Using Feasibility Study (FS) as an Optimization Opportunity – A Smarter FS

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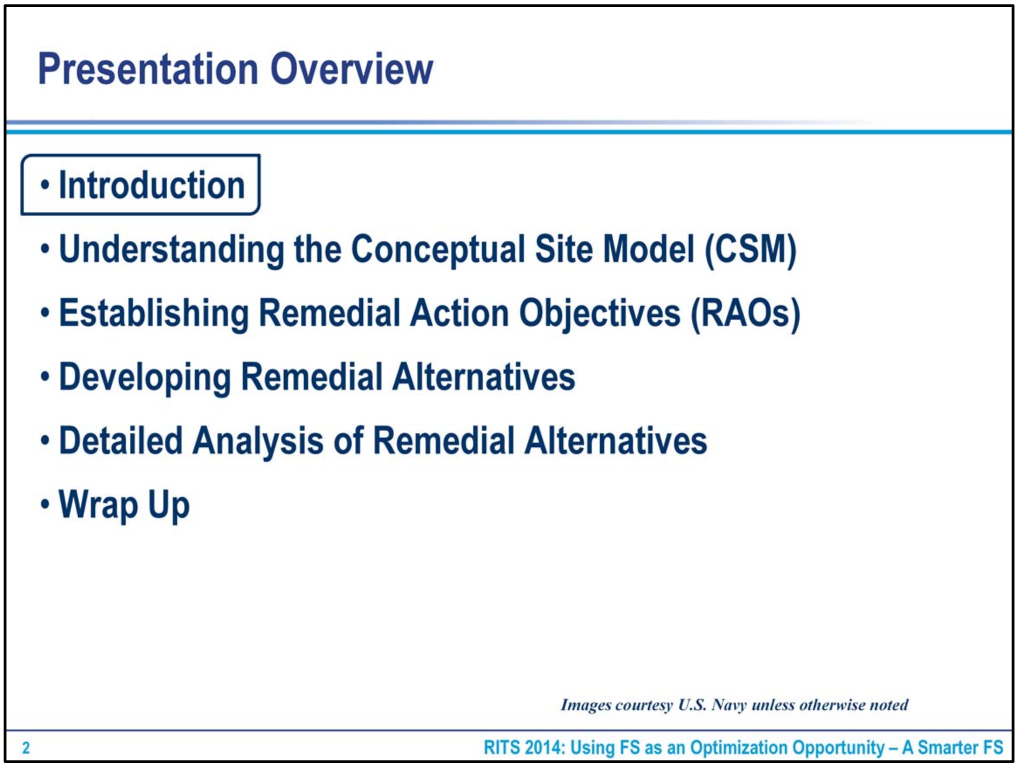
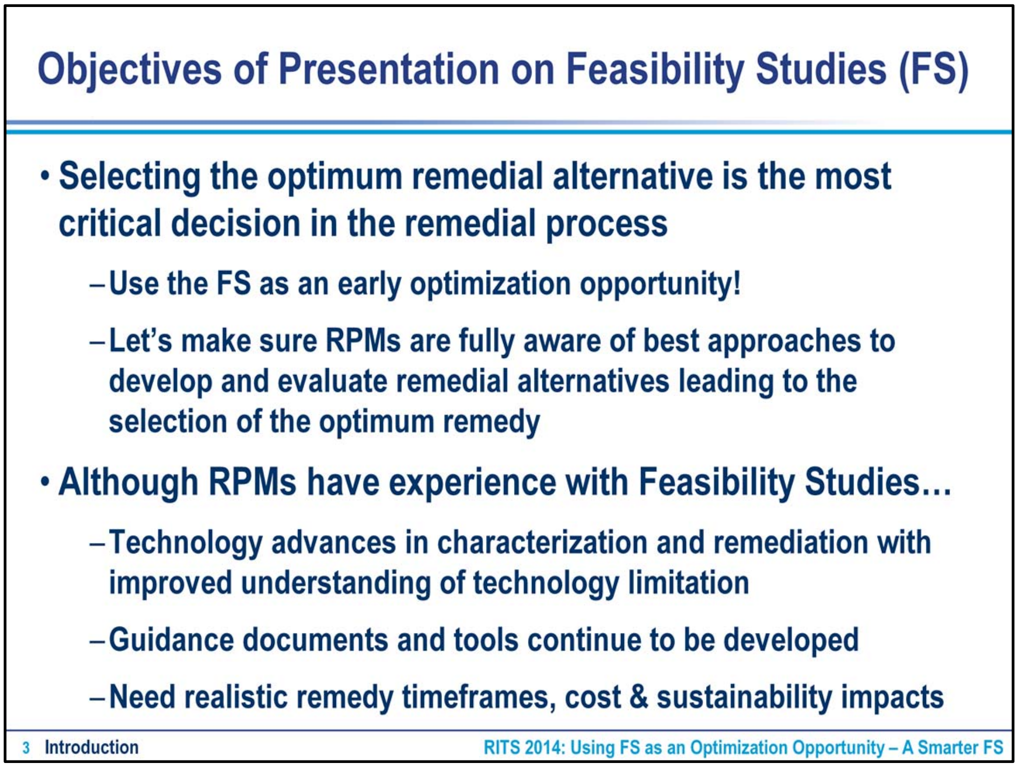


This presentation will cover major aspects of an FS and we will point out common issues and challenges RPMs are faced with and what an FS must contain to address these challenges. Major aspects of an FS include:

- Development of a CSM with a sufficient level of resolution to accomplish the objectives of the FS;
- Establishing RAOs and performing the steps needed such as identifying ARARs and risk based cleanup levels;
- Developing remedial alternatives that can meet the RAOs in the most efficient and cost effective manner; and
- Evaluating the remedial alternatives to select the optimum alternative for the site with consideration of the CERCLA nine evaluation criteria.

We will also discuss the importance of optimization throughout each of the processes and not just at the end.



Before diving into the steps of the FS, let's take a few minutes to discuss the overall objectives of having a presentation on FS development. I think RPMs are fully aware of the importance of the FS phase and how this is where the most critically important decisions are made and where the path of all subsequent phases are established. Before making these important decisions, it is wise to use the FS phase as an opportunity for optimization. So we want to make sure RPMs are fully aware of the best approaches to develop and evaluate remedial alternatives such that the optimum remedy is ultimately selected. We know you all have experience with FSs but things do change from time to time. There are advances in technologies for site characterization and remediation; the industry has developed a better understanding of the limitations of established technologies, there are new guidance documents and tools available. We are finding that sites often don't cleanup as quickly as planned so we need to develop realistic estimates of cleanup time, cost and sustainability impacts because we make decisions based on these estimates. If the estimates are grossly unrealistic, we will not be able to make the best decision.

Related Past RITS

Topic	References	How it helps RPMs with FS
Site Manage-ment Strategies	• RITS. DNAPL Site Remediation, Lessons Learned, 2013 • RITS. Integrated DNAPL Site Strategies, 2012 • RITS. Managing Sediment Sites Using Navy Policy and Guidance, Fall 2010 • RITS. Strategies for Environmental Risk Management at LNAPL Sites, Spring 2009 • RITS. Optimization, Spring 2004	Site Management Strategies for Complex sites (*e.g.*, NAPL, sediment sites), Alternate remedial goals, RAOs (absolute and functional) how flexible RAOs allow for future remedy optimization, and other site management strategies.
CSM	• RITS. Getting the Most out of Your CSM, Fall 2009	CSM elements, investigation techniques, and use to optimize the remedial action
Environ-mental Molecular Diagnostic (EMD) Tools	• RITS. EMD: Current Capabilities and Future Trends, 2013 • RITS. Application of Molecular Biological Tools for Site Remediation, 2009 • RITS. Compound-Specific Isotope Analysis Today, Fall 2008	Description of EMDs, best practices for their use for decision making, including evaluating the viability of natural attenuation.

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At the beginning of each RITS presentation we like to point out what past RITS presentations are related to this one. Developing an FS requires a knowledge of a wide range of technical areas so there are many past RITS topics that are related. There are so many that I broke it down into topics and provided a listing of RITS presentations along with a brief description of how these presentations can help an RPM in the FS process. These slides are here for your reference and if you want to refer back to the presentations they are available on the ERB Website that was mentioned earlier this morning. These past RITS topics include several related to site management strategies that can be applied to manage complex sites, developing a CSM and what elements need to be included to optimize the remedial action, Environmental Molecular Diagnostic Tools that can be used for evaluating site conditions and the viability of MNA.

Related Past RITS (cont.)

Topic	References	How it helps RPMs with FS
Modeling	• RITS. Groundwater Modeling System Tool in NIRIS to Support CSM, Fall 2009 • RITS. Evaluating the Groundwater/Surface Water Interface, Fall 2009 • RITS. MNA: Estimating Remedial Timeframes with Natural Attenuation Software (NAS), Spring 2008	Describes how these tools can be used to understand fate and transport mechanisms and build this into the CSM to evaluate risk and risk-based remedial goals and viability and sustainability of natural attenuation.
Remedial Goals	• RITS. Embracing Mass Flux and Mass Discharge to Enhance Groundwater Plume Management, 2011 • RITS. Alternative Endpoints, Fall 2010 • RITS. Establishing SMART Sediment Cleanup Goals, Fall 2010	Methods for developing alternative endpoints and approaches, such as ARAR waivers, alternate concentration limits (ACL), use of passive remedies over long time frames.

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There are past topics on modeling showing how these tools can be used to understand fate and transport, evaluate risk and the viability of MNA. There area also topics on developing remedial goals including various methods for developing alternative endpoints.

Related Past RITS (cont.)

Topic	References	How it helps RPMs with FS
Land Use Controls (LUCs)	• RITS. Land Use Controls, Spring 2005	LUCs implementation and how LUCs can be used to achieve protectiveness while optimizing remedial approach
Optimization Concepts	• RITS. Optimization, Spring 2004 • RITS. Performance Objectives, Spring 2005	Use of optimization concepts (target treatment zones [TTZs], Treatment trains, performance objectives and exit strategies) to develop creative remedial alternatives that account for technology limitations and life-cycle characteristics associated with site cleanup
Remedial Alternatives Analysis (RAA)	• RITS. Optimization Part 1 Optimization Policy and Part 2 RAA, 2012	Describes the benefits of the RAA and how the process is implemented

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There is a topic on LUCs and how they can be used to maintain protectiveness and optimize the remedy. Going back 10 years, there have been topics on optimization concepts although it would be best to review these by looking at the more recent optimization guidance documents. Finally there was a topic on the RAA process that describes the benefits of the RAA and how the process is implemented.

Focus of the Presentation

- Emphasis is on sites with potential for long-tailed management/monitoring (*e.g.,* complex groundwater sites)
  - Common issue with the Navy and drives installation restoration costs into future
  - Points discussed here can also apply to soil and sediment sites and to munitions response sites
- Avoiding common problems
  - Remediation proceeding with inadequate site characterization
  - Unrealistic remedy timeframes
  - Ineffective remedies with escalating long-term costs

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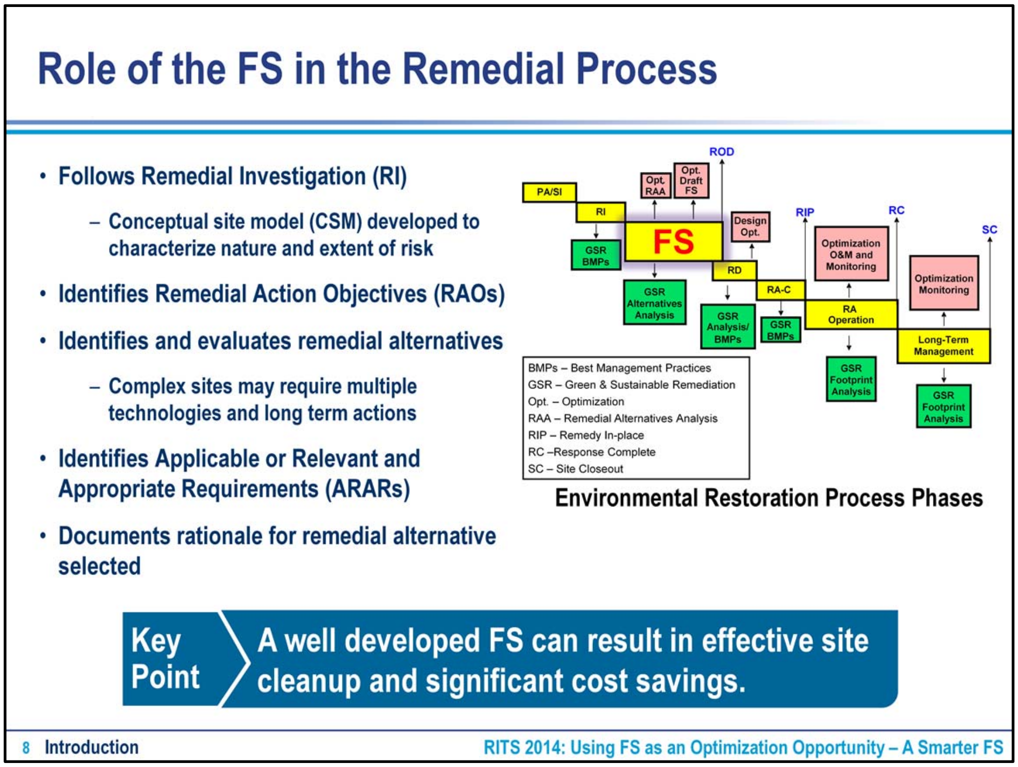
There have been many related presentations but the focus of this one is to bring it all together in the context of FS developing with an emphasis on complex sites, particularly complex groundwater sites. These types of sites are common within the Navy and we are finding that these sites have long cleanup times and that drives the installation restoration costs into the future. Although many of the points we will discuss here apply to other types of sites including soil, sediment and munitions sites, the focus is on complex GW sites. For these sites we need to think about exit strategies early in the process and think about trade-offs between long-term costs with low up front cost versus the reverse. We need to avoid some of these common problems that are often encountered. One common problem with these types of sites is that the complexities of the CSM may not be adequately understood but because of pressures to move forward towards cleanup, the remediation begins before the site is sufficiently characterized. This common problem often results in sites that do not cleanup as expected. Another and related common problem is having unrealistic remedy timeframes for some of the remedies evaluated. This can lead to poor decision making and selection of a non-optimum remedy. These two problems often lead to the third which is remedies that are not effective and continue in the remedial action operation phase longer than anticipated resulting in escalating long-term costs.



I'm sure most of you have seen this chart of the ER process phases. This shows how the FS fits into the overall CERCLA process coming after the RI. One point I want to make is that the RI does include development of a CSM but it is developed primarily for the purpose of characterizing the nature and extent of contamination and risk. It does not necessary provide the data needed to ensure that the optimum remedy is selected. Another point is that complex sites typically require multiple technologies and long-term action that will extend long into the future. As part of the FS, you need to develop your ARARs and once established in the ROD you are committed to complying with those and for long-term remedies, that can be well into the future. The FS is where you develop your rationale for selection of the remedy so FS leads to decisions documented in the ROD that you will need to live with long into the future. Trying to make post-ROD decisions that help reduce cost or remedy footprint are not as effective as those decisions you make pre-ROD. So the key point to all of this is to emphasize the need for a well developed FS to achieve effective cleanup and avoid cost escalation down the road.

Goals of a Smarter FS

- **Identify remedial action objectives (RAOs)**
  - Flexible but clearly describes goals and how unacceptable risks are addressed
  - Consider current and reasonably anticipated future land use
  - Understand mass distribution and impacts on achievable end points
- **Develop remedial alternatives that addresses unacceptable risk**
  - Understand limitations of technologies and timeframes for cleanup
  - Use creative approaches consisting of multiple technologies to account for life-cycle characteristics
  - Have end goals/exit strategy in mind
- **Evaluate remedial alternatives**
  - Ensure sufficient data/information is available for detailed evaluation
  - Apply appropriate level of science-based analysis (*e.g.*, modeling tools)

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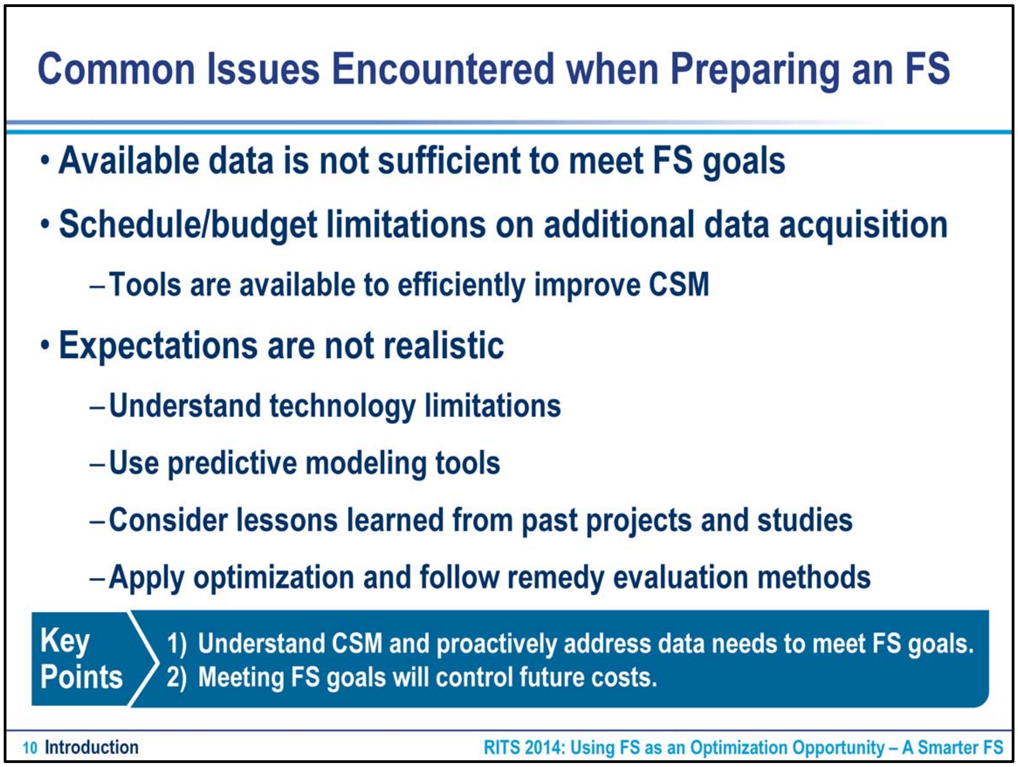
This slide summarizes what we are trying to achieve with our FSs. WRT the RAOs, you want to make sure they are flexible but clearly describe goals of the remedy and how unacceptable risks are addressed. You need to consider current and reasonably anticipated future land use rather than necessarily assuming unrestricted use. It is also important to understand mass distribution and what impacts this will have on selecting achievable end points.

As you develop remedial alternatives you need to understand limitations of technologies and what they can realistically achieve. Once you consider these limitations, it usually leads you towards the need of using multiple technologies at different phases of the cleanup. The slide refers to life cycle characteristics. By this we mean that as the site cleans up, not only does the concentration of contaminants change but also the location of the majority of the remaining mass may change. So during the life cycle of the cleanup, the characteristics change and thus the optimum technology changes. I'm sure you have all heard the phrase to start with the end in mind. This is very true with FS development. The FS is the start and as you design your approach, you need to consider all the different stages you will go through, what goals and exit strategies are achievable.

When you evaluate the remedial alternatives, you need to have sufficient data/information available to perform your comparative analysis. Some remedies may be more sensitive to site data than others so once you know what approaches you are evaluating, you may determine that you need additional data to perform a comparative analysis that you can base you decision on and you need to apply appropriate level of science-based analysis, which for some cases will require the use of tools such as groundwater flow and solute transport models.



This slide summaries some of the issues that may prevent you from reaching the goals on the previous slide. First two bullets are related. The available data is not always sufficient to meet FS goals. As I mentioned earlier on, the CSM for the RI has different objectives than that of the FS and thus an adequate CSM for the RI may be inadequate for the FS. The solution seems simple – go out and get the required information. The problem with that is you may have schedule and budget limitations that make it difficult to get the additional data that you need. You just saw a presentation that discussed the various tools that are available to efficiently and quickly improve CSM and enhance the resolution. You may need to take advantage of these tools. Also, you feel that the data is really not sufficient to proceed with the FS, adjustments may be needed in the schedule to allow the data to be obtained or else you run the risk of developing unrealistic expectations and having remedies that do not meet your objectives. To avoid that it is important that you not only have an adequate CSM but that you also understand the limitation of the technologies being evaluated. In some cases, it is important to use predictive modeling tools. These tools also have their limitations so you also want to consider lessons learned from past projects and studies and apply optimization concepts presented in guidance. Key points here are the importance of proactively address data needs to meet FS goals before going too far down the road as this is necessary to control future costs – spending a little now can save a lot of money and time in the future.

Available FS Guidance

- **EPA Guidance from 1988**
- **Numerous developments since 1988**
  - **New site characterization methods including data acquisitions, management, and visualization and modeling**
  - **New treatment technologies focusing on *in situ* methods**
  - **Data regarding technology performance**
    - *e.g.*, failure of pump and treat to reach remedial goals
  - **Recognized need for long-term site management strategies**
- **Although not FS guidance, relevant guidance is available…**

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Regarding references for FS development, the original EPA reference is from 1988. There have been many developments since then including new characterization and treatment methods as well as new data regarding technology performance. We understand limitation much better and thus understand the need for long-term site management strategies. Although the original guidance still applies, there are many other relevant guidance documents.

References Related to Site Management Strategies for Complex Sites (*e.g.*, DNAPL, LNAPL, sediment sites)

References	How it helps RPMs with FS
• ITRC. Integrated DNAPL Site Strategy, 2011 • ITRC. Using Remediation Risk Management to Address Groundwater Cleanup Challenges at Complex Sites, 2012 • DON. Guidance for Optimizing Remedy Evaluation, Selection, and Design, 2010 • NAVFAC. Groundwater Risk Management Handbook, 2008	Provides understanding of technology limitations for complex sites with case studies and identification of approaches to manage uncertainties and technology limitations. Includes discussion of alternate remedial goals, RAOs, and other site management strategies.

Here is a listing of several more recent references that provide guidance on site management strategies including two from ITRC and two from the Navy. These documents provide information about technology limitations for complex sites with approaches to manage these limitations and other uncertainties.

Presentation Overview

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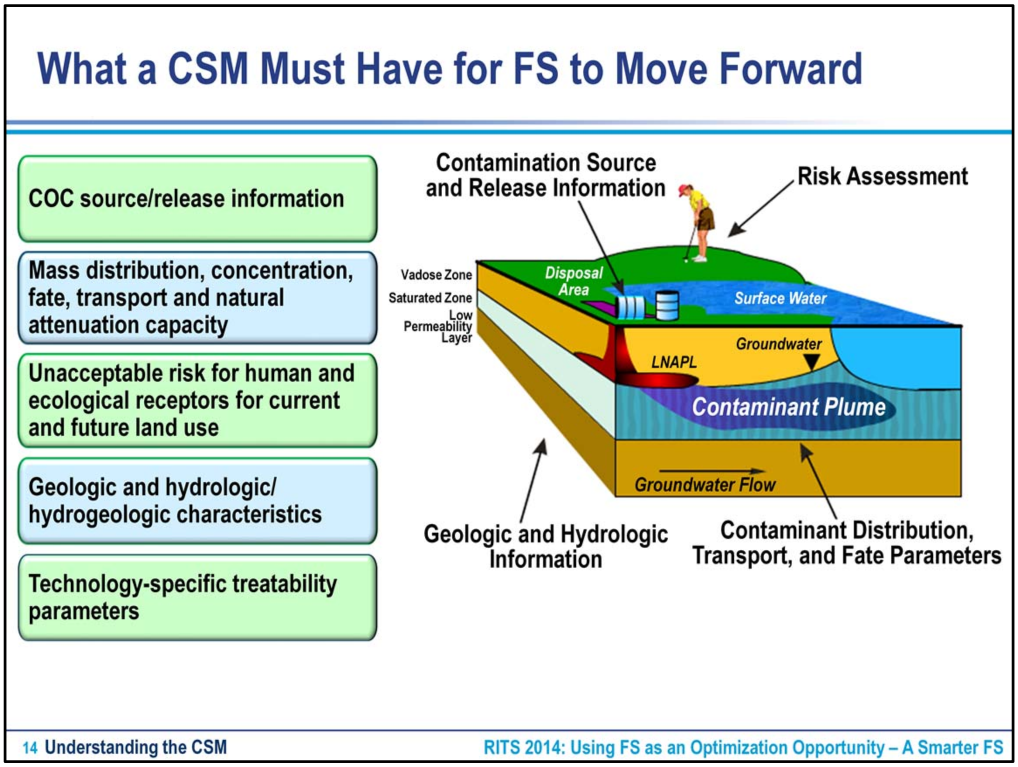
- Understanding the Conceptual Site Model (CSM)
- Establishing Remedial Action Objectives (RAOs)
- Developing Remedial Alternatives
- Detailed Analysis of Remedial Alternatives
- Wrap Up



This slide summarizes key components of what a CSM must have to be able to meet the objectives of a FS. The data needs to be evaluated to identify the unacceptable risks to HH and eco receptors. Technology-specific parameters are often not obtained until after you have identified what technologies are to be evaluated. Before you can evaluate certain technologies, you may need to collect technology-specific data. Examples include SOD to evaluate ISCO or geochemistry to evaluate bioremediation. Understanding how contaminant mass is distributed is also important when developing remedial approaches and very often mass distribution is not adequately characterized.

