Green and Sustainable Remediation (GSR)

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Before We Get Started…

GSR Overview

Presentation #1

Using SiteWise™

Presentation #2

All images courtesy U.S. Navy

Before We Get Started…

Optimization Workgroup is tasked with promoting and developing Navy's GSR approach and guidance

WE ARE HERE TO HELP!

Presentation Overview

- Defining Green and Sustainable Remediation (GSR)
- Policy, Guidance, and Standards
- Application
- Cost of Implementation
- Benefits and Challenges
- Case Studies
- Summary and Conclusions

Environmental Footprint

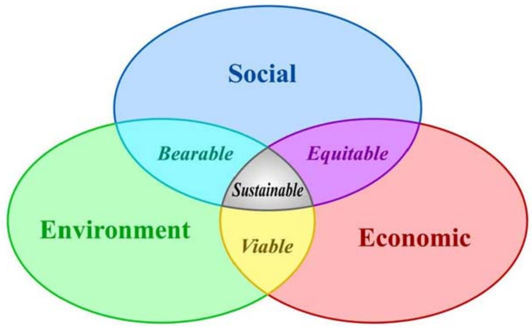
-Impacts to environmental media and society resulting from an action

-We are focusing on footprint of soil, sediment, and groundwater remedies

-Think about extending the concept of carbon footprinting to other parameters

ITRC Definition of GSR

- "Green and sustainable remediation is a spectrum standard for site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects" *(Working draft definition of ITRC GSR team, 2009)*



EPA Definition of Green Remediation

- Consider all environmental effects of remedy implementation and incorporate options to minimize the environmental footprints of a cleanup

From: www.cluin.org/greenremediation/

- EPA prefers "Green Remediation" terminology rather than "Green and Sustainable Remediation"
- EPA excludes some parameters that Navy includes
  - Discussed a few slides from now

Important GSR Practices & Strategies

- **Practices & Strategies identified in the GSR Fact Sheet include:**
  - Energy Consumption
  - Greenhouse Gas (GHG) Emissions
  - Criteria Pollutant Emissions
  - Water Impacts
  - Ecological Impacts
  - Resource Consumption
  - Worker Safety
  - Community Impacts
  - Other Social/Economic Aspects

GHG Focus for Remedies

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)

Criteria Pollutant Focus for Remedies

- Sulfur Oxides (SO_x)
- Nitrogen Oxides (NO_x)
- Particulate Matter (PM)

Environmental Impacts Include:

- Health effects
- Acid rain
- Ground level ozone
- Haze

Simple Real-Life Sustainability Example

- What is the more environmentally friendly method of drying your hands after using a public restroom?
  - Drip dry? (i.e., the "no-action" alternative)
  - Paper towels?
  - Hand air dryers?
- One approach is to conduct a Life-Cycle Assessment (LCA)
  - Detailed approach to evaluating "cradle to grave" environmental impacts
  - Typically applied to product manufacturing
  - Typically conducted with proprietary software
  - Governed by ISO (International Organization for Standardization) Standards

Navy, DoD, and EPA approaches to GSR were derived from LCA analysis but are more streamlined

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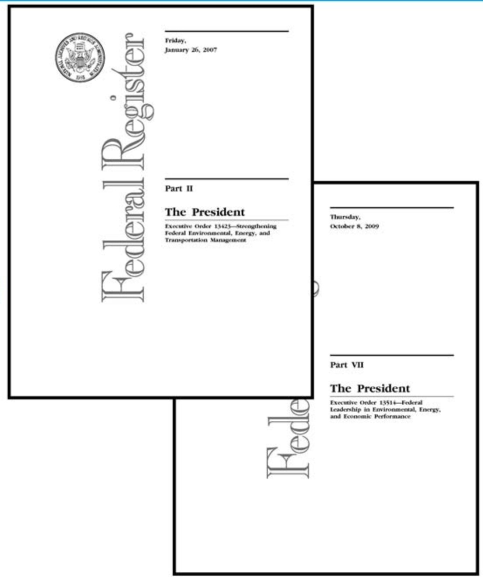
Executive Orders

- **Executive Orders 13423 & 13514**
  - Mandate all federal agencies to conduct their environmental, transportation, and energy activities in an environmentally, economically, fiscally sound, integrated, continuously improving, efficient, and sustainable manner and create a "clean energy economy."



