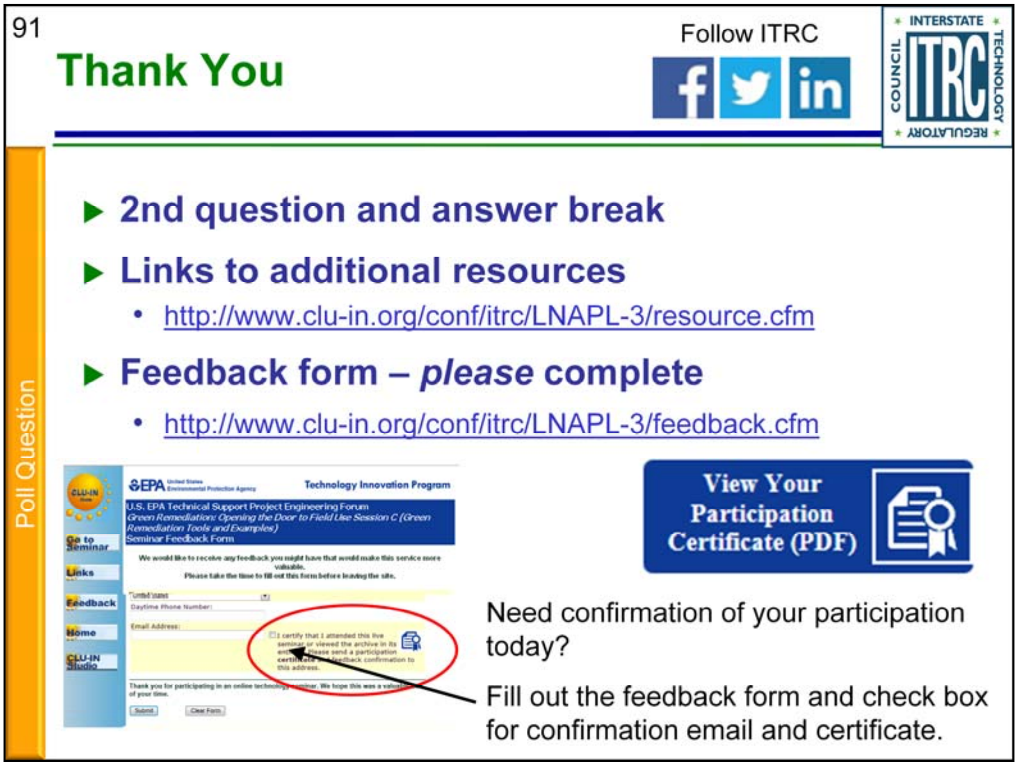
Apply Part 2 on the Job

Apply What You Have Learned

Think about one of your sites and what data is available to go through a short Remedy Selection LCSM exercise to select potential remedial technology mechanisms or confirm the current remedial technology.

Additional insight on remedial technologies will be provided in Part 3, which will help further the evaluation.

No associated notes.



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