Example of COC Mass Distribution Estimate

Estimate of TCE Mass in Shallow Groundwater, Site 17 Groundwater FS
NSF-IH, Indian Head, Maryland

Area Type	Area, sqft	Soil Vol. CY	TCE Mass, pounds			% of Total Area		% of Total TCE Mass	
			Adsorbed	Dissolved	Total				
Source Zone									
Residual DNAPL	1,471	654	715	11	726	6%	15%	93%	98%
Dissolved Source	2,061	916	35	2	37	9%		5%	
Dissolved Plume									
100-1,000 µg/L	6,886	3,060	12	1	12	30%	85%	2%	2%
5-100 µg/L	12,827	5,701	2	0	2	55%		0%	
Total									
Total	23,245	10,331	764	13	777	100%		100%	

Notes: NSF-IH=Naval Support Facility-Indian Head; Vol.= Volume; sqft=square feet; CY=Cubic Yards

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This shows an example of where estimates of mass distribution where made in order to better evaluate remedial approaches. The site is was broken down into a source zone and a dissolved plume zone and then for the source zone it was broken down further into the area of residual DNAPL and dissolved source and also the dissolved plume was broken down based on TCE concentration ranges. The key point here is that 98% of mass is in 15% of site area and 93% of mass is in only 6% of the area. I wouldn't take these exact numbers too literally but the important message is that most of the mass is in a relatively small area and you need to understand this distribution in order to optimize the remedial strategy. Could also mention few examples of non-optimum execution such as:

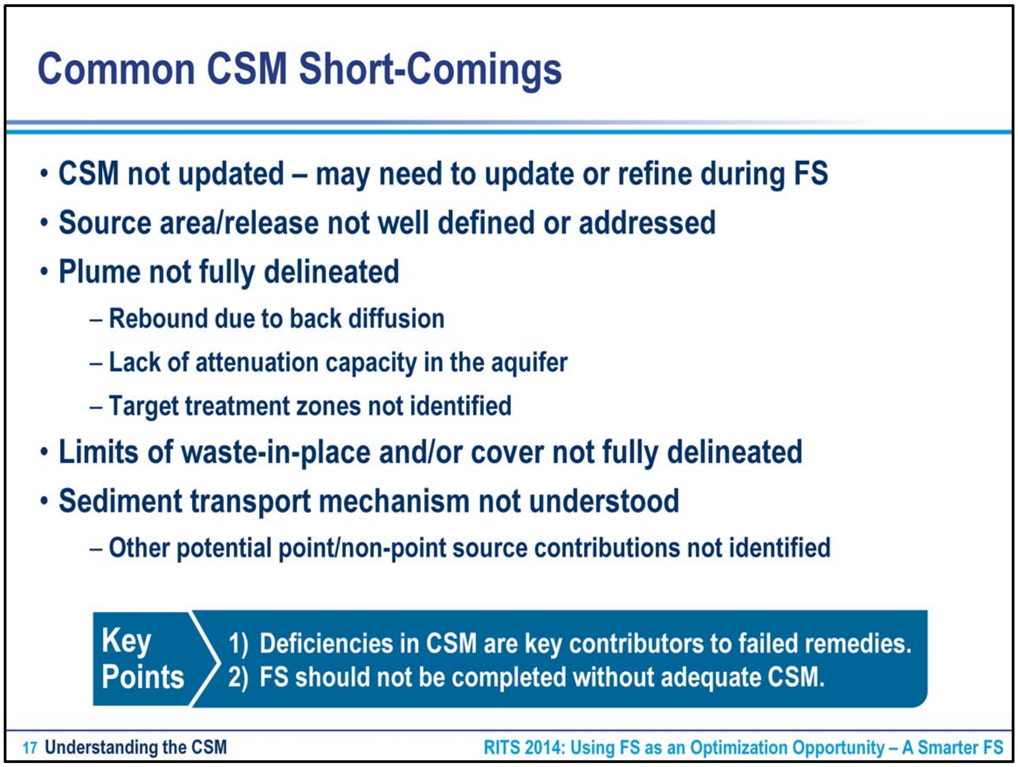
- Chemicals injected into areas or zones not needed and insufficient chemicals into areas where the bulk of the contaminants reside.
- Excessive groundwater pumping

With HRSC you could narrow this down further by locating certain strata within the high mass areas and that would reduce the volume in which you need to target to get at most of the mass.

CSM with Appropriate Resolution Promotes Efficient FS Process and Effective Remedies

- Allows RPMs to screen out inappropriate alternatives
- Select and implement effective remedial actions
  - Prevents site cleanups from stalling with ongoing costs
  - Allows more realistic estimate of remedial time frame
  - Prevents ROD Amendments for remedy change and escalating costs
  - Prevents not meeting response complete/site closure goals
- Ensures protectiveness
  - Prevents liability if exposure to unacceptable risk exists

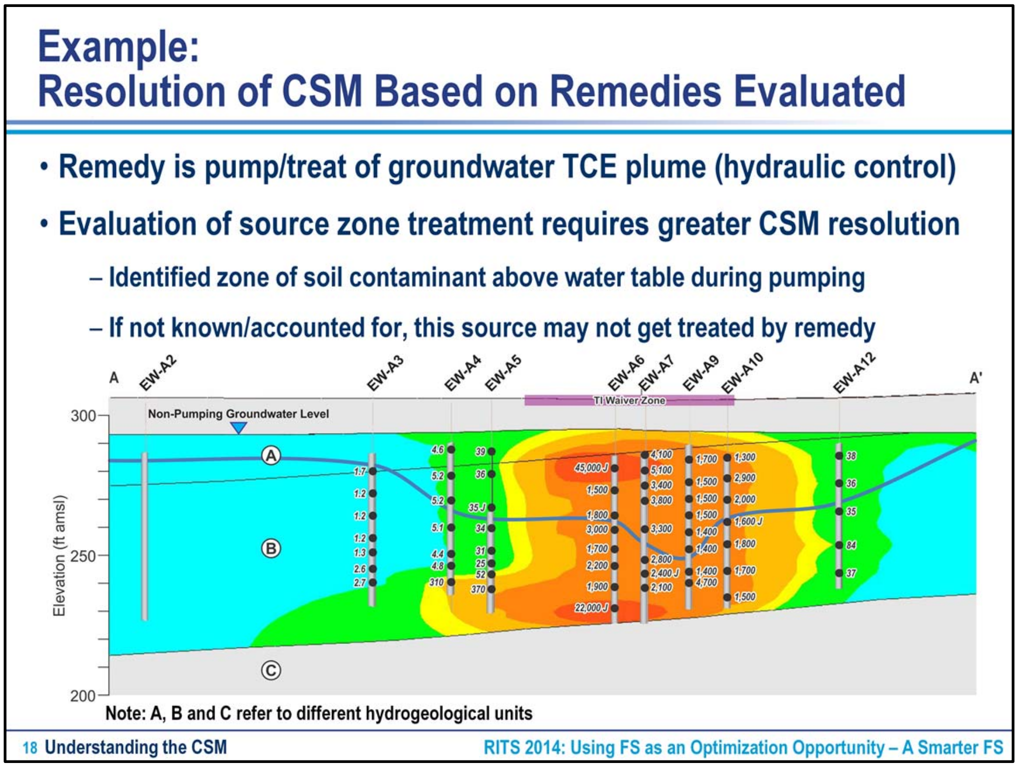
I just mentioned HRSC but I prefer to use the term ‘appropriate resolution’ meaning you obtain the level of resolution that you need to select a remedy that will be effective for your site and screen out those alternatives that would not be effective. If you look at remedies that have failed, the most common reason for failure is inadequate site characterization. As you implement a remedy you tend to continue collecting data and if the site is not cleaning up you may investigate further to find out why the remedy is not meeting the objectives. At that time you may find out that you had an additional source of contamination or maybe a low permeability zone with high levels of COC that are not being addressed. While it is good to find out why the remedy is not working, it would have been a lot better to have this information before selecting your remedial approach and prevent remedy failure and the need for ROD amendments and escalating costs and not achieving the OSD RC/SC metrics.



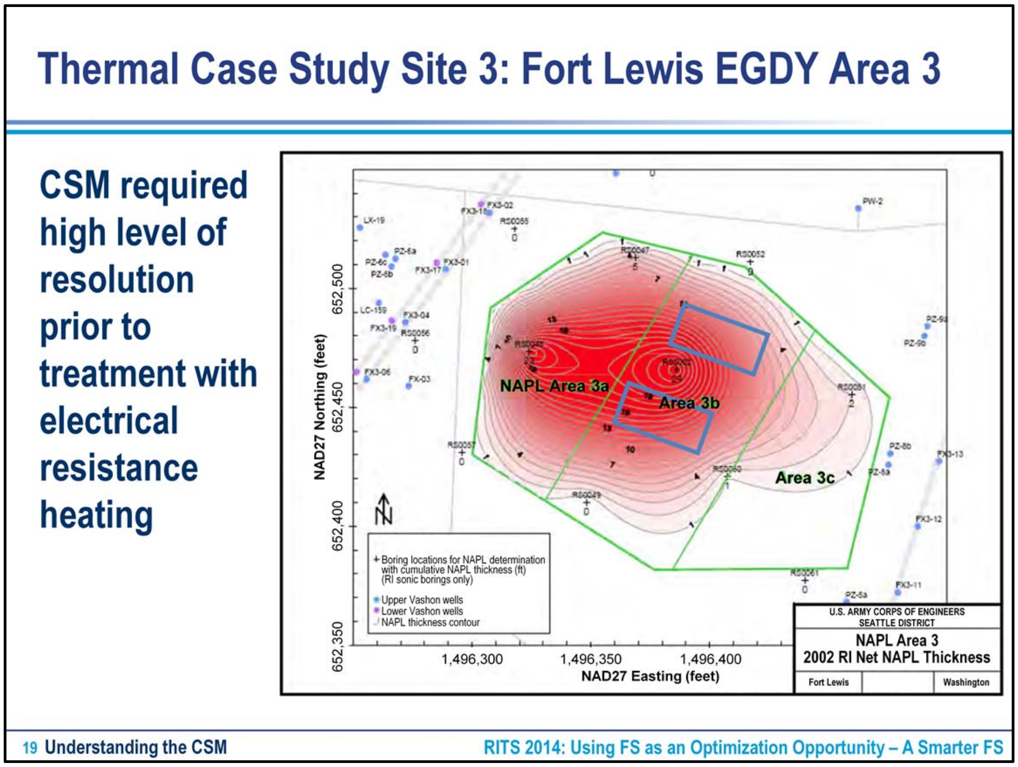
Here are some examples of common CSM short-comings. Source area or high conc areas not identified can result in money spent on areas that will only be re-contaminated as COCs flow down from the identified source. Could be upgradient contamination that was not known or perhaps COCs in the unsaturated zone soil. Mention case in Novato where NAPL flows upgradient of spill b/c of the stratification in the unsaturated zone.

For sediment sites, sediments can be dredged but only to be re-contaminated by other sources.

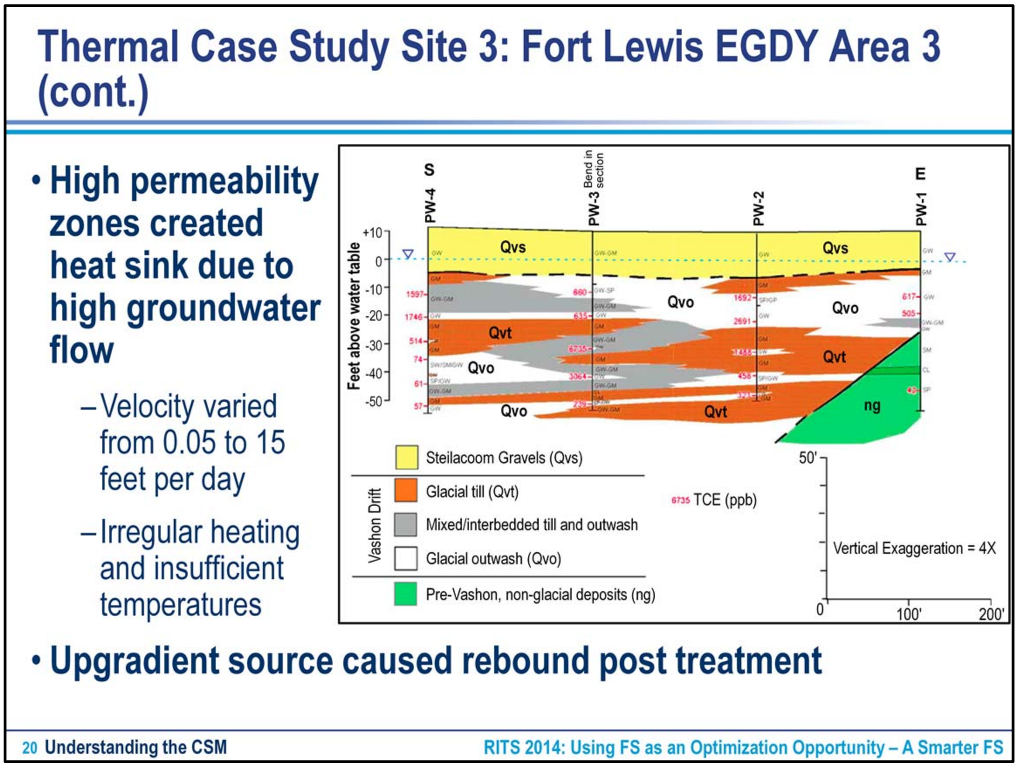
Key points: Inadequate site characterization is the most common cause of remedy failure so it follows that the FS should not be completed unless there is an adequate CSM



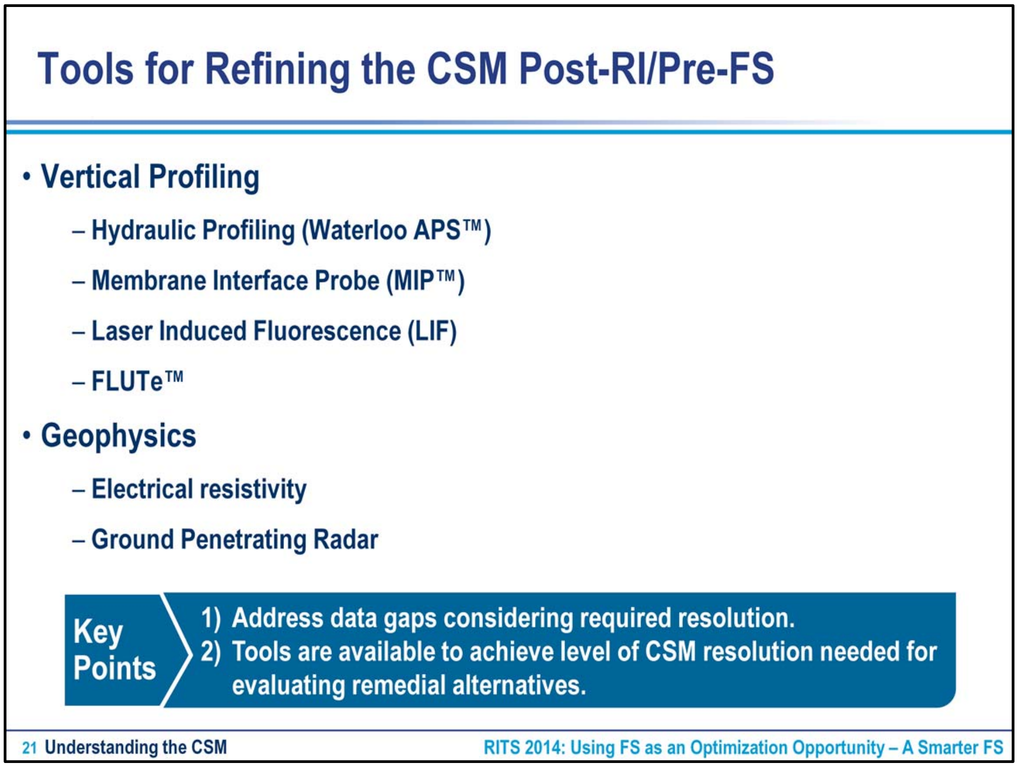
Here is an example of where the resolution needed for a CSM changes based on the remedies evaluated. There is a ongoing remedy to address TCE contamination with an active pump and treat system with a TI waiver which means the remedy is not intended to cleanup the source area but only maintain hydraulic control. For a remedy like that, the resolution needed was not as high as that required for source zone treatment. Because the pump and treat system is expensive to operate, a decision is made to attempt to address the source area but this required a higher level of characterization. Is was then found that the original CSM did not delineate soil contamination above the water table. As shown in this figure, peak levels of contamination and COC mass resides in unsaturated zone soil. That does not impact a hydraulic control remedy but we need to understand where COC mass resides in order to address the COCs with treatment. For example, what if we injected treatment chemicals in GW while the water table remains depressed. We would not have addressed a significant mass of COCs and that would cause rebound and an ineffective remedy.



Another example is one if the case studies you just heard during the thermal remediation presentation. This is Site 3: Fort Lewis where they applied thermal treatment using electrical resistance heating.



As was discussed in that presentation, the remedy had problems achieving the temperatures needed for effective treatment. When they evaluated the cause of this problem, they discovered that high permeability zones created heat sinks because of high groundwater flow rates. The GW velocity ranges from 0.05 to 15 feet per day and the zones with high moving GW caused the heat to be carried away from the treatment area. This resulted in irregular heating and insufficient temperatures for effective treatment. It was also found that upgradient sources existed which caused rebounding post treatment. These are examples showing how the technologies evaluated impact the site characterization data needed.



These can be used during RI also and are high-resolution site characterization tools to acheive vertical delineation, plume transects, permeability profile, depth-discrete GW samples, NAPL layer identification, mass flux

Hydraulic profiling- Waterloo Advanced Profiling System is a subsurface data acquisition system that *collects both groundwater samples and an integrated set of companion data including* Hydraulic Conductivity vs depth, Hydraulic head measurements, pH, specific conductance (SC), dissolved oxygen (DO), and oxidation/reduction potential (ORP) and can get analytical chemistry results from groundwater samples using MobiLab™.

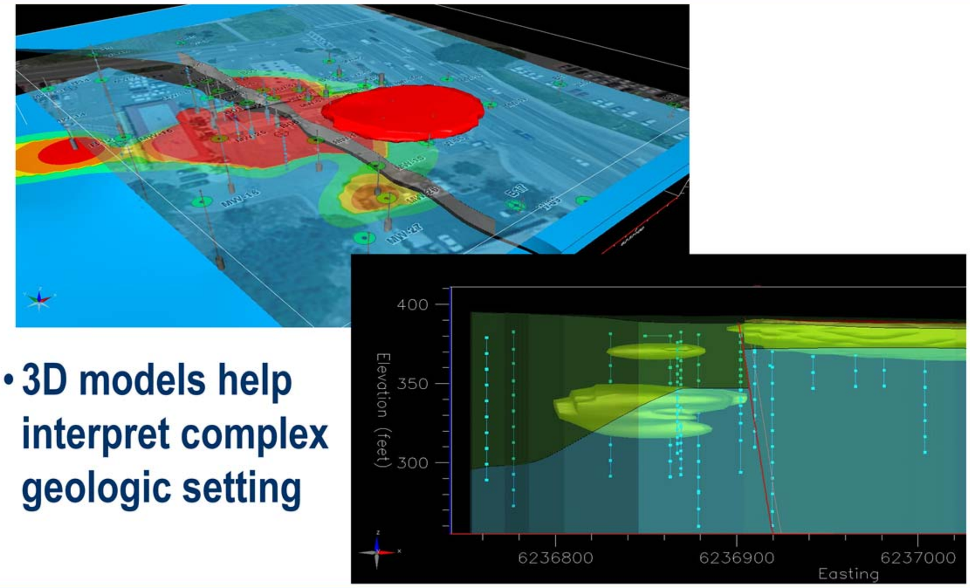
MIP is a rapid screening tool for locating volatile organic compounds in the subsurface. generates a large body of data, locating source areas and plume cores in three dimensions. [It is capable of completing 200 linear feet of exploration in a typical day, and the data are immediately available to the site investigator for decision making. effective in both the saturated and unsaturated zones, and provides data even in clays and silts,] It *cannot collect water samples.*

LIF is a Non-Aqueous Phase Liquid (NAPL) mapping tool used to delineate the depth and horizontal extent of free product and residual petroleum contamination.

FLUTe is the trademarked short name for the company **"Flexible Liner Underground Technologies, LLC"** is used for mapping ground water contamination (hydraulic profiling), locating NAPL sources, and measurement of hydraulic head distributions.

Geophysics (*e.g.,* Electrical Resistivity and GPR) is used for mapping subsurface structural features and stratigraphy; identifying disturbed zones, significantly conductive or resistive groundwater plumes, and depth to groundwater and bedrock.

Tools for Refining the CSM



- **3D models help interpret complex geologic setting**

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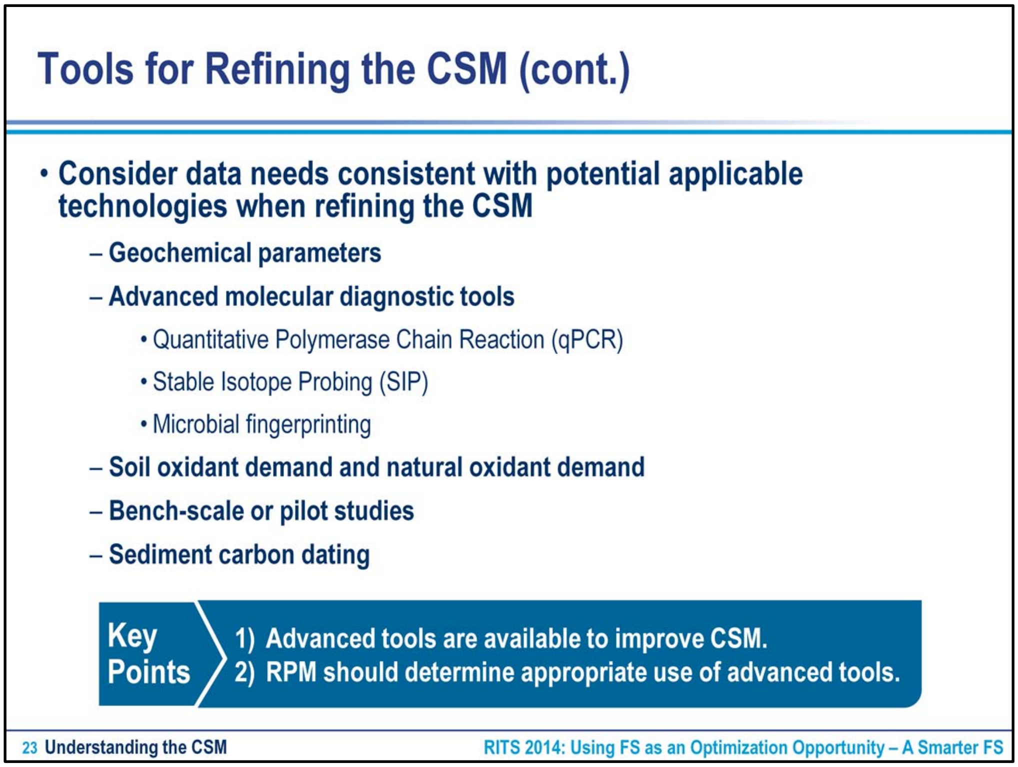
Once you have the data, tools for visualization is important to understand the CSM. This is from 13 Area at Camp Pendleton. Note the fault and resulting groundwater (GW) level drop. This caused GW flow direction to change from being generally NE to SW upgradient of fault and then S to N down gradient of fault.



Geochemical parameters are important for determining whether conditions on the site are favorable for particular types of biological processes. For example, if you are under aerobic conditions, trying to promote anaerobic dechlorination would be more difficult.

qPCR determines the number of gene copies of a specific gene in a sample (This analysis will evaluate if biodegradation is likely at the site)
Quantity of target determines potential for biodegradation typically represented as cells/mL or cells/gram

(SIP) can be used to demonstrate active biodegradation and to identify unknown microorganisms

Microbial fingerprinting (PFLA, DGGE) demonstrates changes in community structures can be used to demonstrate active biodegradation and to identify unknown microorganisms; DGGE - denaturing gradient gel electrophoresis PFLA- phospholipid fatty acid

SOD (Soil Oxidant Demand) which can be used interchangeably with NOD (Natural Oxidant Demand) is the demand generated by reactions occurring between an oxidant and naturally occurring substances in the subsurface (natural organic matter, inorganic minerals). The oxidant consumed by these reactions is unavailable for reaction with target COCs. Is it important information when evaluating how much chemical is needed to implement ISCO.

Treatability testing can be important in some cases to confirm the applicability of a technology for your site and if so it can be used to optimize the design including the injection strategy.

Sediment carbon dating to evaluate MNR

Some of this information could be obtained in the RI, but done in FS if necessary.

COD: The Chemical Oxygen Demand (COD) test measures the oxygen equivalent consumed by organic matter in a sample during strong chemical oxidation. The strong chemical oxidation conditions are provided by the reagents used in the analysis.

Microbial fingerprinting summarizes microbial diversity in a sample using analyses of biomolecules (*e.g.,* phospholipids, DNA)
They can demonstrate large changes in microbial community structure (size and numbers) and identify dominant microbes
(*e.g.,* did biostimulation impact numbers and types of microorganisms at a site?)
Note that Bioaugmentation has a variety of issues – contact w/COC, ability to survive in environment, contact time, what caused a lack of a microbial community to begin with

Notes about qPCR: Quantity (cells/mL)
Practical Interpretation
~$10^{6:}$ MNA is probably appropriate treatment
10^1 to < 10^4 Biostimulation would be appropriate
< 10^1 Bioaugmentation would be needed

References Related to Conceptual Site Models

Topic	References	How it helps RPMs with FS
Site Characterization and Development and use of the CSM	• DON Guidance for Planning and Optimizing Monitoring Strategies, NAVFAC. 2010 • Guidance for Optimizing Remedy Evaluation, Selection, and Design. NAVFAC. 2010 • EPA. Effective Use of the Project Life Cycle Conceptual Site Model, 2011	Description of detailed elements of the CSM, investigation techniques to obtain data to refine the CSM and how the CSM is used to optimize the remedial action.
Environmental Molecular Diagnostics (EMDs)	• ITRC. EMD Site Characterization and Remediation Enhancement Tools, 2013 • ITRC. Fact sheet on Microbial fingerprinting methods, 2011	Description of EMDs, best practices for their use in decision making, including evaluating biological degradation and MNA.
Modeling	• NAVFAC. Guidance for Optimizing Remedial Action Operation (Section 9), 2012 • EPA. An Approach for Evaluating the Progress of Natural Attenuation in Groundwater, 2011 • ITRC. Integrated DNAPL Site Strategy (IDSS), 2011 (list of models included in Table 6-3) • USGS. A Framework for Assessing the Sustainability of MNA, 2007	Describes how these tools can be used to understand fate and transport mechanisms and build this into the CSM to evaluate risk and risk-based remedial goals and viability and sustainability of natural attenuation.