DoD Memorandum on GSR (August, 2009)

- Implementation of EO 13423 was the genesis for this memo
- Requests GSR opportunities be evaluated and considered for implementation throughout all phases of remediation
  - Site investigation
  - Remedy evaluation
  - Design & construction
  - Operation, monitoring, and site closeout
- It is not DoD policy to re-open decision documents for GSR
- Remedy selection criteria the same, but may include sustainability considerations
- Navy GSR briefings to Office of Undersecretary of Defense (December 2009 and Jun 2010)

More Navy Drivers for GSR

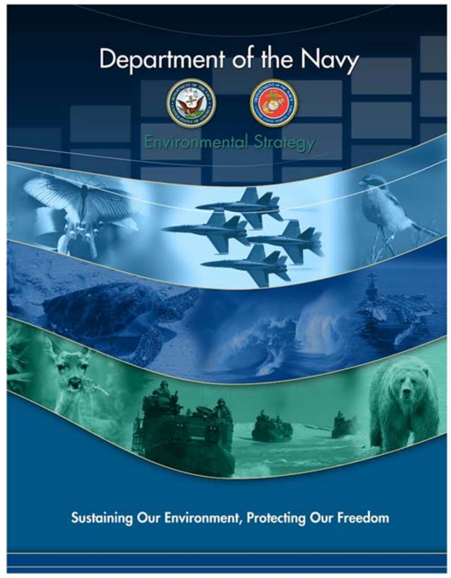
- **Sustainability Vision as defined by the Navy's Environmental Strategy:**

  "Environmental stewardship protects and preserves the mission capabilities of our installations and training areas, ensures operational flexibility by meeting environmental laws and regulations, and sustains the resources and public support needed to carry out the mission. The environment must be considered before, during, and after the operations we undertake as part of our National Defense mission."

  Department of the Navy Environmental Strategy: "Sustaining our Environment, Protecting our Freedom"

  The Office of Assistant Secretary of the Navy [Installations and Environment]

  April 22, 2008



Navy GSR Guidance

- Optimization Workgroup tasked to develop and promote Navy's GSR approach, implementation, and information
  - Developing guidance due for release in 2010
- GSR emphasized in NAVFAC Technology Transfer Plan for Environmental Restoration 2010 – 2014
  - "Incorporating Optimization and Sustainable Environmental Remediation Practices" is one of the top 8 technical challenges
- Working with other Federal partners, state regulators, and industry through FRTR, ITRC, SuRF, & ASTM
- Full compliance with the National Contingency Plan and CERCLA

Navy GSR Guidance

- GSR Fact Sheet
  - Introduction – What, Why, How
  - Sustainability metrics
  - Footprint assessment methodology
  - Incorporating GSR into the environmental restoration process
  - Footprint reduction methods

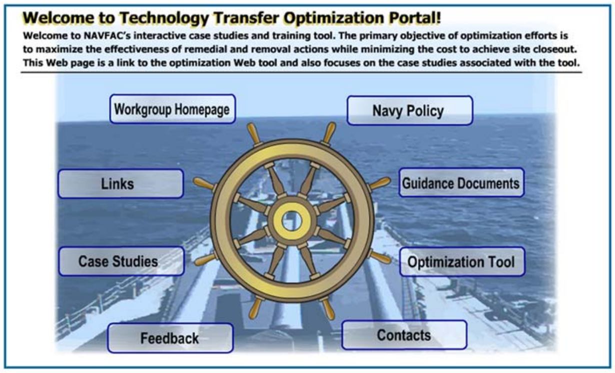
See
GSR Fact Sheet
Handout

Navy GSR Guidance

- GSR Web portal
  - Educational Web tool
  - Fact sheet
  - Case studies
  - Drivers
  - Resources
  - Tools (e.g., SiteWise™)
  - Contacts