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Here are a list of references related to developing CSMs. This is broken down into three general topics, the first being site characterization and the use of the CSM. There are two Navy optimization guidance documents related to this and an EPA document and these documents provide a description of the elements of the CSM, various investigative techniques and how this information can be used to optimize the RA. There are two ITRC documents related to EMDs and provide best practices for their use in decision making including evaluation of biodegradation and MNA. There are four references for modeling from Navy, EPA, ITRC and USGS that describe how these tools can be used and built into the CSM to evaluate risk, develop risk based goals and determine the viability of NA.

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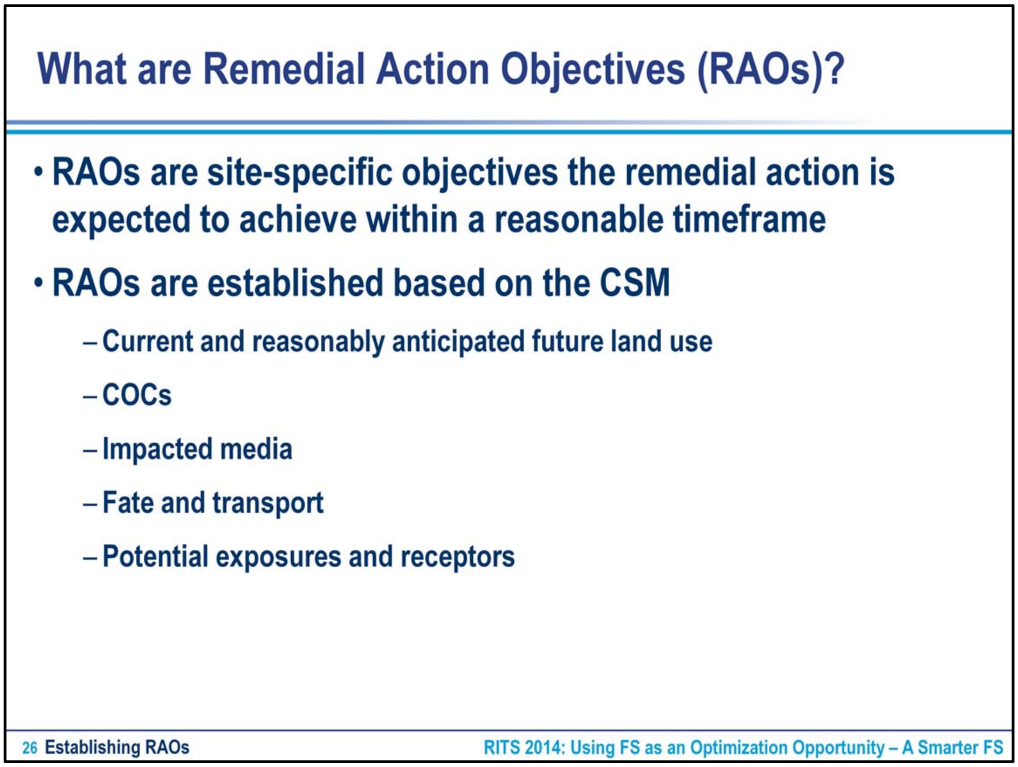
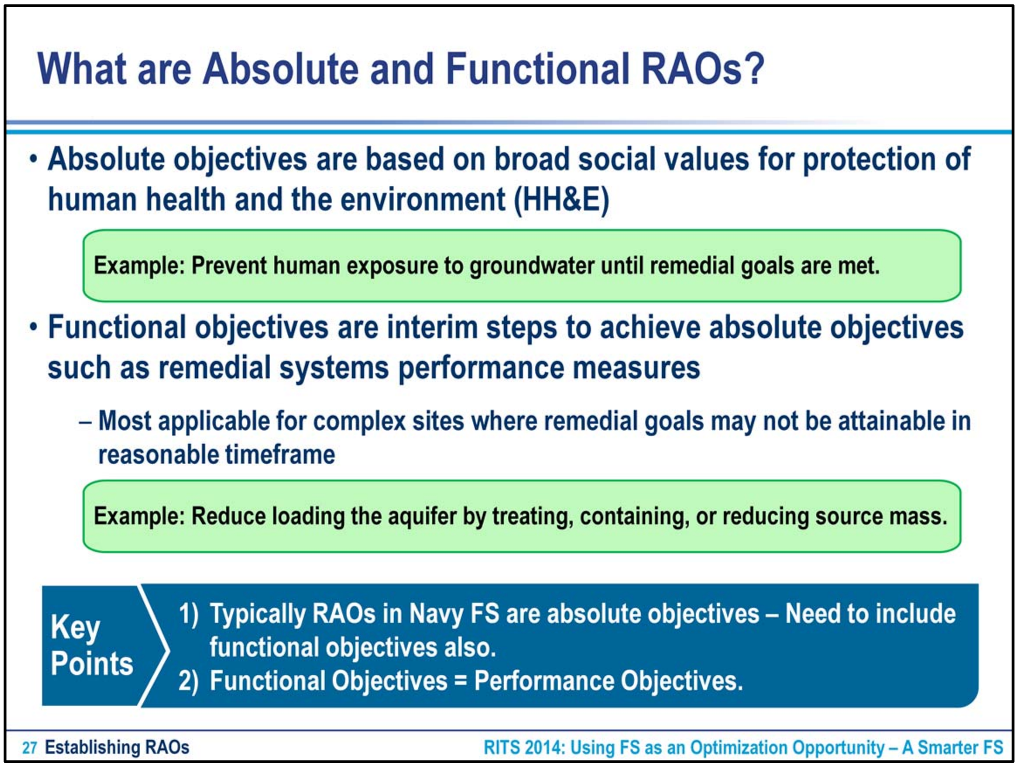


ROAs are the site-specific objectives that the RA should achieve within a reasonable timeframe. What is a reasonable time frame is subjective and must be agreed upon by the stakeholders and when doing so you should be basing that on the CSM including those factors listed here. The current and reasonably anticipated future land use needs to be considered. If there is a need to transfer the property for a particular land use within a certain time frame, that may result in a RAO that would be different than a site that will remain undeveloped and within the boundaries of an active installation. Some CSM factors will influence the ability of the remedy to meet cleanup goals within a certain timeframe for example, if you have DNAPL in clay or fractured media, it may be quite difficult to meet MCLs within a short period of time, if at all, so you need to be realistic in setting the RAOs.

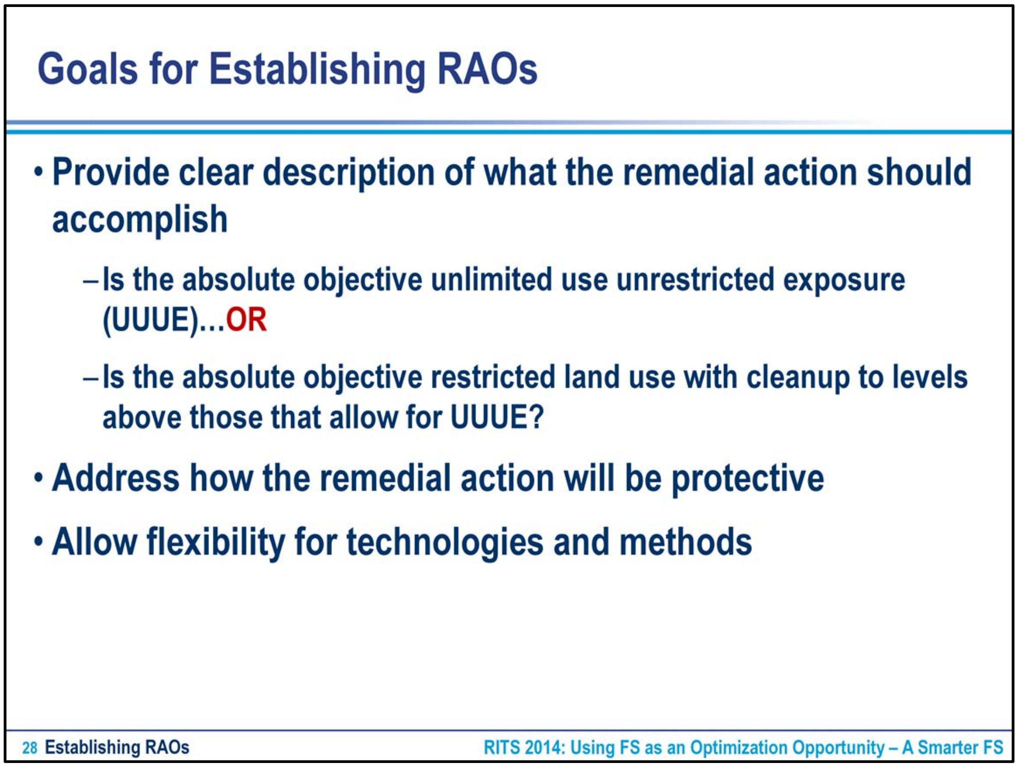


Absolute and functional objectives are relatively new terms but they have been introduced by ITRC and are becoming more widely used in the industry.

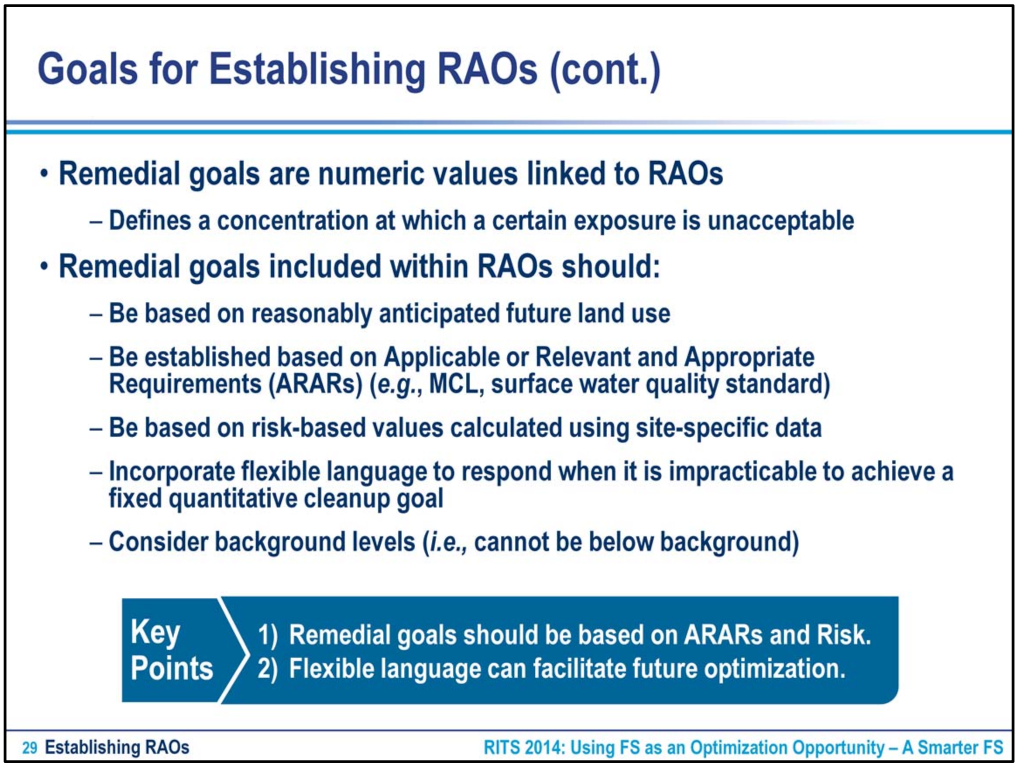
Functional objectives are more applicable to sites where cleanup is anticipated to take an extended time (e.g., decades rather than years). The functional objectives are meant to provide interim goals to ensure that cleanup of the site progresses in an effective/efficient manner.

Functional objectives can be included in the FS as part of the detailed description of each alternative. Therefore, the selected alternative in the PP and ROD has functional objectives in it which can also be refined in the RD.

Relating these terms to Navy terminology, absolute objectives are RAOs in an FS and functional objectives are performance objectives as described in Navy optimization guidance.



The goals of establishing RAOs is to have a clear description of what the RA should accomplish. A major consideration is whether the remedy will achieve UUUE or allow for land use restrictions. In developing the RAO, you need to demonstrate how the RA will be protective of HH & Env but at the same time be flexible enough to allow different technologies and methods to be used to meet the RAO. If you want to prevent COCs from reaching a receptor, then say just that instead of saying achieve hydraulic control.



RAOs are first established and from that, cleanup goals can be developed. RGs define a concentration beyond which a specified exposure is unacceptable. RGs should be based on reasonably anticipated land use and ARARs. RGs should be risk-based values generated using site specific data [although in some cases they will be based on MCLs]. It is preferable to incorporate flexible language in case it is impractical to achieve a fixed cleanup goal and you nee to consider background levels, and never allow a RG to be specified that is below background. Key points here are that RGs should be based on your ARARs and risk but also use flexible language to allow for future optimization.
(Note: final remediation goals are established when the remedy is selected.)

Example Absolute RAOs

Technology Specific	Flexible RAO
Permeable cap	Limit receptors from direct exposure to COCs in surface soil
Hydraulic control	Prevent COCs in groundwater from reaching compliance points above remedial goals
Soil Vapor Extraction (SVE) to meet numeric value of COC in soil	Remove contaminant mass in vadose zone to the degree necessary to prevent further degradation of groundwater above groundwater cleanup standards
Impermeable cap/containment system	Prevent infiltration of precipitation into landfill waste to minimize leachate and prevent surface exposure

Key Point **RAOs should not specify a technology to be implemented.**

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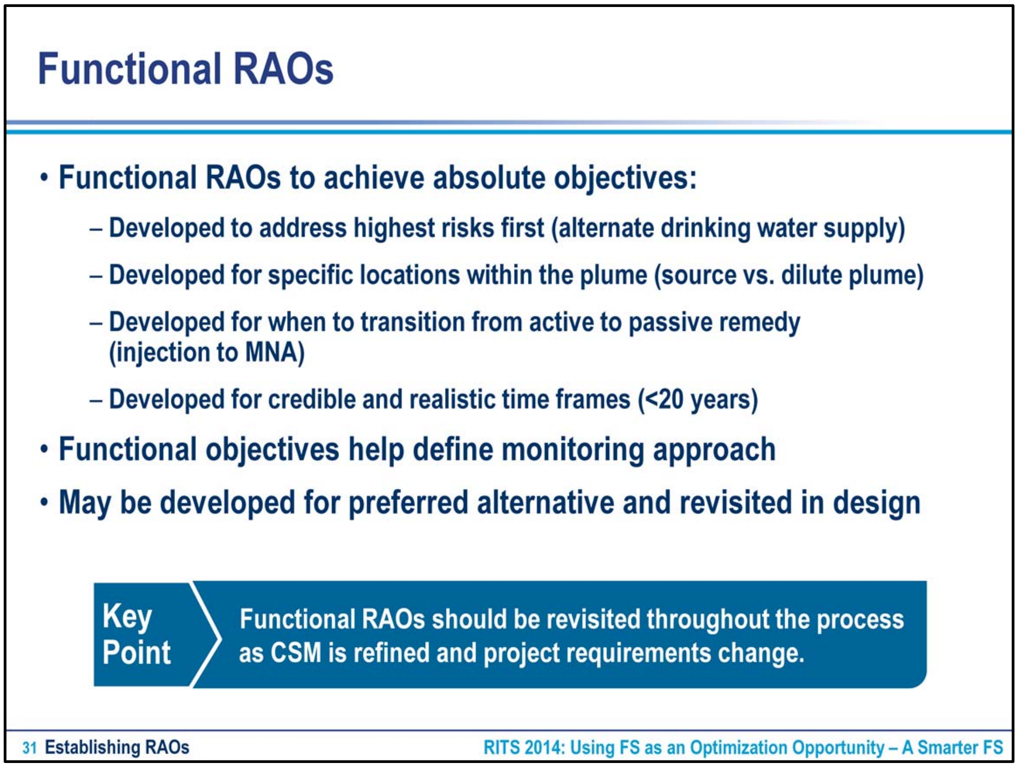
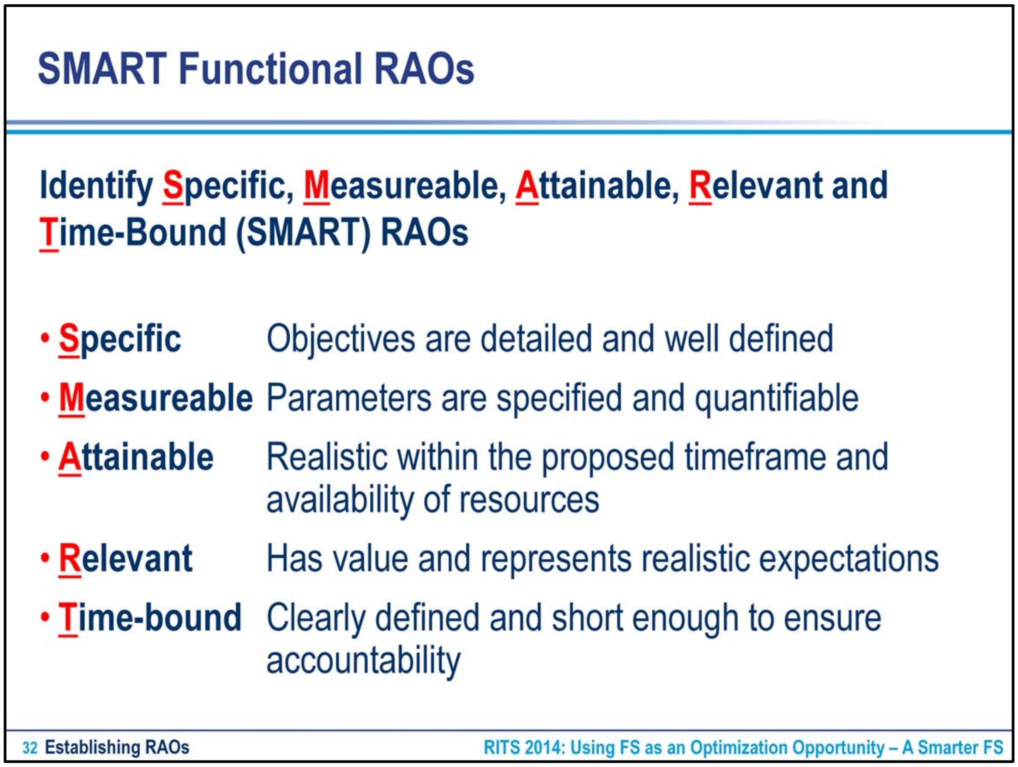
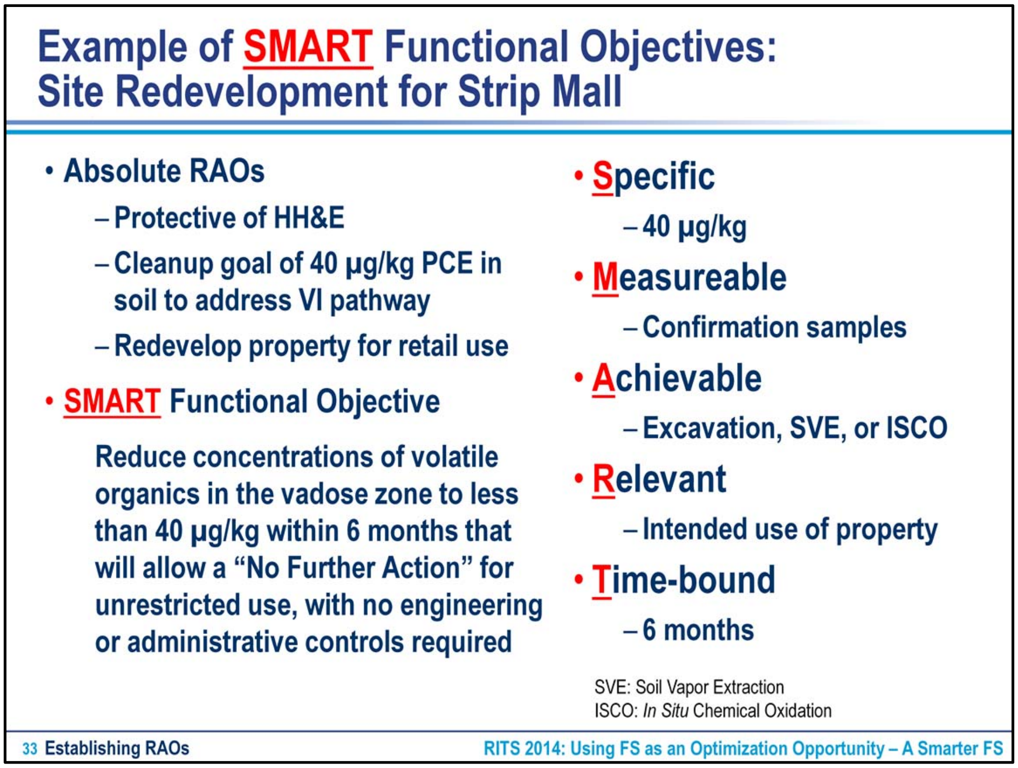
Here are some examples of RAOs. An overly prescriptive RAO may state that groundwater in a certain area must be hydraulically controlled to prevent migration of COCs to a downgradient surface water body. This is a poorly written RAO because it requires that groundwater extraction and treatment be performed over the area where clean-up goals are exceeded. A preferred RAO would be to prevent migration of COCs to the surface water body at concentrations that would cause surface water standards to be exceeded.



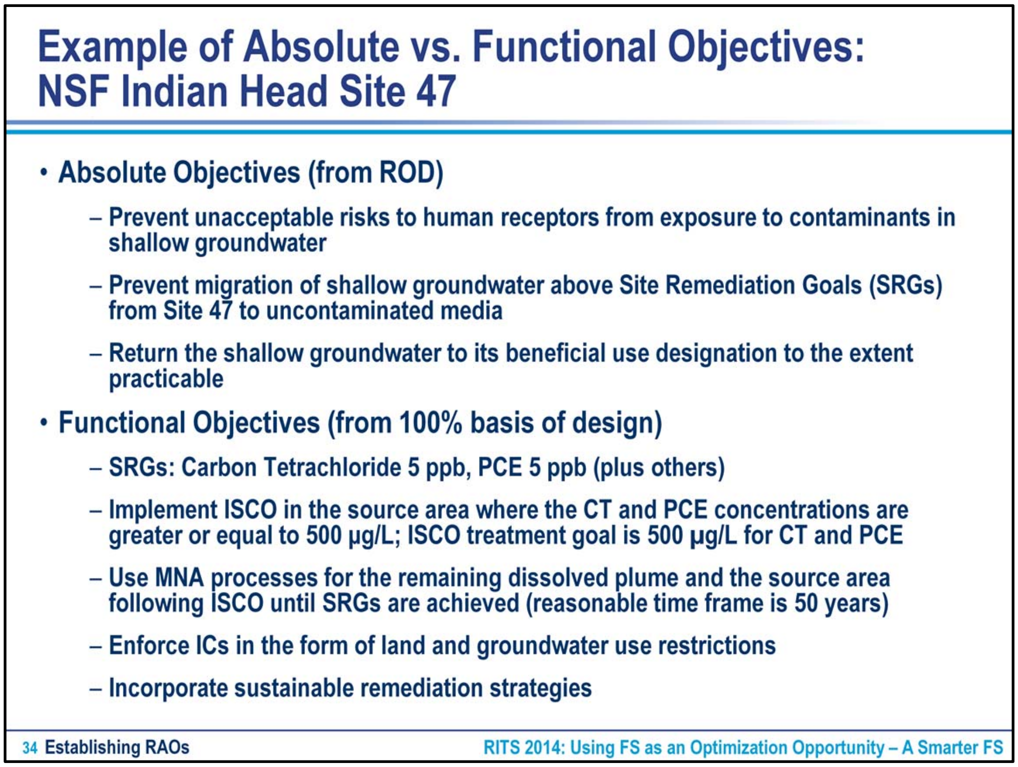
This is relatively new terminology introduced by the ITRC integrated DNAPL site management team. It is applicable not just to DNAPL sites but for any site where it is anticipated to take a relatively long time to achieve the RAOs and site closeout. These are similar to performance objectives discussed in Navy optimization guidance. In route to achieving the RAOs, we can have functional objectives or performance objectives to guide the way and make sure we are on track. They can be used to ensure protectiveness such as establishing alternate DW supply. They can also be used to ensure efficiency by promoting the transition from active to passive technologies at the optimum time. It is better to establish this upfront or else you could be operating beyond the point of diminishing returns while you convince regulators and stakeholders that it is time to transition technologies. Regarding when and where they are defined, functional objectives can be developed for the preferred alternative and then refined during the remedial design. They should also be revisited throughout the remedial process as part of optimization.



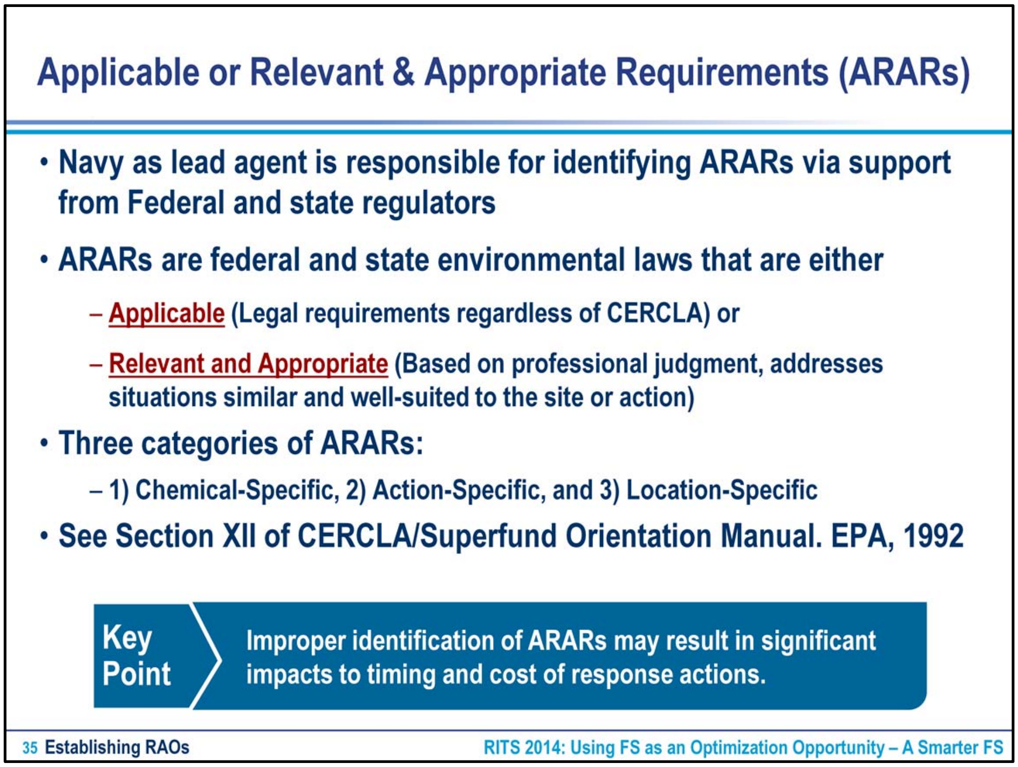
- Many of you may have seen this SMART acronym before as it is often related to performance goals. It can also be applied to functional RAOs.
- This is relatively new terminology for RAOs and these apply to functional RAOs and discuss how they are only for functional and not absolute.



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



The absolute objectives are in the ROD and are flexible, using words like ‘preventing unacceptable risks’ and ‘preventing contaminant migration’. WRT to returning GW to beneficial use designation, it includes to extent practicable. The functional objectives are specified in the design document and these are more SMART-like. They are specific numerical values for the goals that can be measured, we hope they are achievable, they are certainly relevant, and they are timebound, identifying 50 years as a reasonable time frame.



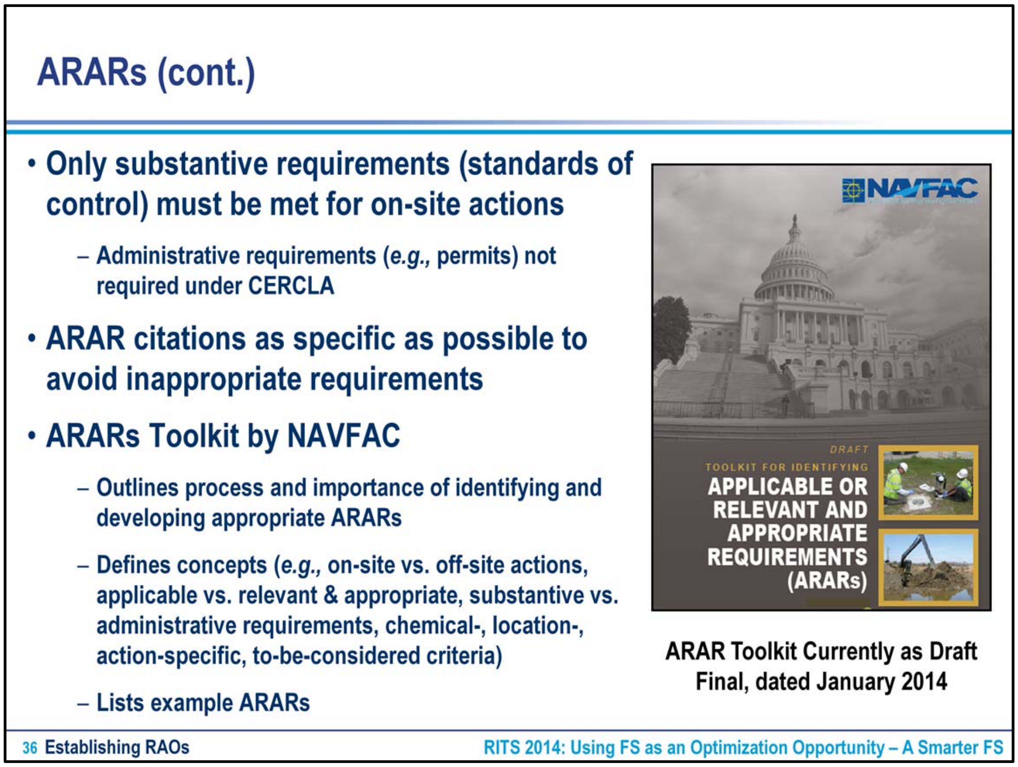
The NCP states that both the lead and supporting agencies (EPA & states) are responsible for identifying ARARs, but Navy identifies these via support from Federal & state regulators.

Key difference between Applicable versus relevant and appropriate. Applicable is a legal requirement. There are more steps needed to determine if something is relevant & appropriate vs applicable. Relevant and appropriate is not a legal requirement until it is identified as an ARAR in an executed ROD. See referenced EPA document and Navy ARAR toolkit.

Chemical, location, and action-specific ARARs are site-specific substantive requirements to be met for removal and remedial actions.
Chemical-specific ARARs are usually numerical values that establish the treatment and discharge standards for the removal or remedial action and cleanup levels for the media posing unacceptable human health or ecological risks at the site.
Location-specific ARARs prevent damage to unique or sensitive areas, such as floodplains, historic places, wetlands, and fragile ecosystems, and restrict other activities that are potentially harmful because of where they take place.
Action-specific ARARs are activity or technology based and control removal or remedial activities involving the design or use of certain equipment, or regulate discrete actions.

Involve counsel early on.

The ARARs tool kit will help RPMs to address these issues.



Only substantive requirements need to be met for on-site actions.

Be specific when citing ARARs; do not cite the entire regulation as an ARAR. Emphasize the consequence for citing too much of a regulation.

For example, cite the specific subsection of RCRA Subtitle D that contains the applicable or relevant and appropriate standard (*e.g.*, 40 CFR Part 264.310(a)) rather than citing all of RCRA Subtitle D (*e.g.*, 40 CFR Part 264).
Example of FS that called a disposal area a landfill and caused landfill monitoring requirements to be applied, increasing cost of monitoring.

Notes about the toolkit: Describes the process, and differences between on-site vs off-site actions and substantive vs administrative, types of ARARs such as chemical, location and action specific, differences between applicable vs relevant and appropriate vs TBC, and discusses the ramifications of not being sufficiently specific when citing ARARs. It also provides an extensive list of common ARARs broken out by ARAR type.

References Related to Development of RAOs, Remedial Goals and ARARs

Topic	References	How it helps RPMs with FS
RAOs	• ITRC. Integrated DNAPL Site Strategy (IDSS) (2011) • DON. Guidance for Optimizing Remedy Evaluation, Selection, and Design (2010)	Detailed information about absolute and functional/performance objectives and how flexible RAOs allow for future remedy optimization
Remedial Goals	• ESTCP. Assessing Alternative Endpoints for Groundwater Remediation at Contaminated Sites, 2011 • NAVFAC. White Paper for Alternative Endpoints for Groundwater Remediation, 2011 • NAVFAC. Plume Management Handbook (2008)	Methods for developing alternative endpoints and approaches, such as ARAR waivers, alternate concentration limits (ACL), use of passive remedies over long time frames. NAVFAC White Paper focuses on states where Navy has multiple sites (*e.g.,* CA, HI, VA, NC, WA, FL, NY, MD, TX, SC).
ARARs	• NAVFAC. Toolkit of Identifying ARARs (Draft final 2014) • DoD. Defense Environmental Restoration Program (ERP) Manual (2012) • DON ERP (NERP) Manual (2006)	Outlines process and importance of identifying and developing appropriate ARARs, defines important concepts and provides example of various types of ARARs

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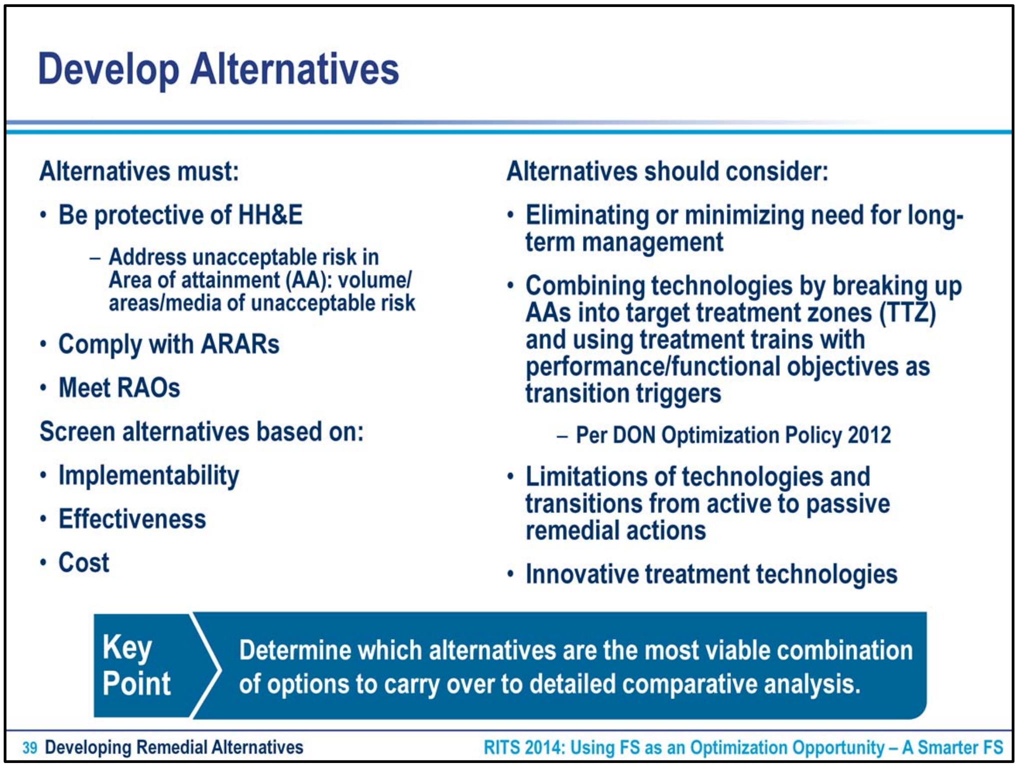
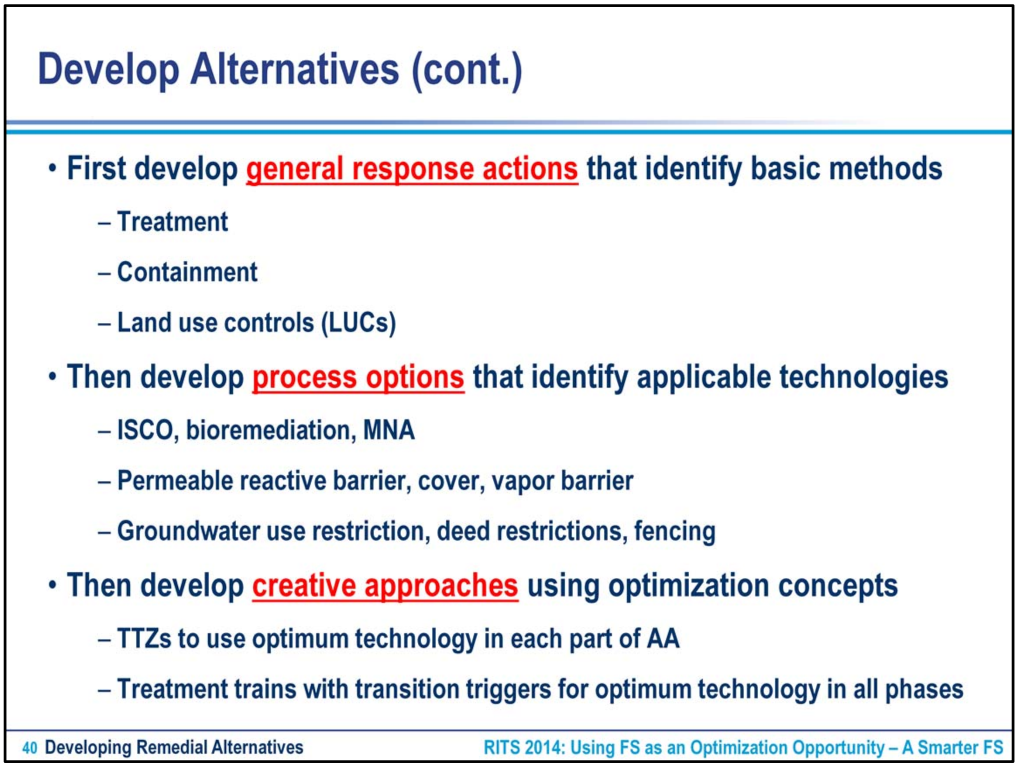
There are many related references and these are broken down into three categories: RAOs, remedial goals, and ARARs. References are included from Navy, ITRC, and ESTCP. The third column discusses how these references help the RPM with a FS.

Presentation Overview

- Introduction
- Understanding the Conceptual Site Model (CSM)
- Establishing Remedial Action Objectives (RAOs)
- Developing Remedial Alternatives
- Detailed Analysis of Remedial Alternatives
- Wrap Up



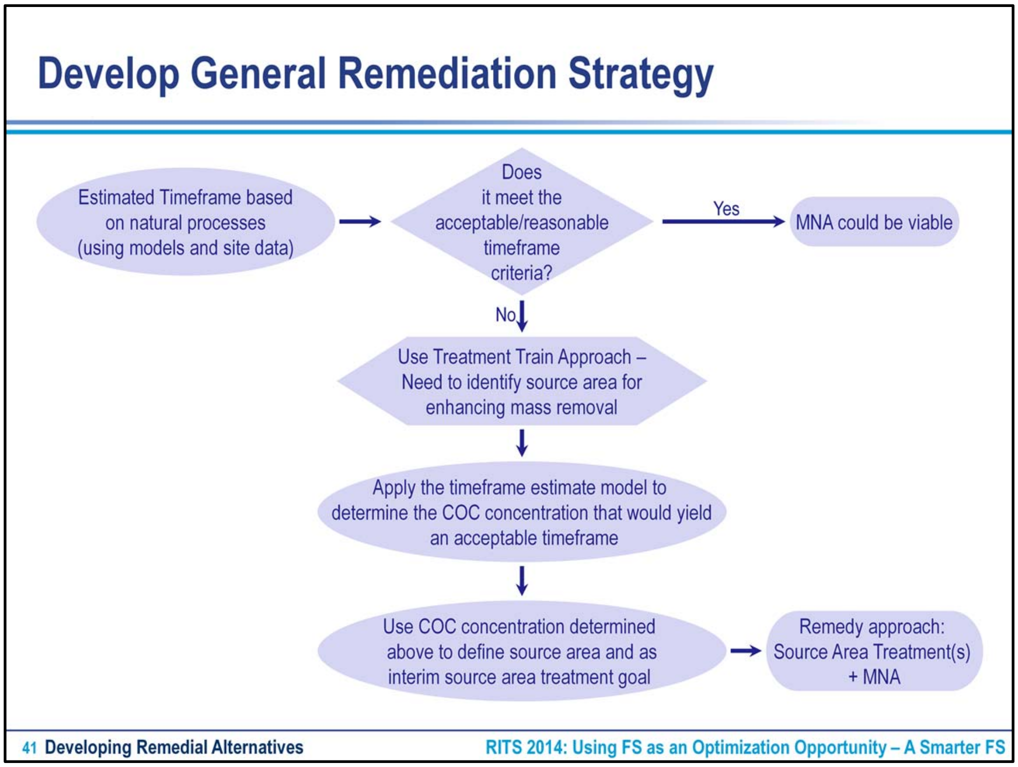
When developing alternatives, keep in mind that they must meet threshold criteria of protectiveness and compliance with ARARs and the alternatives must be capable of meeting RAOs. You will then screen them based on implementability, effectiveness, and cost. On the right side, we are listing factors that are not firm requirements but what we would like to see considered. For complex sites, the most efficient alternatives are typically those that use multiple technologies for different TTZs and at different phases of the treatment train. In the screening phase, you want to determine which alternatives are the most viable combinations of technologies and should be carried over to the detailed comparative analysis.



When developing remedial alternatives, it can be difficult to get started, so it is a good idea to first break the remedy down into general response actions that identify basic methods of remediation including: Treatment, Containment, and Land use controls (LUCs).

Then develop process options that identify applicable technologies. For example, for treatment, you can consider technologies such as ISCO, bioremediation, and MNA. For containment: Permeable reactive barrier, cover, vapor barrier and for LUCS: Groundwater use restriction, deed restrictions, and fencing.

Once you have done this, then develop creative approaches using optimization concepts including TTZs to use optimum technology in each part of attainment area (AA) and Treatment trains with transition triggers for optimum technology in all phases.



This flow chart shows a process you should consider when developing your remedial strategy. The first step shown here is to estimate your remedial time frame based on NA processes alone. If that timeframe is considered reasonable, then MNA is a viable alternative by itself. If not, then you should be looking at the Treatment Train approach. To use this method, you want to evaluate with modeling the cleanup time with NA processes after you have used a more aggressive technology to remove a portion of the COC mass and/or reduce concentration. You can then determine a removal needed for NA to yield an acceptable timeframe and use that information to determine what your source area is that needs more aggressive treatment and define a treatment goal for that area. The leads you to a remedial approach that includes source treatment and MNA.

Develop Alternatives (cont.)

- **Consider alternative(s) for UUUE as a basis of comparison**
  - Required per DoD Policy on Land Use Controls (LUCs) Associated with ER Activities (2001)
  - Additional cost may only be marginal increase to achieve UUUE and avoid LTMgt of site
  - If unrealistic or costly, screen out based on screening criteria (effectiveness, implementabilty, and cost) and apply LUCs

Example Alameda Point OU2C: Comparison of Remedial Alternatives to Address Future Occupational and Residential Land Use

	Occupational	Residential
ISCO treatment	0.8 acres	2.6 acres
Enhanced bio treatment	0.7 acres	6.7 acres
Cost	$2.19 M	$4.98 M
LTMgt required	Yes – ICs	No

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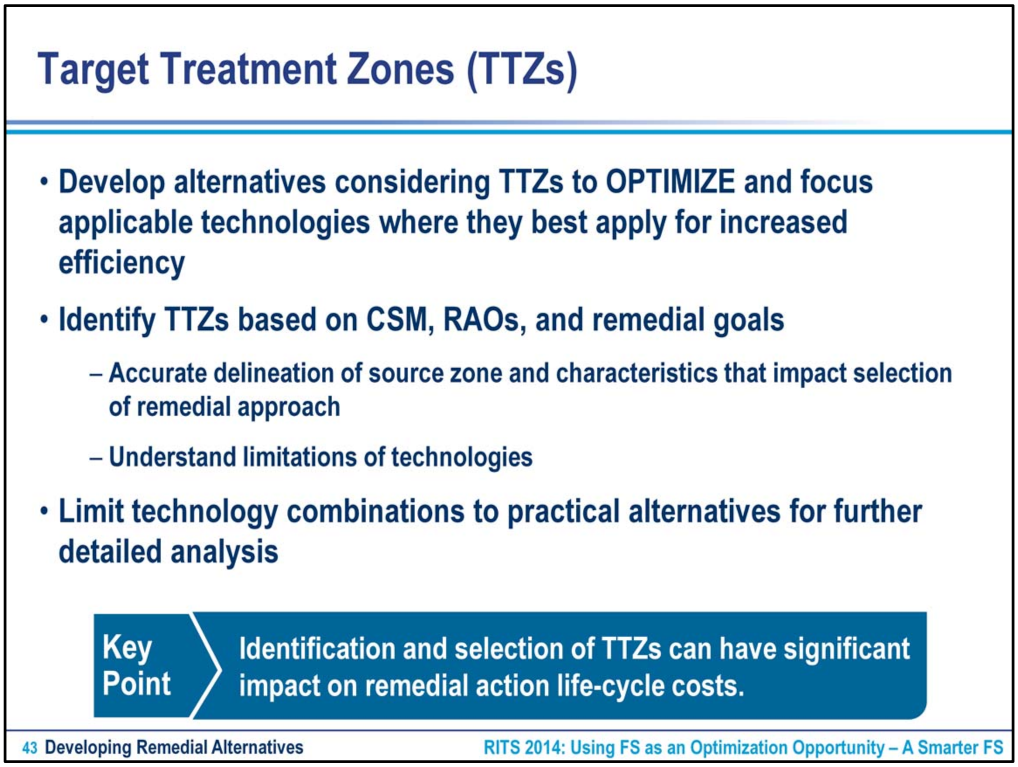
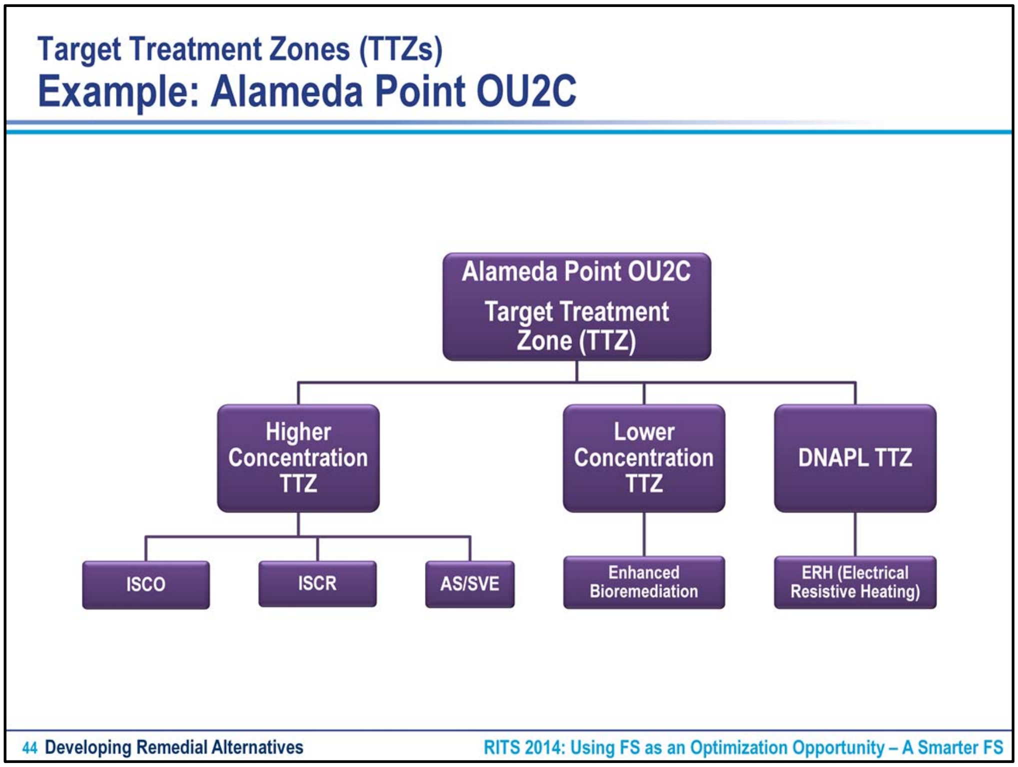
You need to consider at least one alternative for UUUE as a basis of comparison and this is required per DoD Policy on Land Use Controls (LUCs) Associated with ER Activities (2001). If additional cost is only a marginal increase to achieve UUUE and avoid LTMgt of site, then it is worth carrying it forward to detailed analysis. However, if UUUE is unrealistic or too costly, it can be screened out based on screening criteria (effectiveness, implementabilty, and cost) and apply LUCs. In this example at Alameda Point OU2C, the cost for UUUE was over twice as high so occupational was implemented instead of residential.

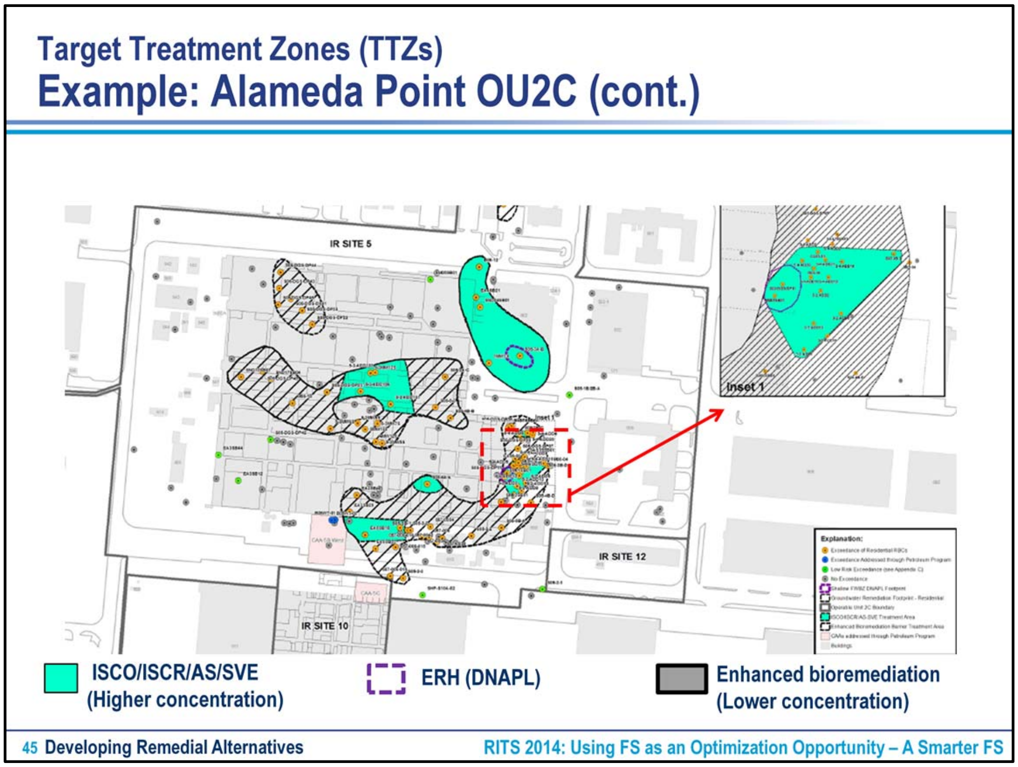


One of the important optimization concepts is the TTZ where the attainment area (AA) is broken up into multiple TTZs in order to use different remedial technologies and have different goals where they make the most sense. Rather than picking one technology or the other, you may want to use both but only where they are most efficient. The way the site is broken up into TTZs depends on the CSM, remedial objectives and technology limitations. The use of TTZs can significantly reduce cost, especially for complex sites.