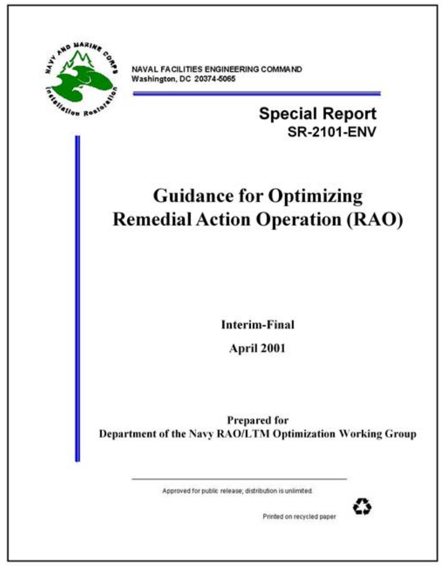
Navy GSR Guidance

- Navy optimization guidance updates to include GSR principles
  - Guidance for Optimizing Remedy Evaluation, Selection, and Design (March 2010)
  - Guidance for Optimizing Remedial Action Operations (planned)



Navy GSR Guidance

- The Navy released the Interim Final Guidance for Optimizing Remedial Action Operations in April 2001, introducing some sustainability-related ideas before it was in vogue:
  - Life-cycle design (LCD)
  - Balance of economic and environmental factors
- Think of Optimization as the nourishment for the seed of Sustainability (i.e., GSR)


NAVAL FACILITIES ENGINEERING COMMAND
Washington, DC 20374-5065

Special Report
SR-2101-ENV

Guidance for Optimizing Remedial Action Operation (RAO)

Interim-Final
April 2001

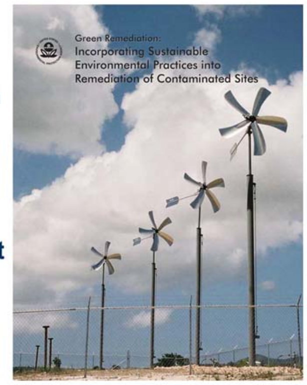
Prepared for
Department of the Navy RAO/LTM Optimization Working Group

Approved for public release; distribution is unlimited.

Printed on recycled paper

EPA Policy and Guidance

- EPA releases Green Remediation Primer (April, 2008)
  - Focuses on minimizing environmental footprints
  - Does not address social & economic impacts of remediation
- "Superfund Green Remediation Strategy" (August, 2009)
- "Principles for Greener Cleanups" (August, 2009)
  - Cleanups/footprint reduction to occur in a manner consistent with statutes/regulations governing EPA cleanup programs without compromising:
    - Cleanup objectives
    - Community interests
    - Reasonableness of cleanup timeframes
    - Protectiveness of the cleanup actions



- Working on voluntary standard and verification program for green remediation with ASTM, Navy, and others

U.S. EPA Policy and Guidance: By Region

- Many EPA Regions have adapted region-specific policies
  - Region 1: Clean and Green Policy for Contaminated Sites (2/10)
  - Region 2: Clean and Green Policy (3/09)
  - Region 3: Greener Cleanup and Sustainable Reuse Policy (1/10)
  - Region 4: Clean and Green Policy (2/10)
  - Region 5: Greener Cleanup Interim Policy (11/09)
  - Region 7: Interim Green Cleanup Policy (9/09)
  - Region 9: Green Site Cleanups (9/09)
  - Region 10: Clean and Green Policy (8/09)

Overlap of GSR and Existing CERCLA Process

GSR already fits into the CERCLA remedy selection process

CERCLA 9

- Overall protection of human health and the environment
- Compliance w/ARARs
- Long-term reliability
- Reduction of toxicity, mobility or volume
- Short-term effectiveness
- Ease of implementation
- Cost
- Community acceptance
- State acceptance

Green Cleanup Goals

Greenhouse Gases & Energy

- Minimize ancillary impacts such as CO_2 emissions to the air
- Minimize total energy use and promote use of renewable energy

Resource Conservation

- Preserve natural resources
- Maximize the recycling of material
- Maximize reuse options for land

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Transition from Tom Spriggs to Doug Sutton or Rob Greenwald.