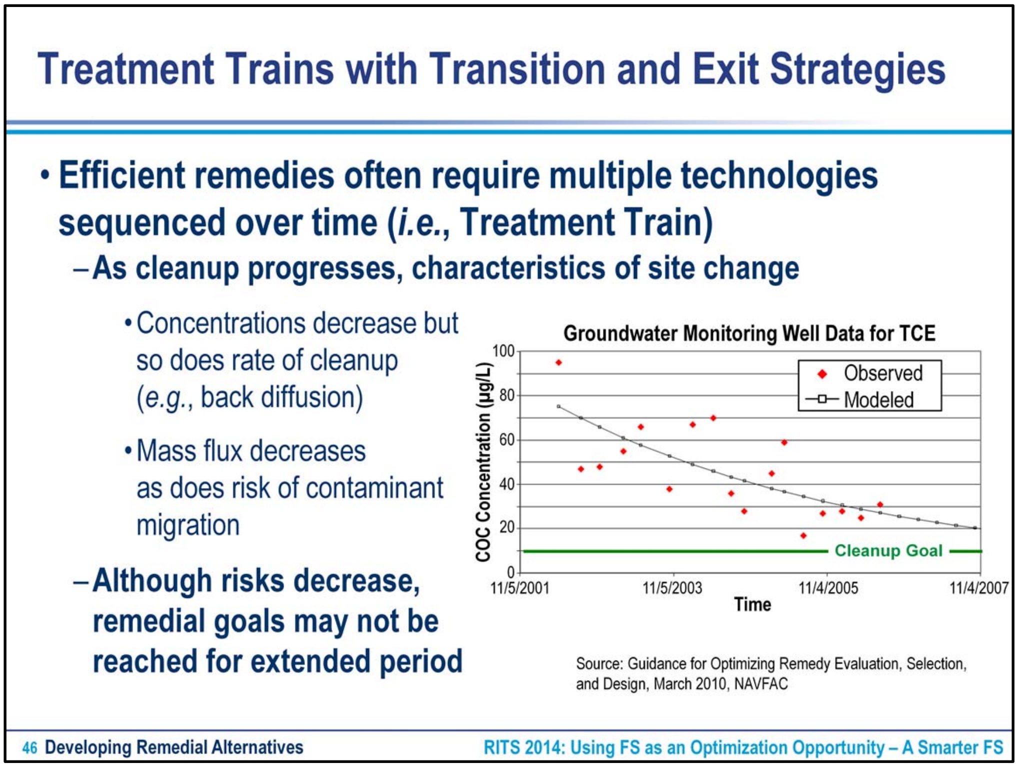


Example of breaking a site up into TTZs and how that increases efficiency - Alameda OU2C
The alternatives include a more active (ISCO, ISCR, AS/SVE) approach for higher concentration areas and then enhanced bio for lower concentration areas. DNAPL

The site was broken into three TTZs, DNAPL source zone where ERH was applied, then for the higher concentration plume TTZ, three technologies were evaluated and ISCO selected, then for lower concentration plume, enhanced bio was used.



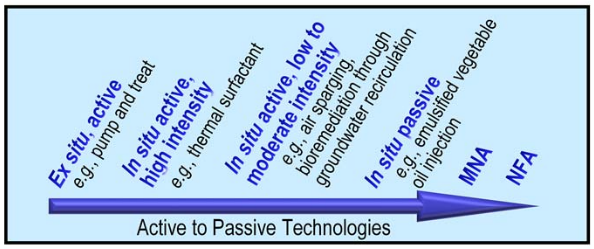
Alameda
This is multiple plumes with different sources.
Note that the DNAPL area where ERH was used is small in comparison to other portions of the site. It is important to focus the more aggressive technology in the area where it is really needed.



The next optimization concept is treatment trains (TT) where multiple technologies are sequenced over time. This is important because as the cleanup progresses, the site conditions change and what was the optimum technology at one time is no longer. This figure shows a common situation where concentration initially decreases significantly but the cleanup goal is not met for an extended period of time. This is often due to back diffusion where COCs sorbed onto low permeability zones tend to slowly desorb into the groundwater, which prevents meeting cleanup goals such as MCLs, but mass flux decreases, so risk of plume migration reduces, allowing you to use more passive technologies.

Treatment Trains with Transition and Exit Strategies (cont.)

- **Efficient transition from active to passive**
  - As site cleanup progresses, active remedies offer limited benefit over passive and are most expensive to implement
  - Cost per pound removed increases unless transition occurs
  - Treatment train should include MNA at appropriate point of cleanup determined via natural attenuation assessment



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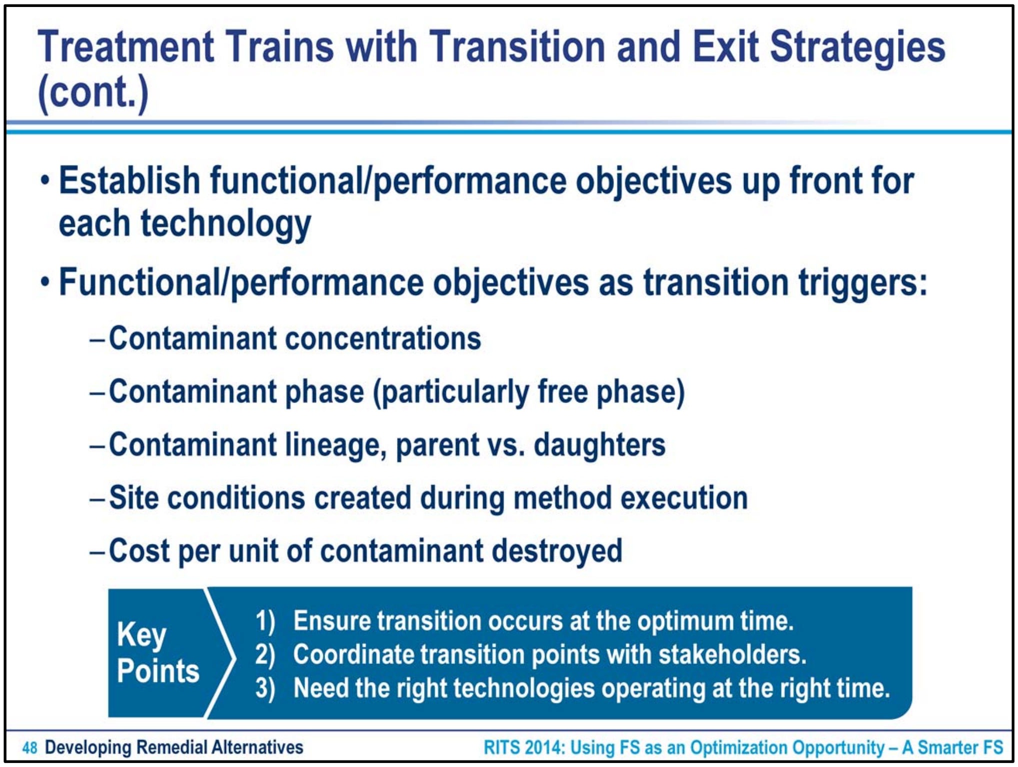
As sites cleanup, the aggressive technologies have limited benefit over the passive technologies and unless a transition occurs, the cost per pound removed increases. Figure shows the spectrum of active to passive technologies and for most of the complex sites, the TT tends to include MNA.



When developing TTs it is better to have TTs tied in with exit strategies and have this established up front to make sure that the transition from active to less active or passive happens at the optimum time. This is where functional or performance objectives can be applied. These can serve as transition triggers that are thought out in advance. They can be based on various measurable metrics as identified below. Key points are that establishing these transition triggers helps to ensure that the transition happens at the optimum time but you need to have stakeholder approval upfront to make sure this happens so the right technologies are being operated at the right time.

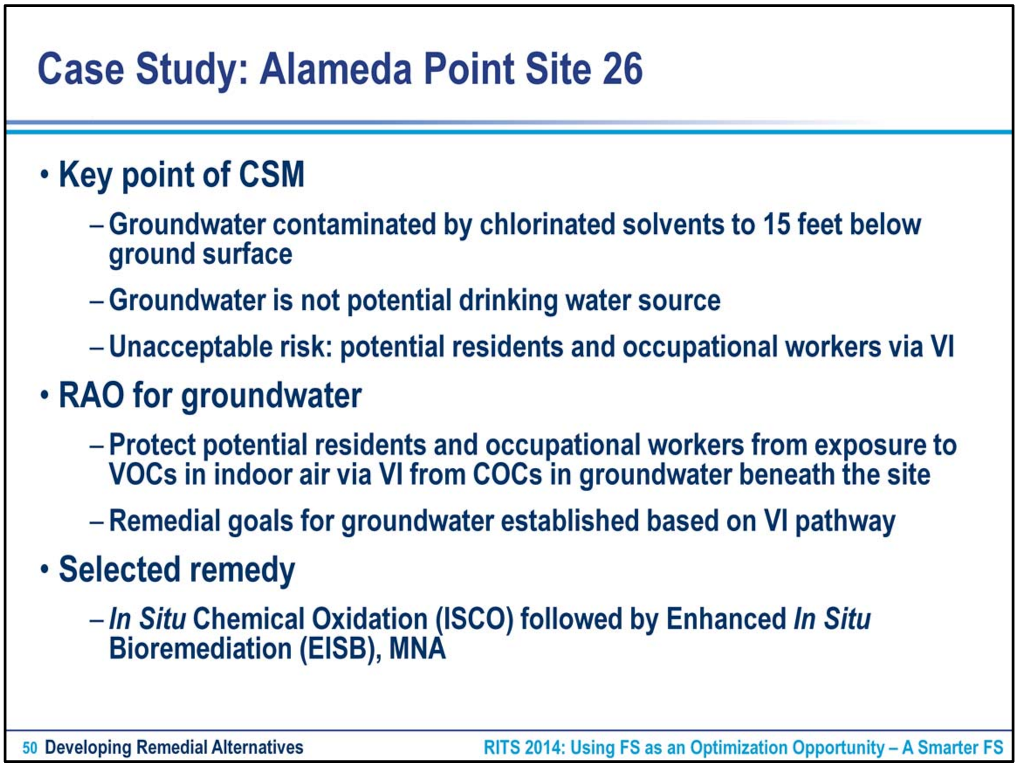
Treatment Trains with Transition and Exit Strategies – Cleanup of Gasoline Spill at Fuel Terminal

Phase	Exit Strategies
Phase I: Soil vapor extraction (SVE)-only	Trigger to transition to Phase II linked to when catalytic oxidizer requires supplemental fuel
Phase II: Pulsed Air Sparging/SVE for aggressive removal of smear zone	• Control air flow to allow catalytic oxidizer to be self-sustaining • Trigger to Phase III linked to risk from benzene in shallow soil vapor
Phase III: Biosparge designed to maintain elevated dissolved oxygen (DO) levels with no SVE	• Low operating cost • Trigger to Phase IV linked to fate and transport modeling
Phase IV: MNA	Site Closeout

Here is an example of fuel terminal remediation for a 14 acre free product plume.

There were four phases of remediation with each becoming less aggressive, and for each there is a clearly defined exit strategy.

Key point is that the exit strategies allowed the transitions to occur at the optimum time.

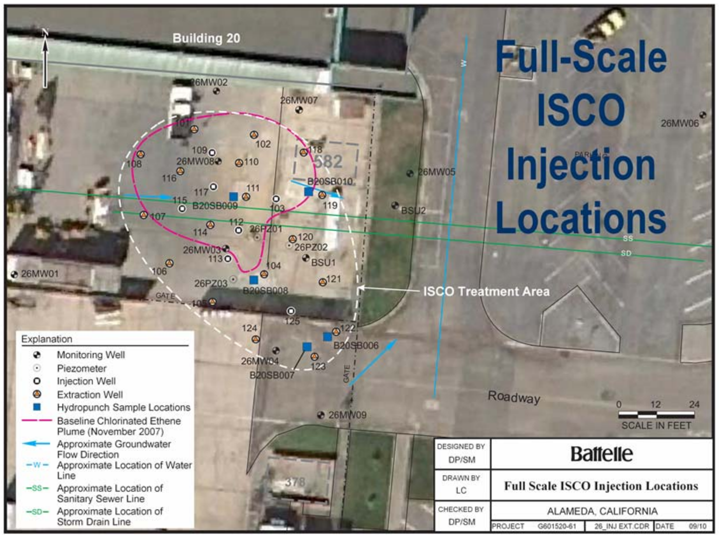


Example of treatment train to improve efficiency – Alameda IR Site 26
Background information:
Site Conditions:

Groundwater contaminated by chlorinated solvents to 15 feet below ground surface
Groundwater is not potential drinking water source
Unacceptable risk: potential residents and occupational workers via VI

RAO for groundwater is to protect potential residents and occupational workers from exposure to VOCs in indoor air via VI from COCs in groundwater beneath the site. The remedial goals for groundwater were established based on VI pathway
The selected remedy is *In Situ* Chemical Oxidation (ISCO) followed by Enhanced *In Situ* Bioremediation (EISB), MNA

Case Study: Alameda Point Site 26 (cont.)



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Example of treatment train to improve efficiency – Alameda IR Site 26: Plan view of site.

Case Study: Alameda Point Site 26 (cont.)

- **Remedy includes treatment train with performance/ functional objectives to trigger transition**
  - **Cleanup goal for *cis*-1,2-DCE is 6 µg/L**
  - **Interim goal or transition trigger from ISCO to EISB is 30 µg/L**
  - **Mass reduction of each COC, asymptotic mass removal, and cost effectiveness also evaluated as factors to determine ISCO/EISB transition**

CCs	RGs
TCE	5 µg/L
cis-1,2-DCE	6 µg/L
VC	0.5 µg/L

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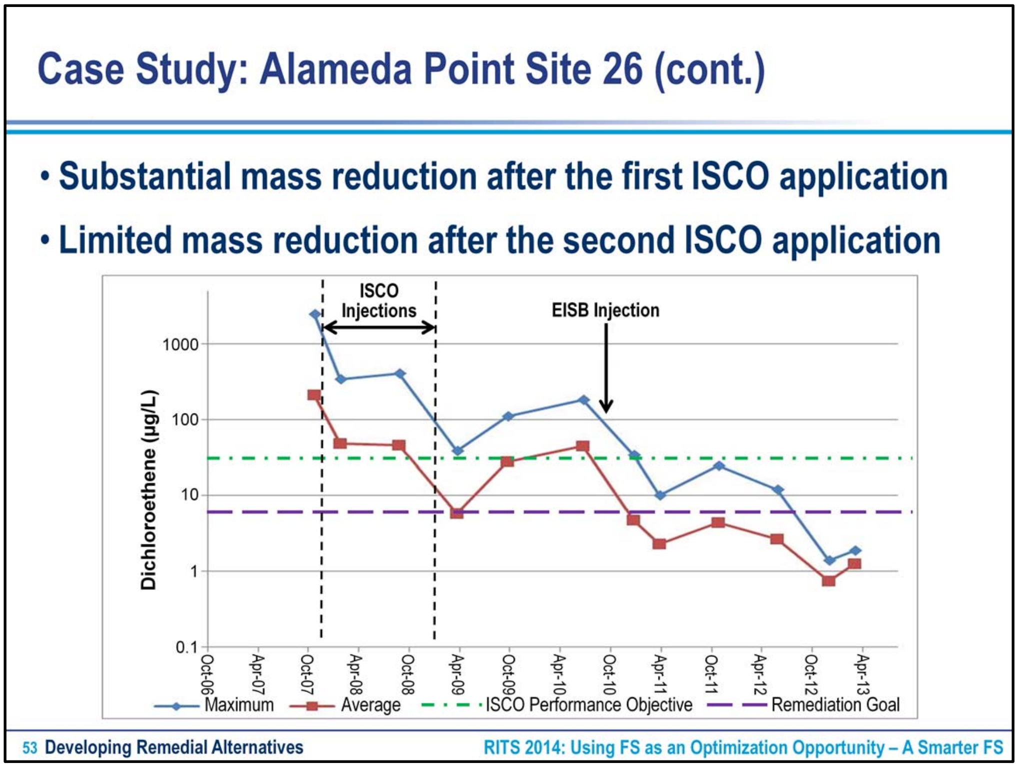
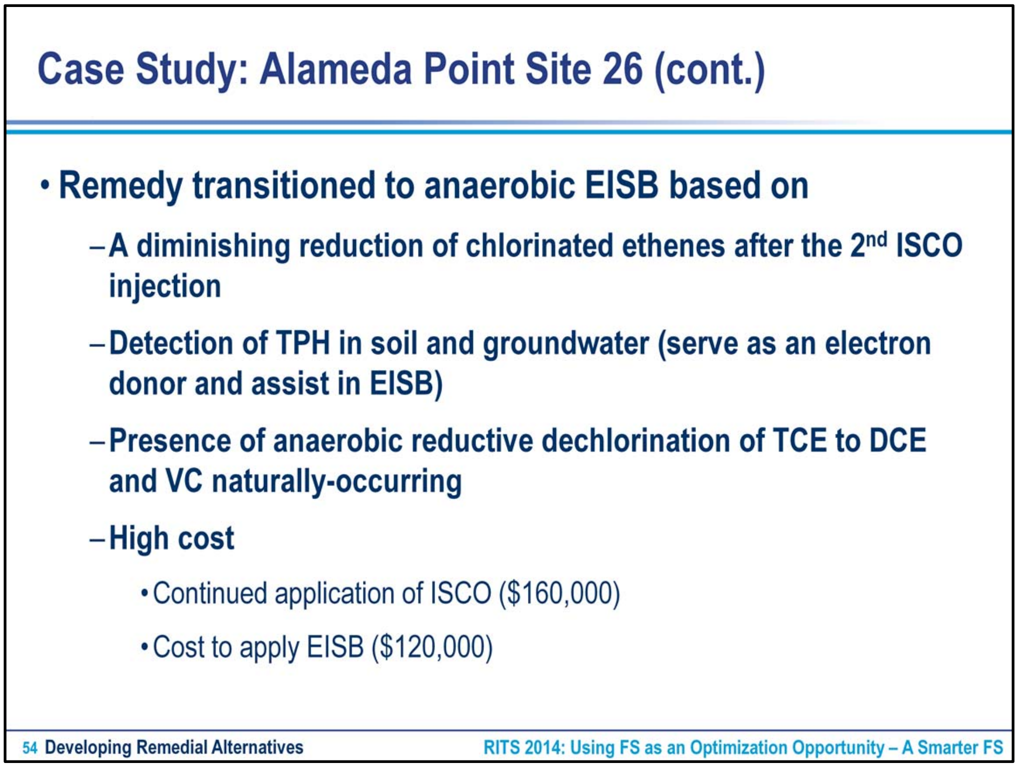
Example of treatment train to improve efficiency – Alameda IR Site 26

Note: the Interim goal for DCE is 30 µg/l and asymptotic mass removal/cost effectiveness are transition triggers similar to functional objectives although they were not referred to that way. Concept was applied although the industry was not using the term functional objective. [Interim goals were more for guidance and we transitioned to EISB after two rounds of ISCO based on the fact that the second round did not appear to result in substantially more reduction than the first, and that we felt that EISB would give us more bang for the buck than performing a third round of ISCO.]

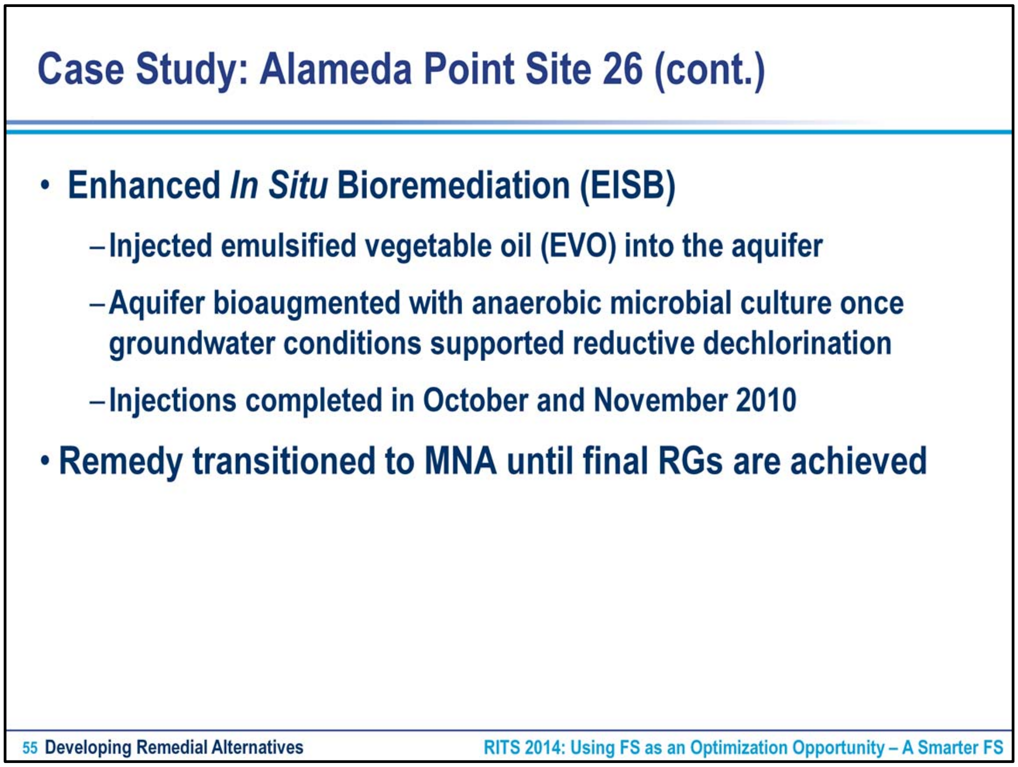


Based on monitoring data from the treatment area, it was determined that the greatest reduction of mass occurred after the pilot test.

A substantial reduction in mass also was noted after the first ISCO application (peroxide); however, the mass did not decrease substantially after the second ISCO application (sodium persulfate) at the site. Based on a diminishing reduction of chlorinated ethenes after the second full-scale ISCO injection event and a high cost for continued application of ISCO compared to the expected cost to apply EISB, the remedy was transitioned to anaerobic EISB in accordance with the ROD.

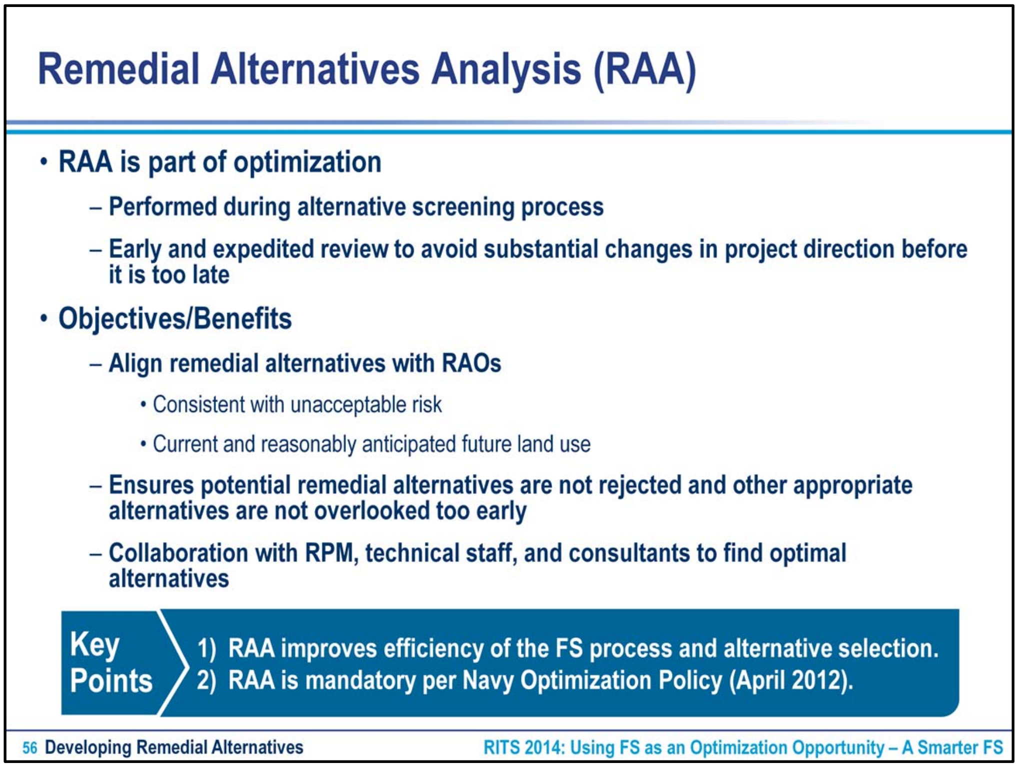


Total mass reduction of TCE/DCE/VC was 51% and then another 17% (total 68%) after the first two peroxide injections. There was no additional mass reduction measured after the sodium persulfate injection. Costs are per injection event for the injection only (no follow-on monitoring as it was assumed this would be the same for each option). Cost for EISB may be higher than someone might expect because it includes bioaugmentation.

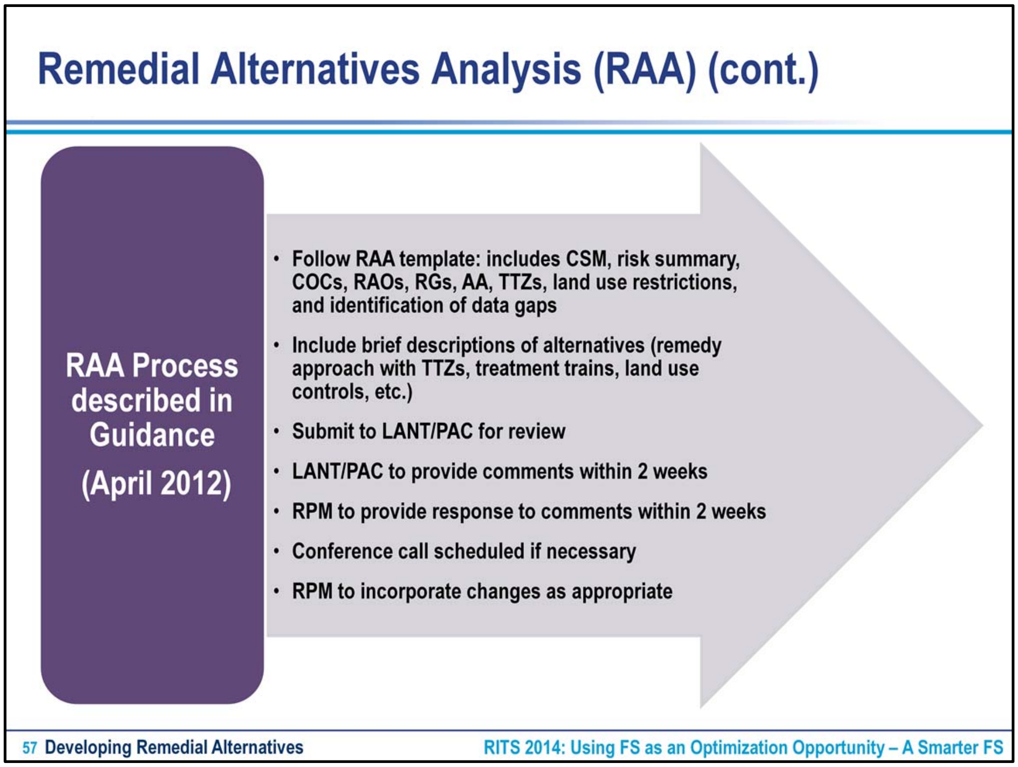


Example of treatment train to improve efficiency – Alameda IR Site 26

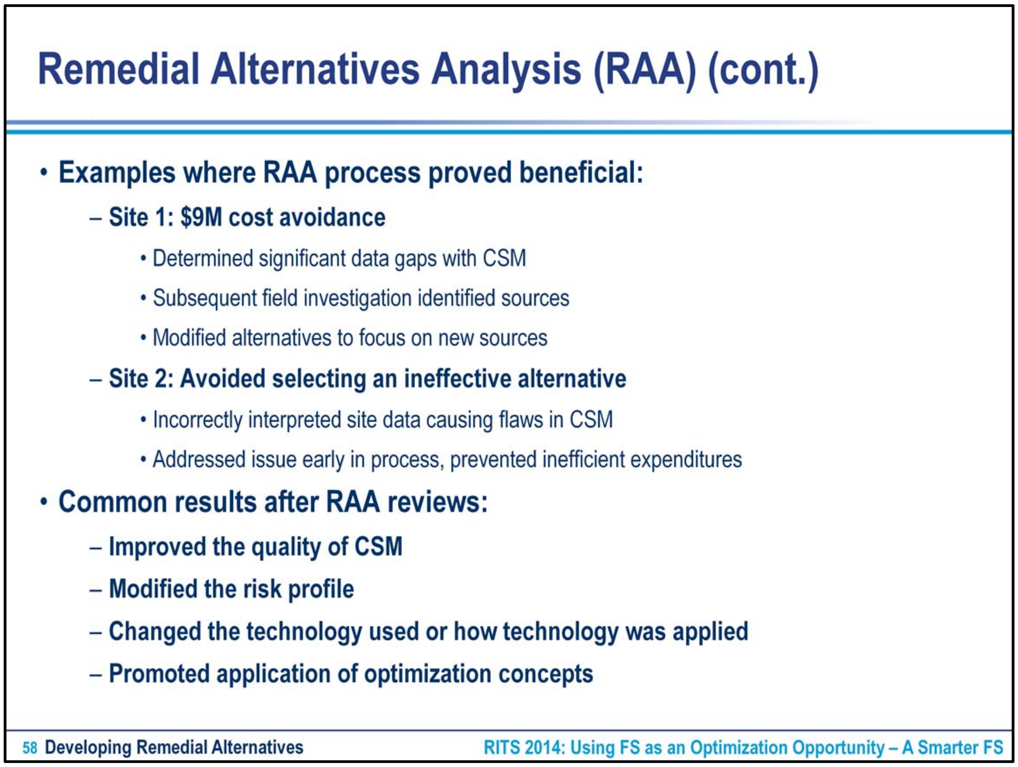
Just one round of EISB injection was completed. The EVO was expected to persist in the aquifer for 3 to 5 years and was completed in October 2010. Exit strategy was to complete one year of quarterly monitoring and use NAS to predict the time of remediation (TOR). Based on the TOR prediction, cost estimates for continued monitoring could be developed. The TOR was anticipated to be less than 5 years. Battelle completed the EISB injections and the site was transferred to the basewide monitoring program for quarterly sampling. The site was designated as Operating Properly and Successfully (OPS) and was transitioned to the City of Alameda, so presumably no additional injections are planned.



The RAA is a great idea because it promotes optimization early in the FS process. Optimization reviews performed at the draft FS phase can sometimes cause problems for RPMs. If the optimization team comes up with new ideas, maybe new technologies that where not considered which could either lead to new alternatives or changes to alternatives, it can be very difficult to make these changes to the FS and remain on schedule/budget. It is better to have a review done before going too far down the road.



Although this occurs before the FS is written, the RAA needs to provide the reviewer with the logic/steps on how RGs, area of attainment, timeframes will be developed.



Here are two examples where the RAA proved to be beneficial:

- Site 1: $9M cost avoidance
  - Determined significant data gaps with CSM
  - Subsequent field investigation identified sources
  - Modified alternatives to focus on new sources
- Site 2: Avoided selecting an ineffective alternative
  - Incorrectly interpreted site data causing flaws in CSM
  - Addressed issue early in process, prevented inefficient expenditures

Common results after RAA reviews:

- Improved the quality of CSM
- Modified the risk profile
- Changed the technology used or how technology was applied
- Promoted application of optimization concepts

References Related to Alternative Development

Topic	References	How it helps RPMs with FS
Optimization concepts	• ITRC. IDSS, 2011 • DON. Guidance for Optimizing Remedy Evaluation, Selection, and Design, 2010	Use of optimization concepts (TTZs, treatment trains, performance objectives, and exit strategies) to develop creative alternatives that account for technology limitations and life-cycle characteristics associated with site cleanup
RAA	• NAVFAC. Guidance for Preparing a Remedial Alternatives Analysis (RAA) Document with Template, 2012	Describes the benefits of the RAA and how the process is implemented

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Here are some references related to alternative development including two optimization guidance documents, one from the Navy and the other from ITRC and then the Navy RAA guidance.

Presentation Overview

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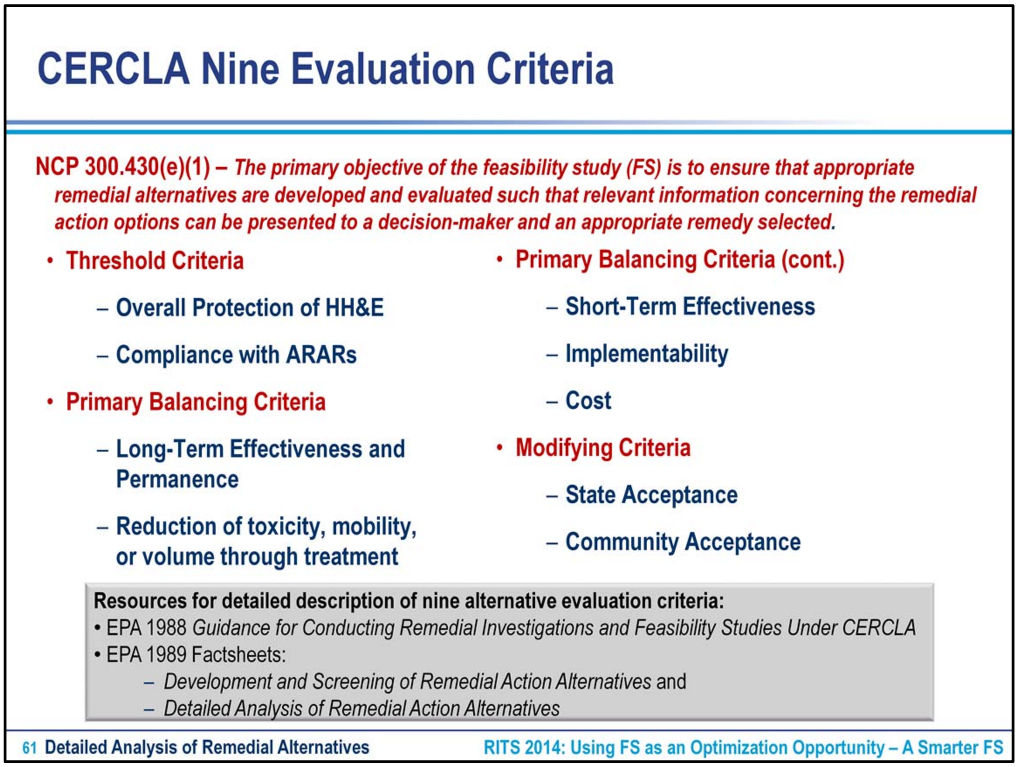
- Detailed Analysis of Remedial Alternatives
- Wrap Up



Threshold criteria must be met

Protection of HH&E and compliance with ARARS

Do not carry forward alternatives for detailed comparative analysis that do not meet threshold criteria.

Balancing criteria

Identify advantages and disadvantages of each alternative relative to one another

Modifying Criteria

Formally assessed after public comment period of the Proposed Plan

Long-Term Effectiveness and Permanence

Magnitude of residual risk and reliability of controls

Reduction of toxicity, mobility, or volume through treatment

Volume of material destroyed, type and quantity of residual remaining

Short-Term Effectiveness

Protection of community and workers during remedy construction, EV impacts

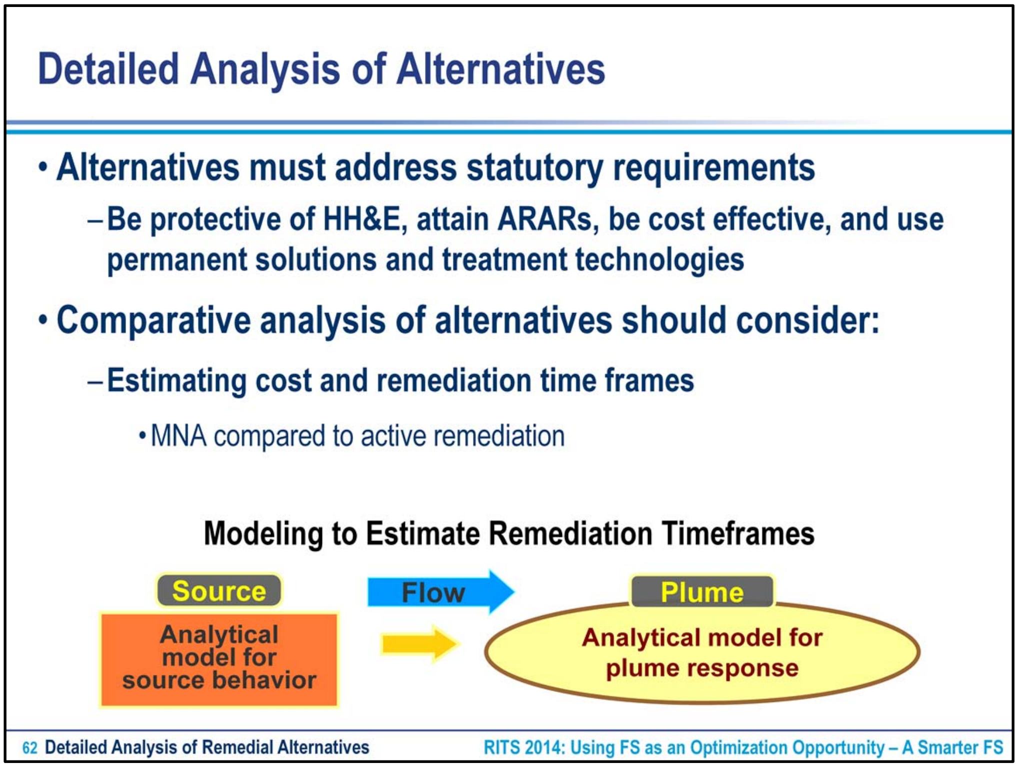
Implementability

Ease of undertaking, availability of services and reliability of technology

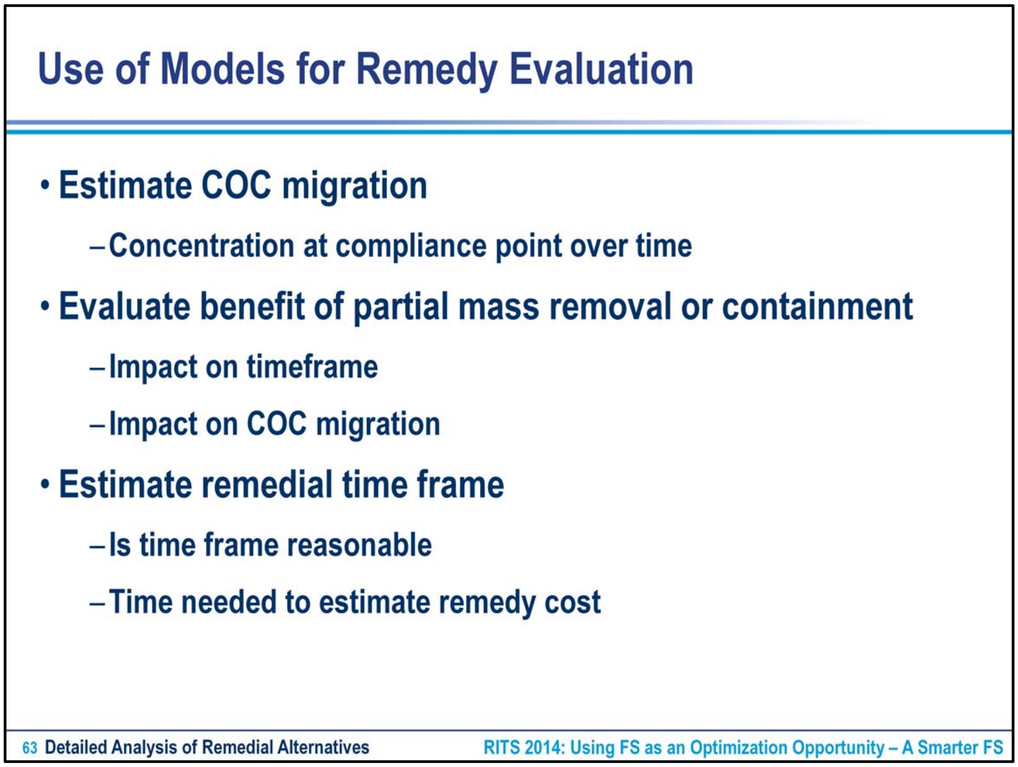
Cost

Capital, O&M, present worth

We will go in detail about ARARs and cost later.

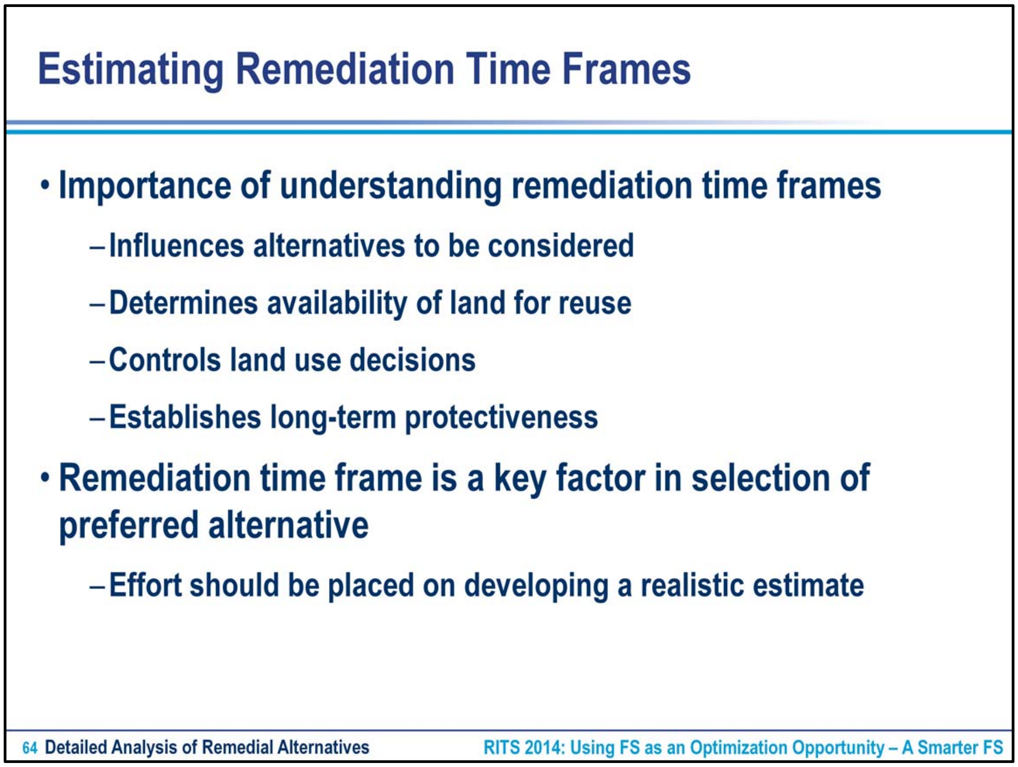


The comparative analysis must consider an estimate of cost and remedial time frames. For complex GW sites, the cost is often driven by remedial time frame and thus the various factors that influence remedial time frame must be evaluated. These include: physical (advection, diffusion, back-diffusion, NAPL dissolution, etc.) and bio processes. Time frame is determined by the slowest process. Tools are available to evaluate time frame and help us to provide apple to apple comparison of alternatives.

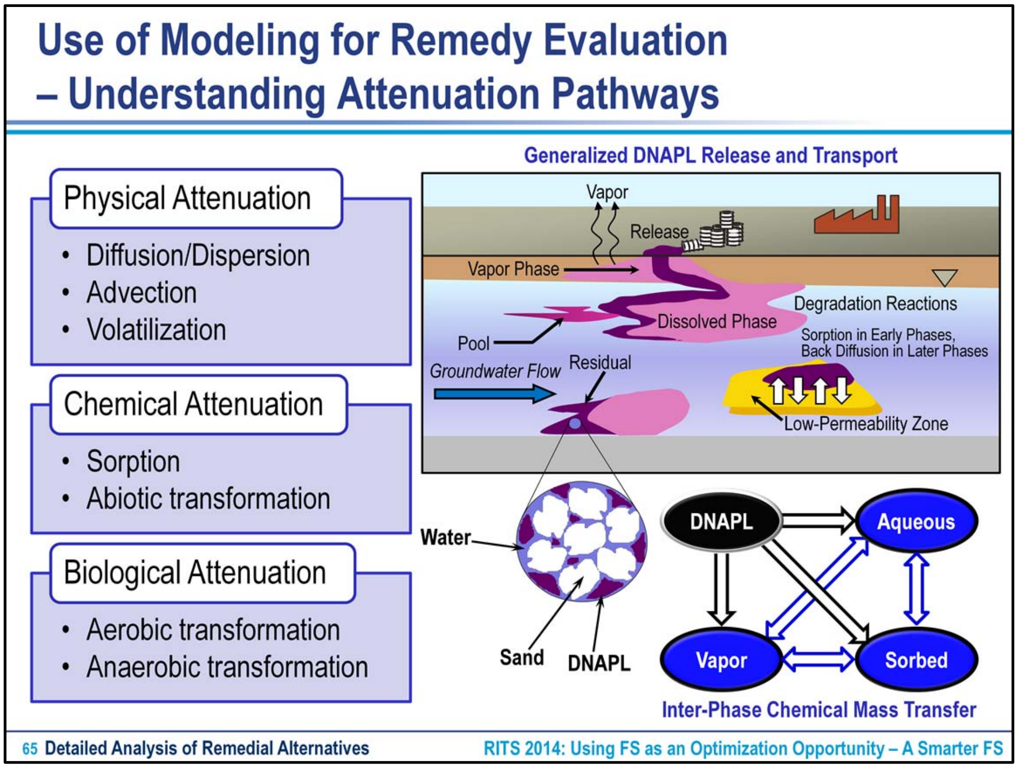


Models can help us evaluate remedies in several ways including:

- Allowing us to estimate the migration of COCs and determine the concentration at compliance point over time.
- Helping us evaluate the benefit of partial mass removal or containment and determine what impact that will have on timeframe and on COC migration.
- Helping us to estimate the remedial time frame so we can determine if the time frame for an alternative is reasonable, and if so, it helps us to better estimate the cost of implementing the remedy.



Understanding remediation time frames is extremely important when evaluating alternatives as the time frame can influence which alternatives to consider. It also allows you to understand the availability of land for reuse and controls land use decisions. It also impacts long-term protectiveness. Since remediation time frame is a key factor in selection of the preferred alternative, you need to place an appropriate level of effort on developing realistic estimates.



- All chemical phases as well as transport should be accounted for within the CSM.
  - Mass transfer – where is your mass? Note direction of movement out of DNAPL phase into aqueous, sorbed, and vapor phases.
  - Contaminant interactions with the subsurface are complicated
- Some of the processes can go both directions
  - This causes back diffusion where COCs go from aqueous to sorbed but then back to aqueous.

Use of Models for Alternatives Evaluation

- **Caution about evaluating model results**
  - **Not to be considered 100% accurate**
    - Approximate and only as good as the data entered
- **RPM to ensure model is used appropriately**
  - **Conduct calibration runs and sensitivity analysis to determine if assumptions on key parameters have large impact on result**
  - **Obtain site-specific data if necessary**
  - **Understand that models are great tools to evaluate cause-effect relationships and that results are approximate**
  - **Supplement evaluation with empirical trend analysis data**

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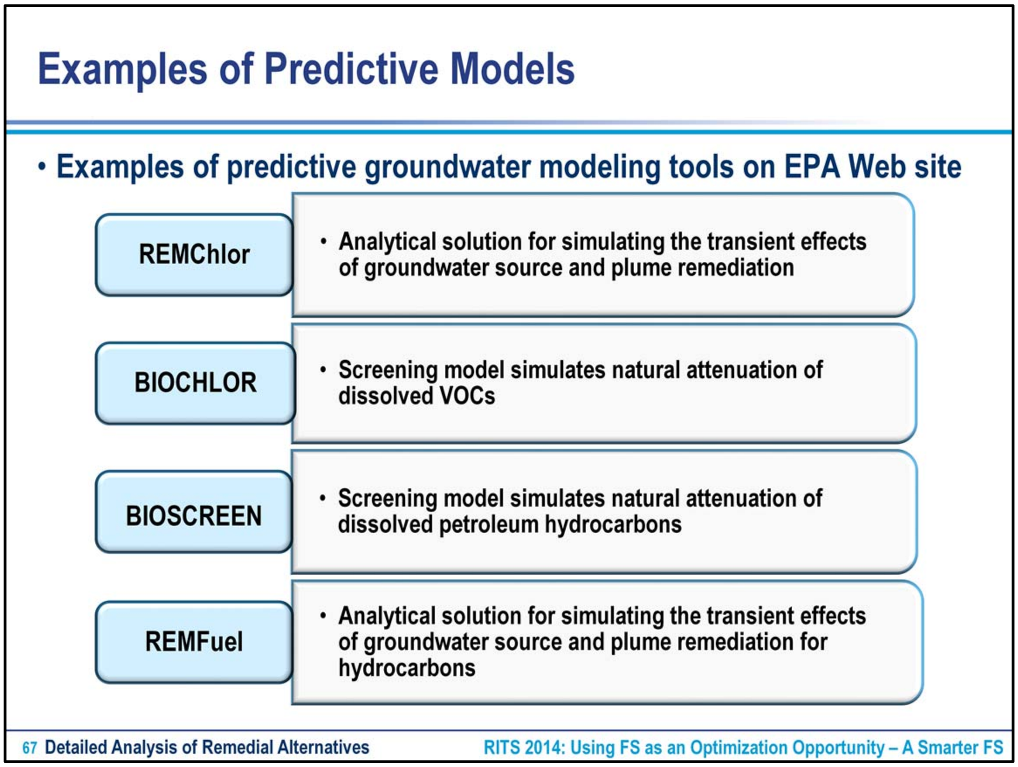
Understand that models are not 100% accurate so you need to account for uncertainties and use model results appropriately.

Best to have site specific data, use it to perform calibration runs with not only hydraulic data but also with MW data. Use the past trends to calibrate model and predict the future.

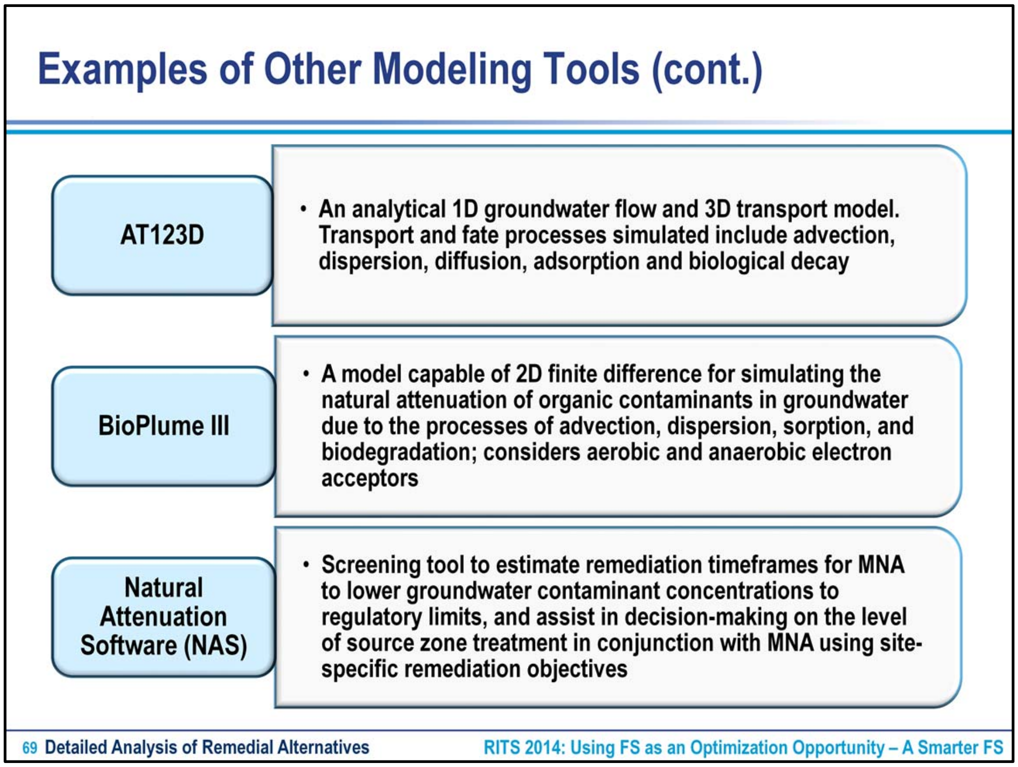


These predictive models are available for free on EPA web site. These are easier to use than many other tools and are good screening tools for groundwater.

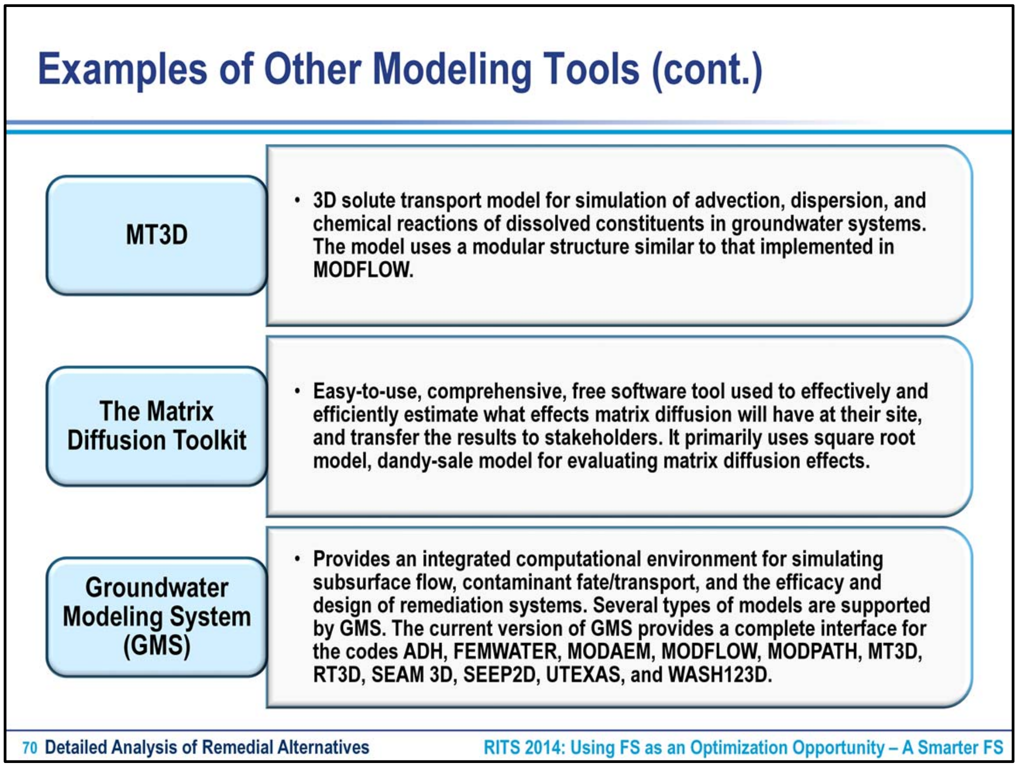
Examples of Other Modeling Tools

Tool	Description
NAPL Simulator	• Simulates the contamination of soils and aquifers that results from the release of NAPLs
VLEACH	• A one-dimensional, finite difference model for making preliminary assessments of the effects on groundwater from the leaching of volatile, sorbed contaminants through the vadose zone
SESOIL	• A one-dimensional vertical transport screening model that simulates unsaturated zone leaching of contaminants based on diffusion, adsorption, volatilization, biodegradation, cation exchange and hydrolysis
EMSOFT	• A model used to determine concentrations of contaminants remaining in the soil over a given time (when the initial soil concentration is known); to quantify the mass flux (rate of transfer) of contaminants into the atmosphere over time

These are tools for modeling other media. NAPL Simulator as the name indicates simulates the impact of NAPL releases on soil and groundwater. Other tools are used for modeling COCs in vadose zone soils.



These tools are a little more robust than some of the others and useful for evaluating natural attenuation processes.

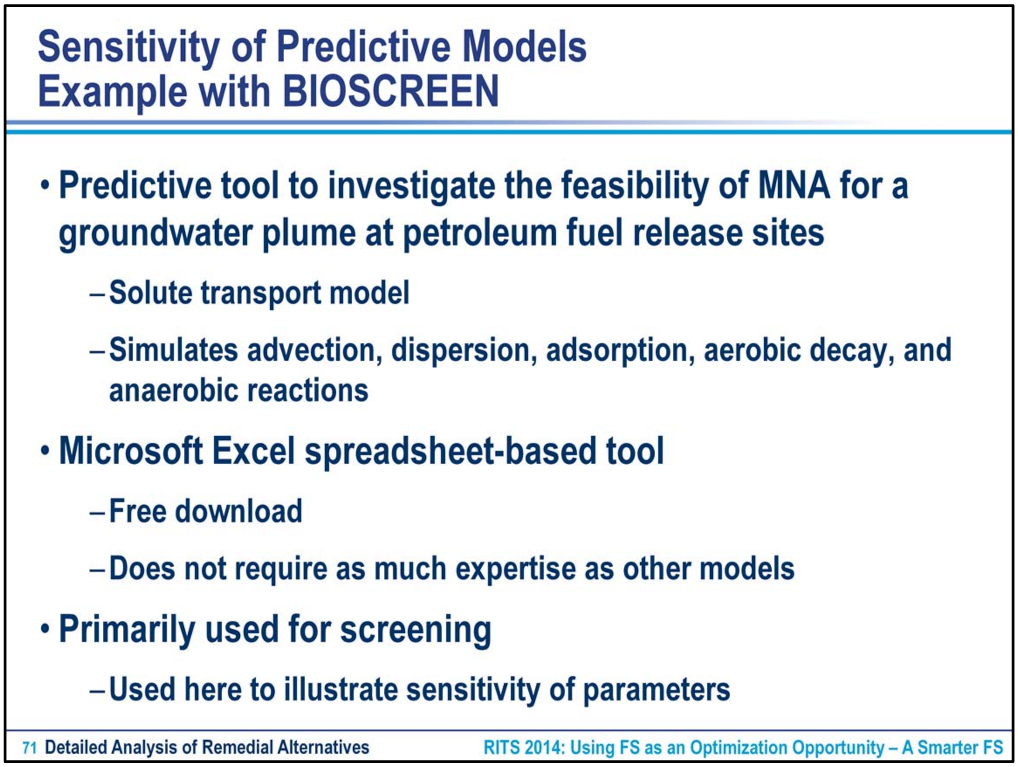


More robust tools for GW modeling.

Matrix Diffusion Toolkit

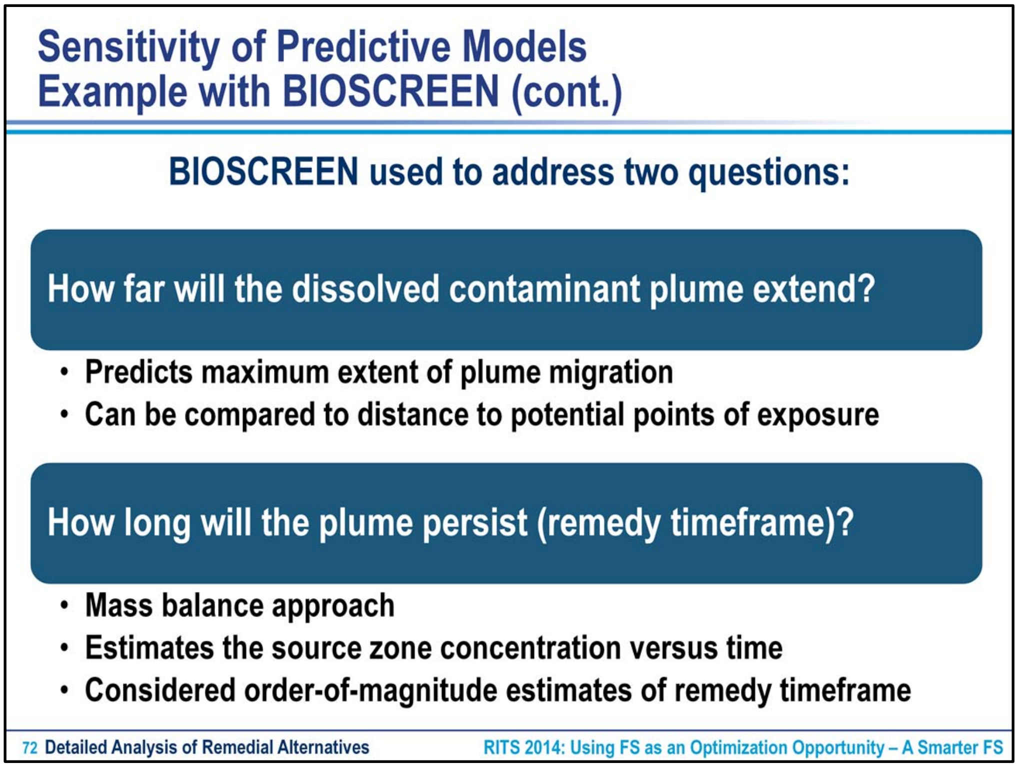
Contaminated groundwater sites can have heterogeneous geology with varied media such as interbedded clays and sands. This can result in a complex distribution of contaminants within the subsurface. As the groundwater plume is remediated, the low-permeability zones (*e.g.*, clays) can continue to serve as an indirect source of contamination via matrix diffusion. This occurs because contamination continues to emanate via diffusion from the stored contamination in the immobile porosity. This process can occur within the source zone or in the downgradient plume. The Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) has released a Matrix Diffusion Tool Kit to assess the impact of this process on a given site. The tool kit can be used to develop a conceptual site model and to determine if the matrix diffusion process would be expected to impact a given groundwater site. The Matrix Diffusion Tool Kit uses a simplified conceptual model of a two-layer aquifer system to estimate mass discharge in the transmissive zone and contaminant mass in the low-permeability zone. The User’s Guide and software can be downloaded at the link below.

Matrix Diffusion Tool Kit
http://www.serdp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201126



Showing example of one of the easier to use tools to demonstrate the sensitivity of inputs on the results and why calibration, sensitivity analysis are important and how this sometimes points to the need for additional data.

The model used for this demonstration is BIOSCREEN, a free, easy to use Excel-based tool.



BIOSCREEN can be used to address two primary questions:

How far will the dissolved contaminant plume extend?

- Predicts maximum extent of plume migration
- Can be compared to distance to potential points of exposure

How long will the plume persist (remedy timeframe)?

- Mass balance approach
- Estimates the source zone concentration versus time
- Considers order-of-magnitude estimates of remedy timeframe

Sensitivity of Predictive Models Example with BIOSCREEN (cont.)

- Investigate downgradient migration of TPH-G in groundwater
- Three TPH-G simulations
  - Varying partition coefficient (K_{oc})
  - Varying first order decay coefficient
  - The instantaneous reaction parameters remained constant for each simulation
- Demonstrates sensitivity of varying parameters
  - Requires site-specific data for improved results

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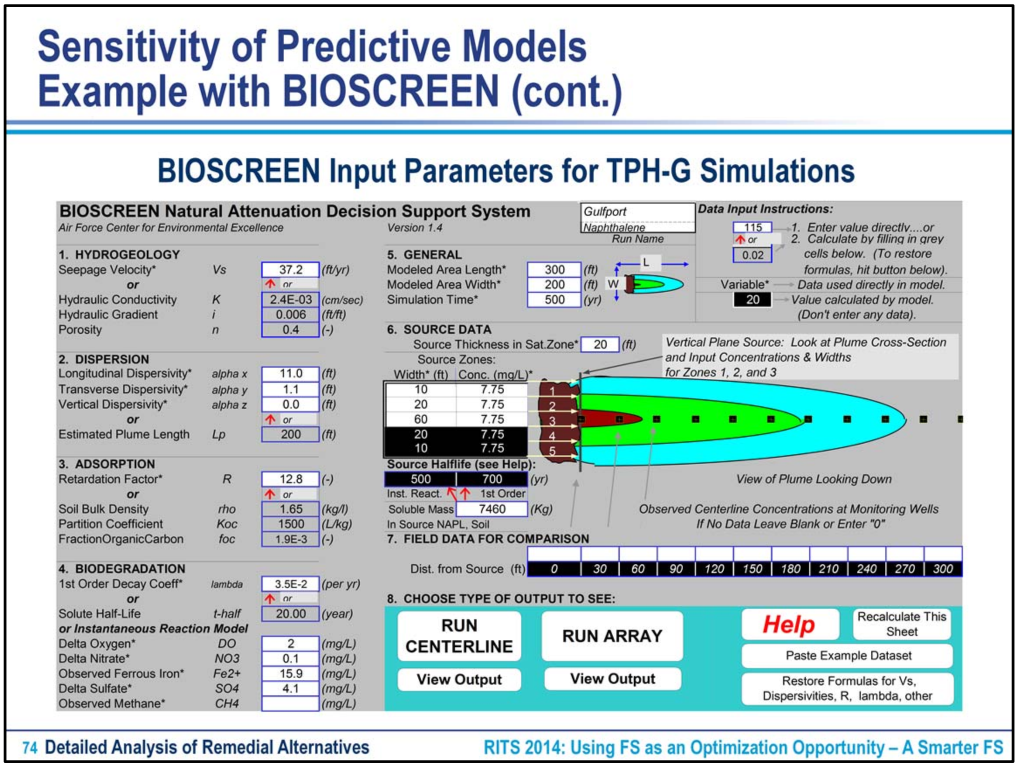
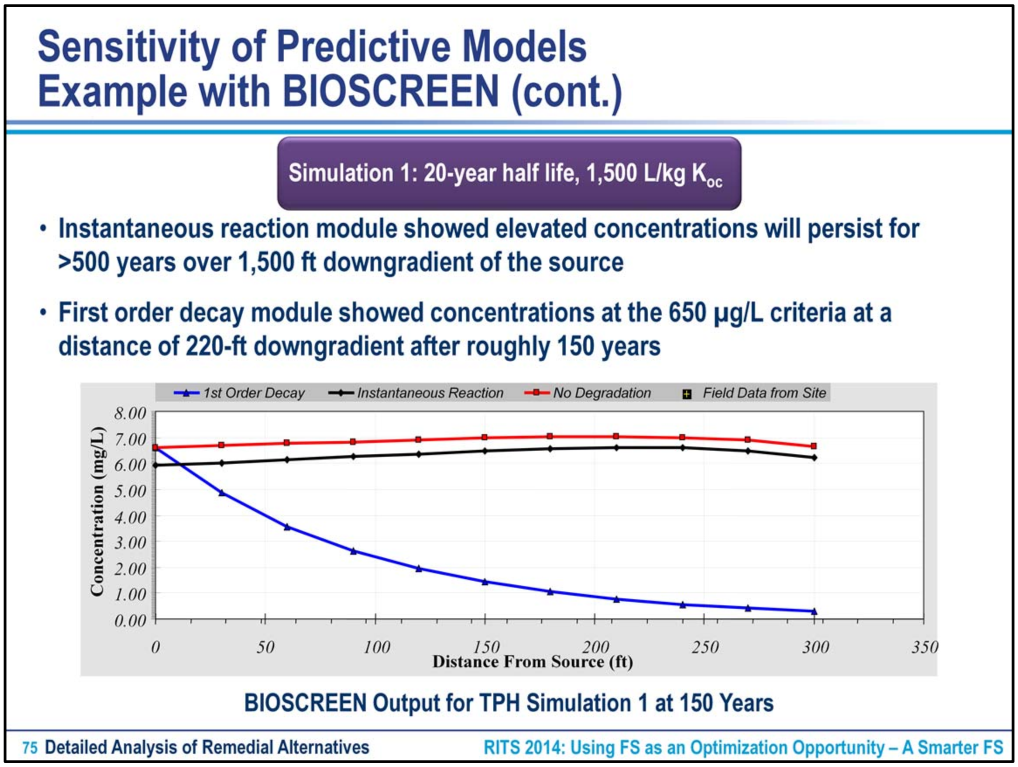
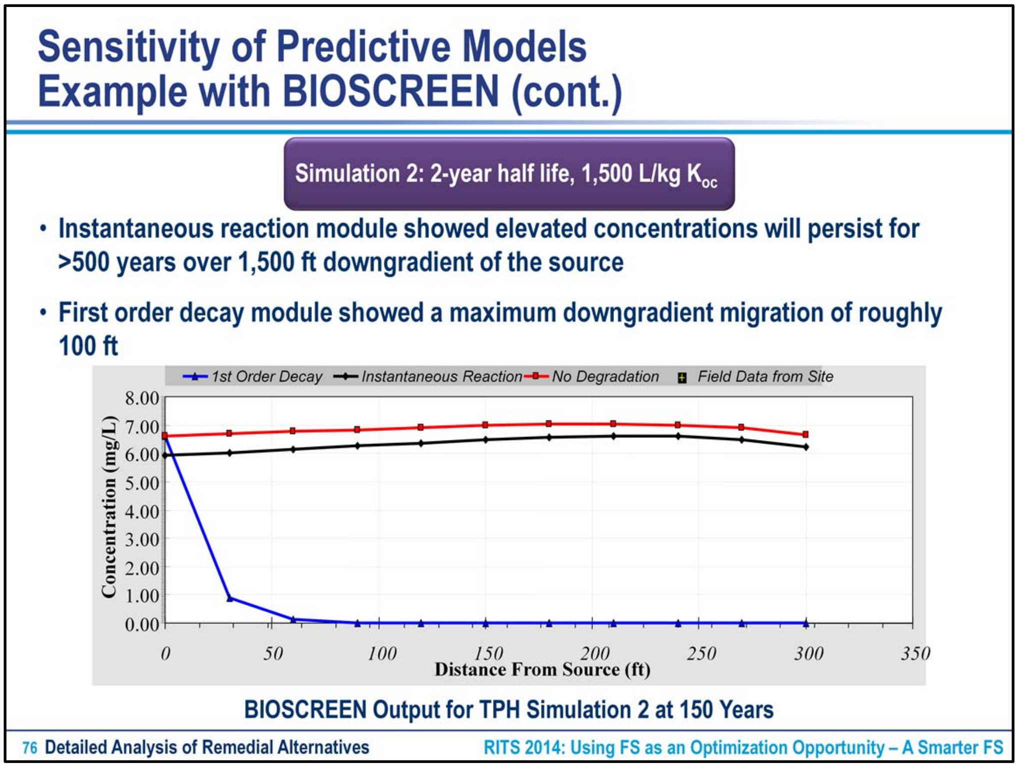
Example is to show the sensitivity to your inputs and how it is important to have site-specific data and perform calibration runs and sensitivity analysis because changes in your input data can have significant impact in your results.



Input screen for BIOSCREEN. You can input aquifer parameters including attenuation mechanisms.



20 year half life, 1500 L/Kg Koc. Focus on only the blue line because we are simulating first order decay. This plot is concentration versus distance to see how far the plume with migrate and you can see at 200 feet from the source, the concentration is still elevated at 650 ug/L

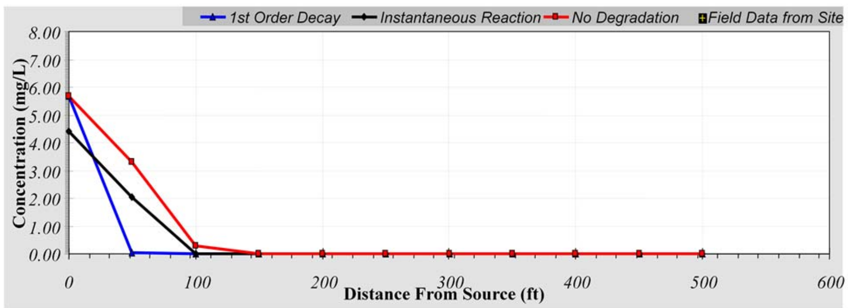


Half life was reduced to 2 years indicating faster decay rate and the result is much different showing the concentration decreasing much more rapidly and the plume not migrating very far.

Sensitivity of Predictive Models Example with BIOSCREEN (cont.)

Simulation 3: 20-year half life, 32,000 L/kg K_{oc}

- Instantaneous reaction module showed a maximum downgradient migration of roughly 100 ft
- First order decay module showed a maximum downgradient migration of roughly 50 ft



BIOSCREEN Output for TPH Simulation 3 at 300 Years

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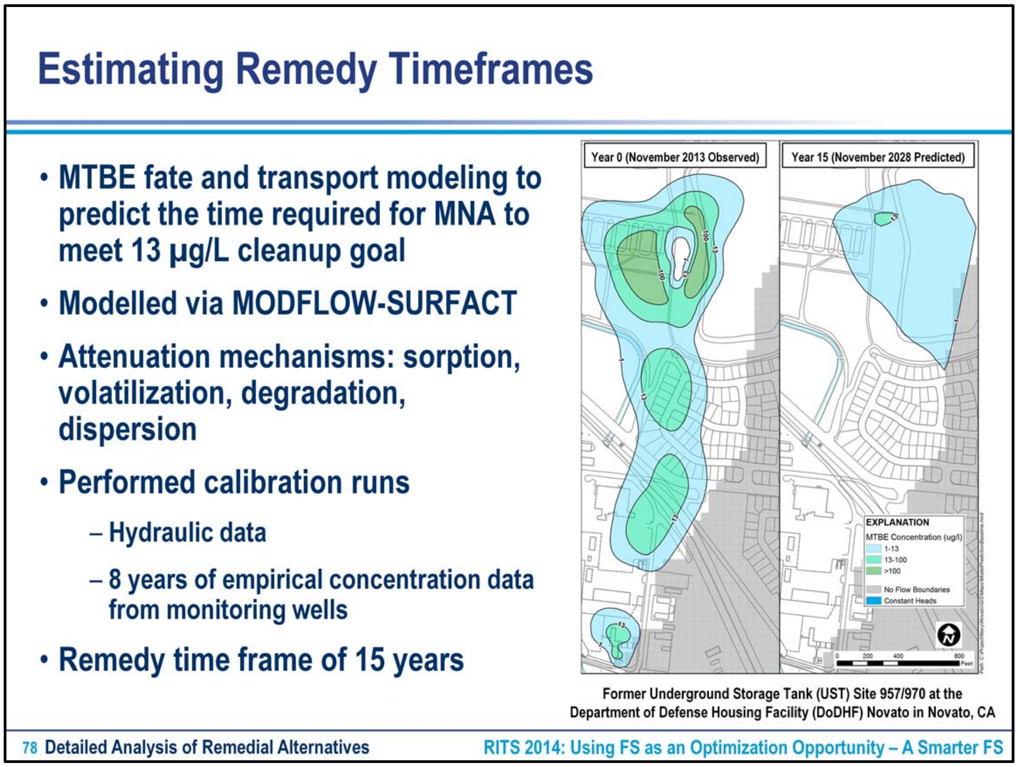
We put the half life back to 20 years but increased the Koc to 32,000 L/Kg and again this shows the concentration decreasing rapidly and plume not traveling far. This is to demonstrate how sensitive the results can be to your inputs and why you need to have site specific data for your analysis.



Here is an example of the use of MODFLOW-SURFACT to predict the time needed to meet the cleanup goal of 13 ug/L. What was nice about this application is that we had 8 years of MS data that could be used for calibration runs. Refer to figure showing current condition on left and the plume in 15 years on the right. This indicated that the cleanup level will be achieved in 15 years.

Estimating MNA Timeframe

- EPA document – "An Approach for Evaluating the Progress of Natural Attenuation in Groundwater" – December 2011
- Use the available monitoring data for trend analysis
- Analysis provides general timeframe for when concentrations can be expected to meet remediation goals
- Analysis requires sufficient data to show temporal trends in COC concentrations
- Apply regression analysis technique for trend analysis
- Use NAVFAC Management and Monitoring Approach format to present trend analysis and as a platform to document progress towards Response Complete and supporting optimization recommendations

EPA recommended approach is to use empirical data and perform trend analysis.

The MMA provides the format for annual reporting. It defines the monitoring and follow on results. The format suggests including information such as the RAOs and decisions so that the data trends can be used to ensure the goals of the ROD are being met and we are documenting progress towards completing actions at the site. The reporting of this information is tailored to meet the five year reviews, and if changes to the remedy/approved LTM program are necessary, the MMA report can serve as the SAP to document/approve these modifications.

If you are following the MMA, the data may be available in the MMA report.

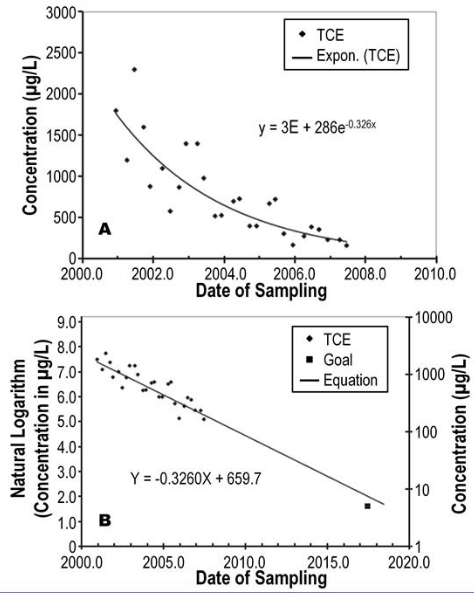
Put the above in context of an FS development.

Estimating MNA Timeframe (cont.)

- **First order rate law**
- **Example – from equation of the line in figure B**
  - **X = (Y - 659.7)/(-0.3260)**
  - **TCE RG mcl = 5 µg/L**
  - **Y = LN (5) = 1.609; X = 2018.7**

RG completion in September 2018

- **If the visual examination of the LN plot (figure B) shows a curved line**
  - **The rate is changing over time, or the rate does not follow the first order**
  - **Don't use this approach to forecast time to reach RG**



This shows an example using the trend analysis approach. This approach assumes that concentration changes follow a first order rate law. If you plot concentration versus time you will see a curve like what is shown in the upper right figure but if you plot concentration logarithmically, you would get a straight line that can be extrapolated. If the points still follow a curved line, then this method cannot be used.

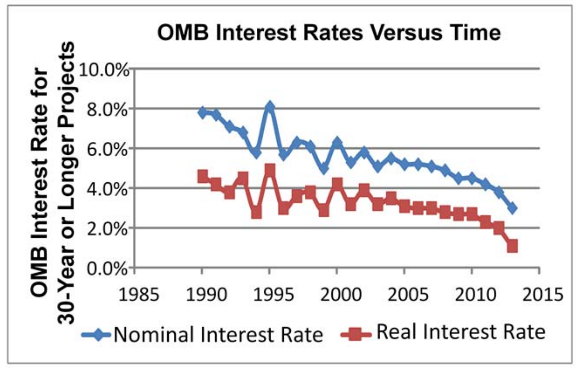
Cost Estimating

- NPV costs developed in FS are used for comparing alternatives
- Both selection of interest rate and estimate of cleanup time impacts cost estimate
- Interest rate is used to calculate present value from future cost

$$P = F * \frac{1}{(1+i)^n}$$

Where,

- P = present value
- F = future cost
- i = interest rate
- n = number of years in future



Interest Rates from Office of Management and Budget (OMB) Circular A-94 Appendix C

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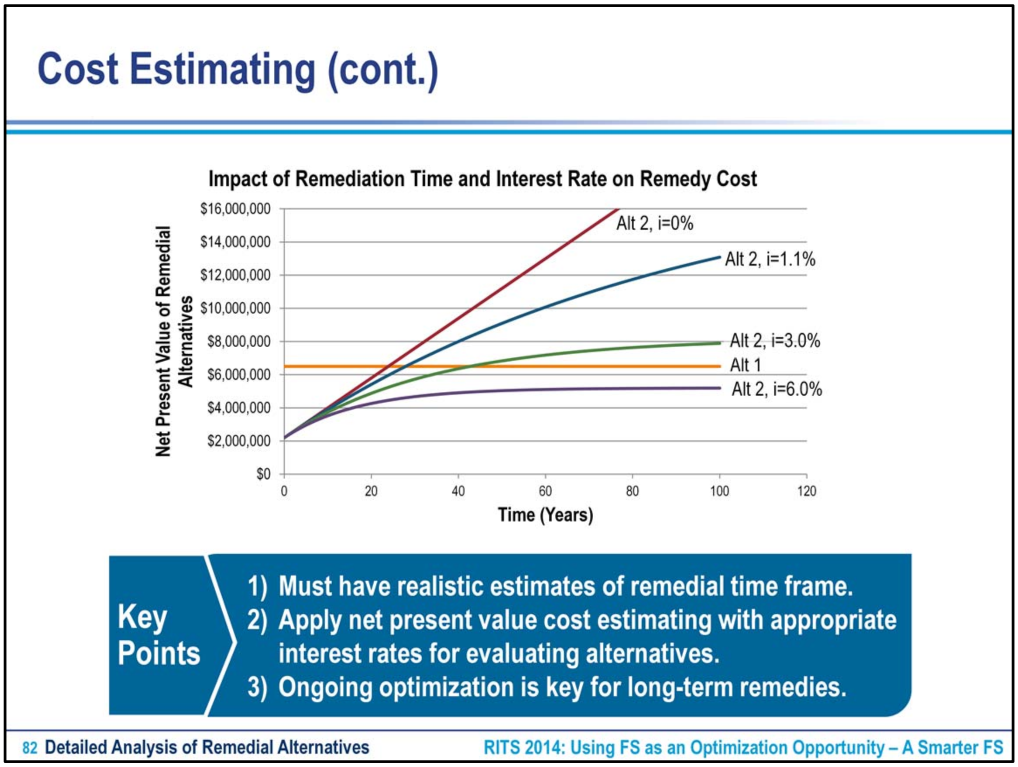
For comparing remedies in FS, you need to calculate the NPV by discounting future costs using an appropriate discount rate from OMB. There are two rates shown. The real rate is lower and that is used for costs that are expected to escalate over time but you are using today's cost in all calculations. The higher nominal rate is used for cases where you have a fixed cost (e.g. a contract where you will pay the same cost each year). Note how the interest rates are currently very low and have dropped significantly over the last several years. This can impact the results of the cost comparison because alternatives that have costs which run way out into the future will be less cost effective when interest rates are low because future costs are not discounted as much. It is possible that you could have done a cost analysis five years ago and determined that a particular remedy is most cost effective, but if you repeated that analysis using today's lower interest rate, you could get a different result.



This is illustrating how the selection of the discount rate impacts the cost analysis. This is comparing two alternatives, the first only has a capital cost (just over $6M) but the second has a $2M capital cost and then annual costs well into the future. At the 6% interest rate, Alt 2 is more cost effective but as the rate decreases, it becomes less cost effective.

Be clear that we apply the same interest rate for all options being evaluated in the FS

Cost Estimating (cont.)

- Non-discounted yearly cost in current year dollars is to be entered in NORM
  - FS cost estimates should include this cost
- Accuracy is understood to be -30/+50%
- For remedial time frames exceeding 30 years:
  - For sites that require monitoring actions in perpetuity, use 30-year rolling timeframe, with an “in perpetuity” box checked
  - If closeout date is known, year 30 cost is to include the cost for the remaining years

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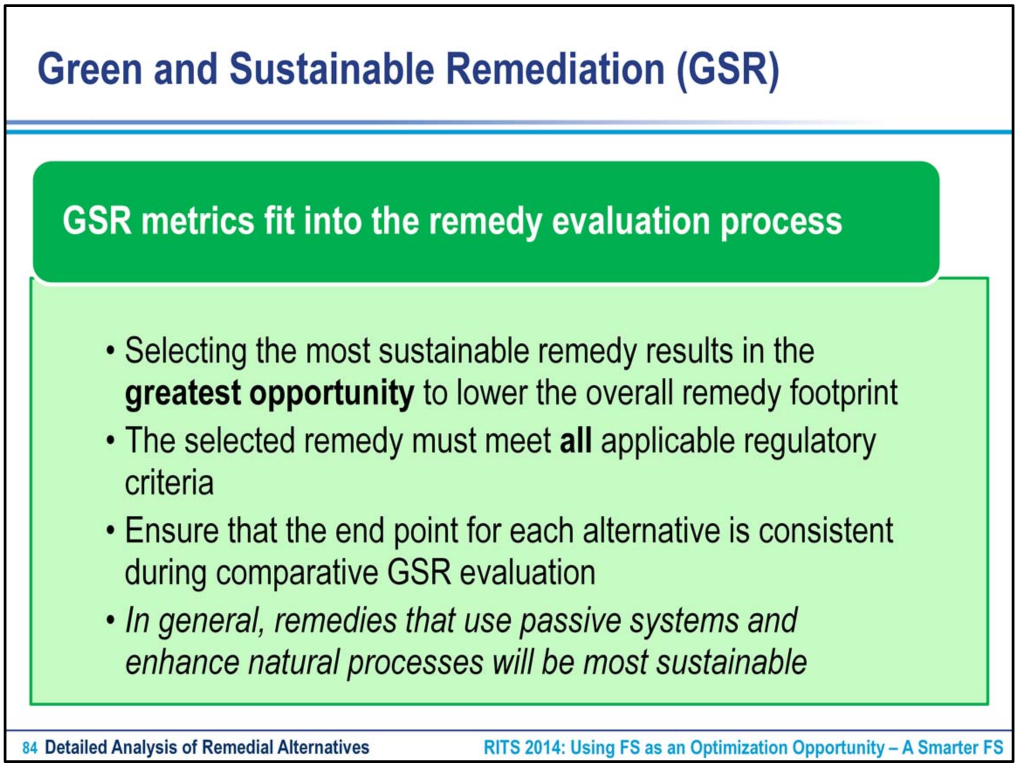
The cost of preferred alternative from the FS is typically used for budgeting purpose in NORM which then support the total ER,N budget submitted to Congress.

As a result, there is a need to present both total cost (not discounted/actual) and NPV. The purpose of NPV is for allowing the plain-level alternatives comparative evaluation.

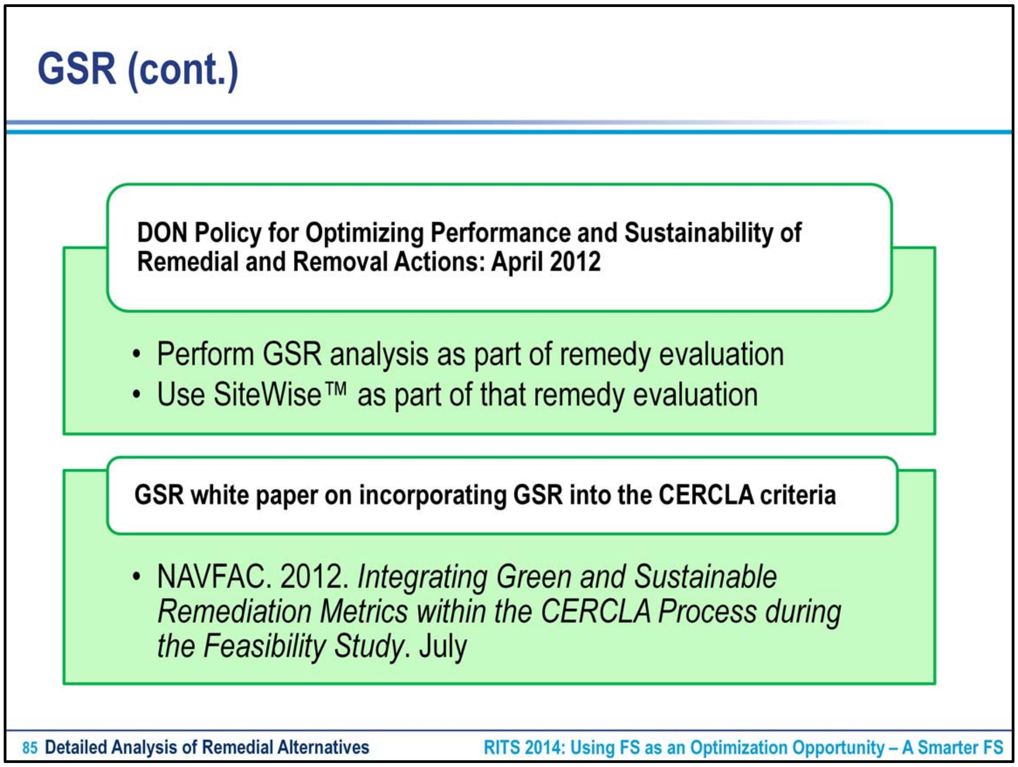
The remediation time frame plays a significant role in estimating the actual cost since there is no discounting.

Budgeting process: Phase 5-5, feed into DERP, feed into liability



Similar to getting most benefit in cost reduction in the FS, you get most benefit in sustainability when done in FS.

Also similar to cost we see that in general passive technologies that enhance natural processes tend to be more sustainable than aggressive technologies, although aggressive technologies that are used in smaller source zone areas can increase the sustainability of the remedy. We tend to see that remedies that have least cost also tend to be more sustainable although this is not always the case.



Required per policy to perform GSR analysis as part of remedy evaluation and you must use SiteWise although you can use other tools to supplement it. A Navy white paper was developed that specifically addresses the question of how to incorporate GSR into the CERCLA nine criteria of the FS.

Evaluating GSR Metrics with CERCLA Criteria

SUSTAINABILITY METRICS	BALANCING CRITERIA					MODIFYING CRITERIA	
	LONG-TERM EFFECTIVENESS	REDUCTION IN TOXICITY, MOBILITY, OR VOLUME	SHORT-TERM EFFECTIVENESS	IMPLEMENTABILITY	COST	STATE ACCEPTANCE	COMMUNITY ACCEPTANCE
Energy Consumption			X		X	X	X
GHG Emissions	X		X			X	X
Criteria Pollutant Emissions	X		X			X	X
Water Impacts/Use	X		X		X	X	X
Ecological Impacts	X		X			X	X
Resource Consumption	X		X		X	X	X
Worker Safety			X		X	X	X
Community Impacts			X			X	X

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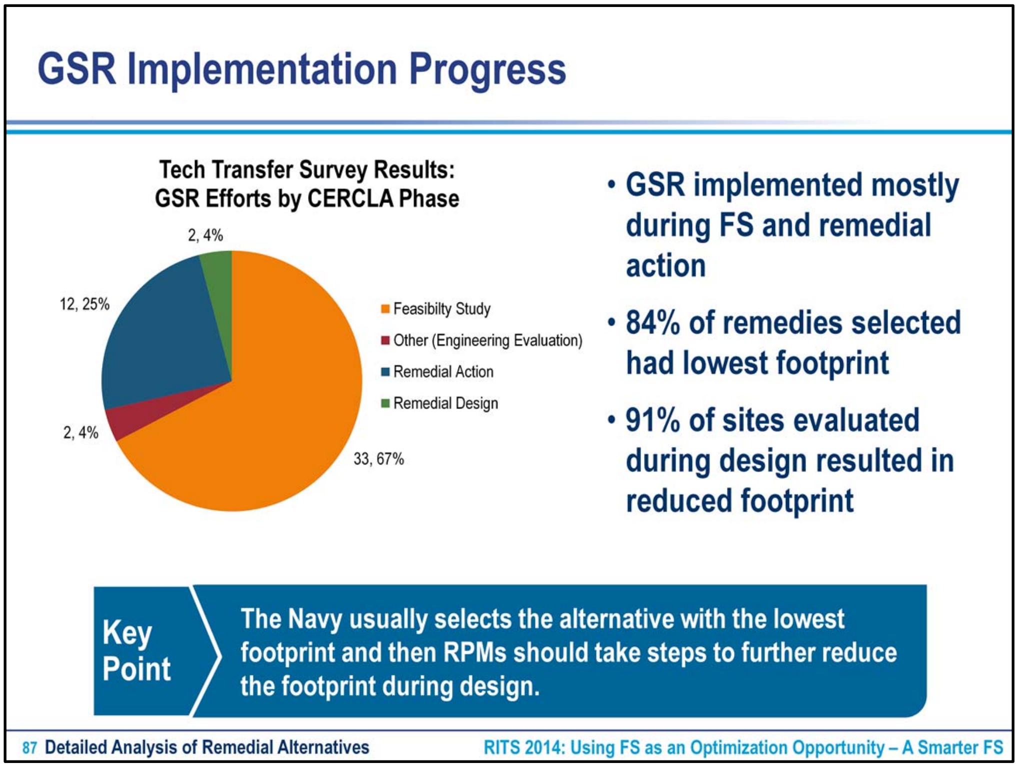
This chart is in the white paper and it maps the Navy's sustainability metrics to the CERCLA 9 criteria. Of the nine criteria, short-term effectiveness matches most closely to GSR because short term effectiveness addresses the impacts of remedy implementation. Note that this evaluation is not technology specific, but site location can impact weight of metric. For a remote site, weighting of criteria pollutants and community impacts is less than for a site in a residential area.

There is more detailed information about how to incorporate GSR into the FS study in the white paper.



Among those sites where a remedy was selected, the results show that 84% of the GSR evaluations resulted in the selection of the lowest footprint remedy and 69% resulted in the selection of the lowest cost remedy. These results suggest that the GSR evaluation process is in fact leading to the selection of more sustainable and cost-effective remedies at Navy sites as originally envisioned.

No. of case studies where GSR was implemented in RD/RA = 14

Among 14 case studies, no. of case studies with not enough info available = 3

No. of case studies (out of 11) where footprint reduction was implemented during the RD/RA phase= 10 (91%)

Independent Optimization Review of Draft FS

- Implemented at time of internal draft FS prior to regulatory submittal
- Detailed review of alternatives performed to ensure optimum remedy implementation
- DON Optimization Policy (2012): all alternatives carried forward to detailed evaluation must be optimized in accordance with DON Guidance for Optimizing Remedy Evaluation, Selection and Design (2010) and a SiteWise™ GSR analysis conducted
  - Identifies requirements for CSM, RAOs, TTZs, treatment trains, performance objectives and exit strategies

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In addition to incorporating optimization throughout the process and during the RAA, an independent optimization review of the draft FS is required per Navy policy. This will allow the optimization team to perform a detailed review of the alternatives evaluated.

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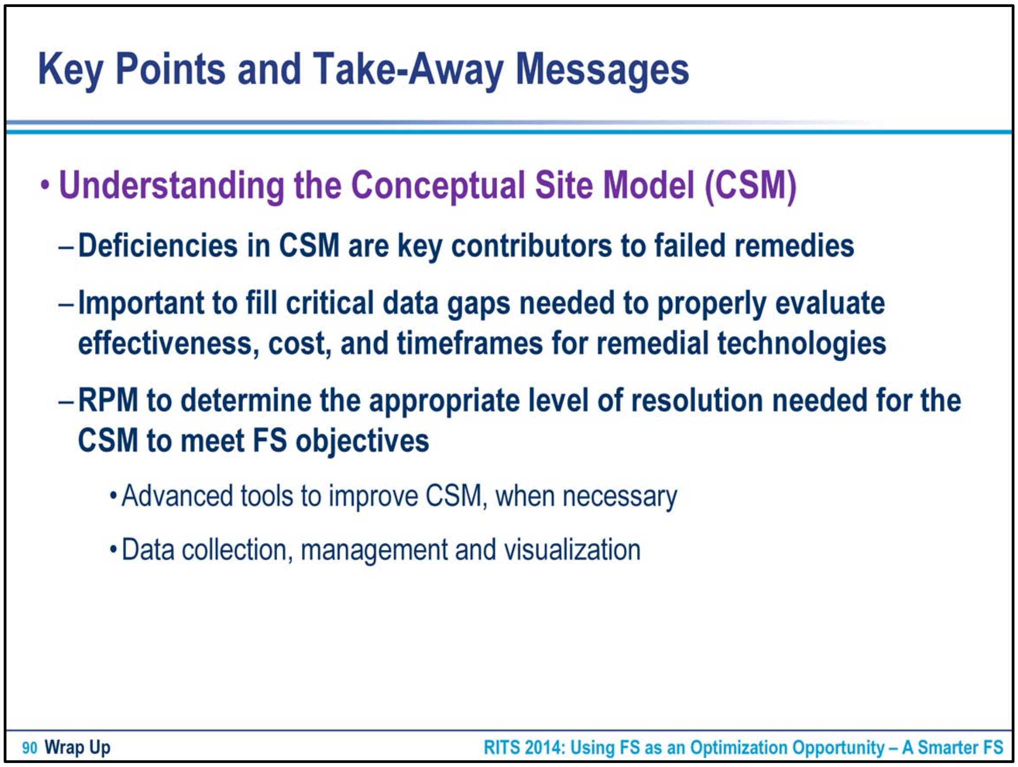
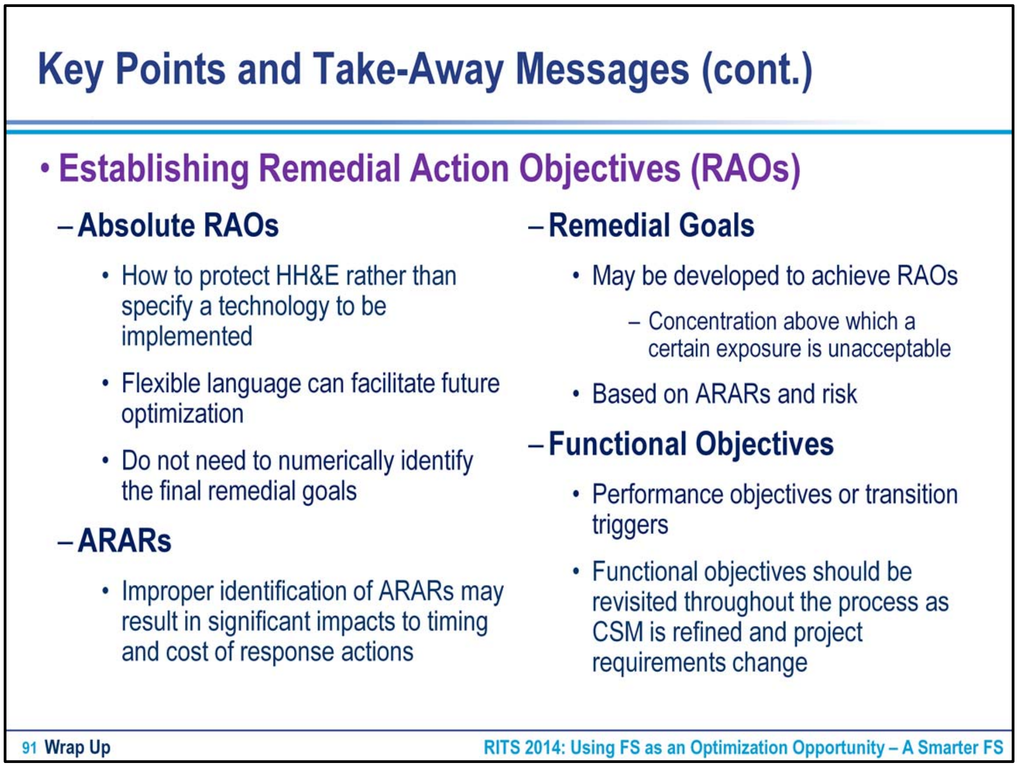


Deficiencies in CSM is most common cause of remedy failure

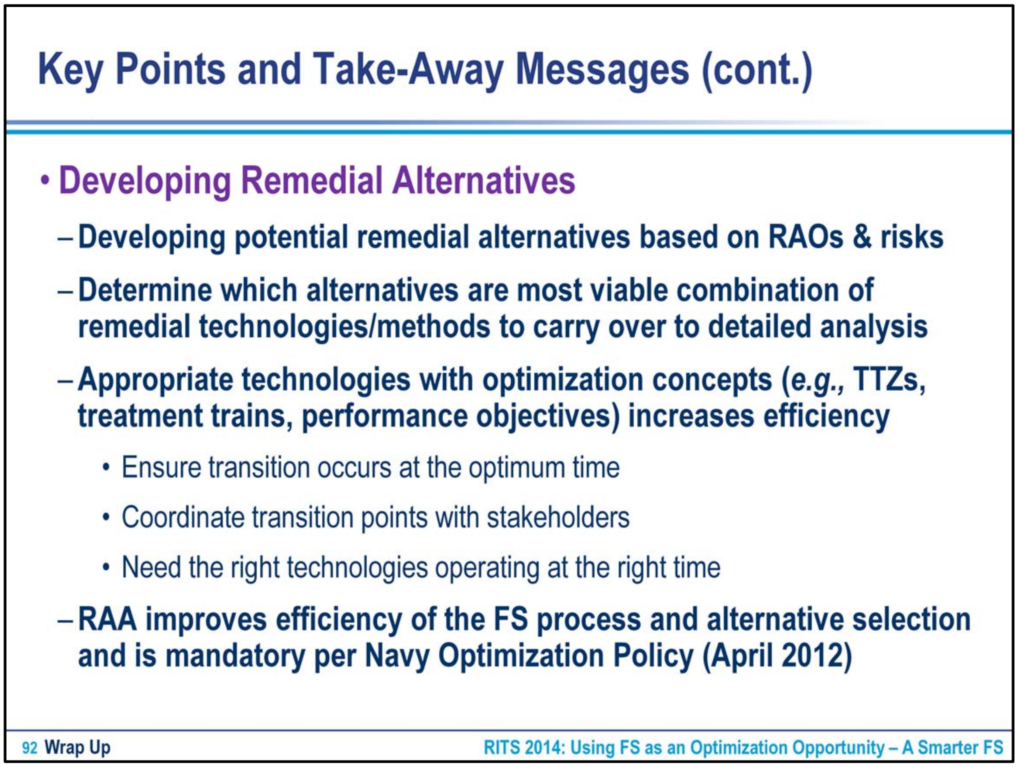
A CSM that was adequate for a RI may not be adequate for FS because additional data may be needed to evaluate the remedial alternatives



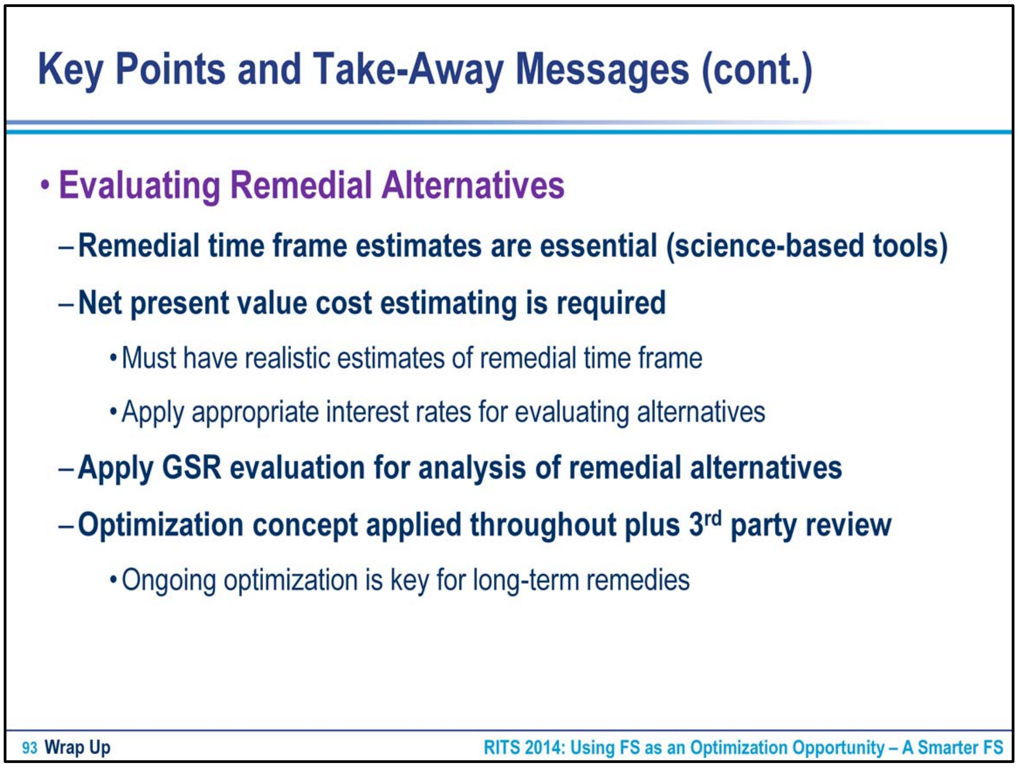
Absolute RAOs need to be flexible enough to allow future optimization.

Be careful in selecting relevant and appropriate ARARs because once an ARAR in an executed ROD, it is legally binding. Be careful in citing ARARs and be specific in the citation so as to not cause requirements of a broad regulation to become a requirement.

Functional objectives can be used as transition triggers to ensure that the optimum technology is used at the optimum time.



For complex sites, need multiple technologies to be efficient and need to be creative in the use of TTZs, treatment trains, and transition triggers to optimize the remedy.



For evaluating the alternatives, it is critically important to estimate remedial time frame. Apply science-based tools to support this evaluation using site specific data for inputs and calibration.