RPM Perspective – When Do I Perform GSR?

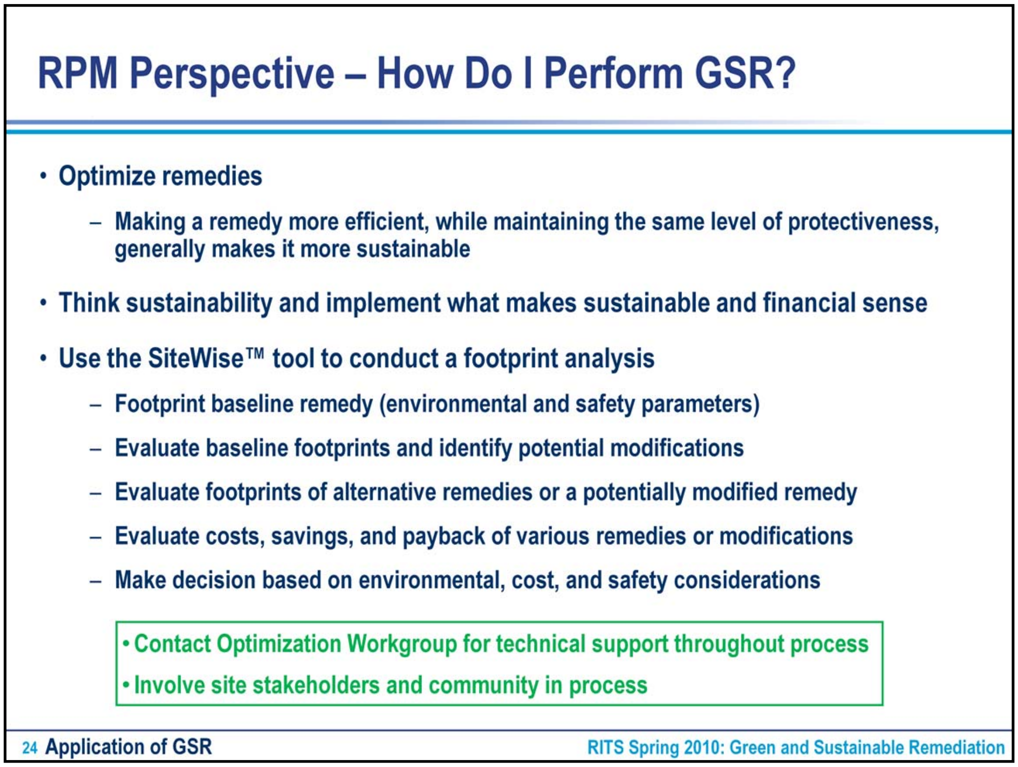
- Remedy Selection
  - Link GSR effort with Feasibility Study
  - Integrate GSR into development and evaluation of alternatives, in context of existing CERCLA criteria
- Remedial Design
  - Use GSR information from Remedy Selection stage and link with Remedial Design effort
  - Remedial Design should optimize or reduce environmental footprints
- Remedial Operation
  - Integrate sustainability practices (GSR) into optimization efforts

Conduct GSR in association with other remedial efforts
to streamline process and avoid duplication of effort

There are several benefits to performing GSR evaluations in conjunction with other specific remedial activities:

1) The GSR process is greatly streamlined if you are already collecting the pertinent information anyway. For example, much of the information that is needed for a GSR evaluation is collected as part of a feasibility study, remedial design, or optimization evaluation. It saves effort to link GSR evaluations with these other activities.

2) The feasibility study, remedial design, and optimization evaluations can benefit from the insight gained from conducting a GSR evaluation.

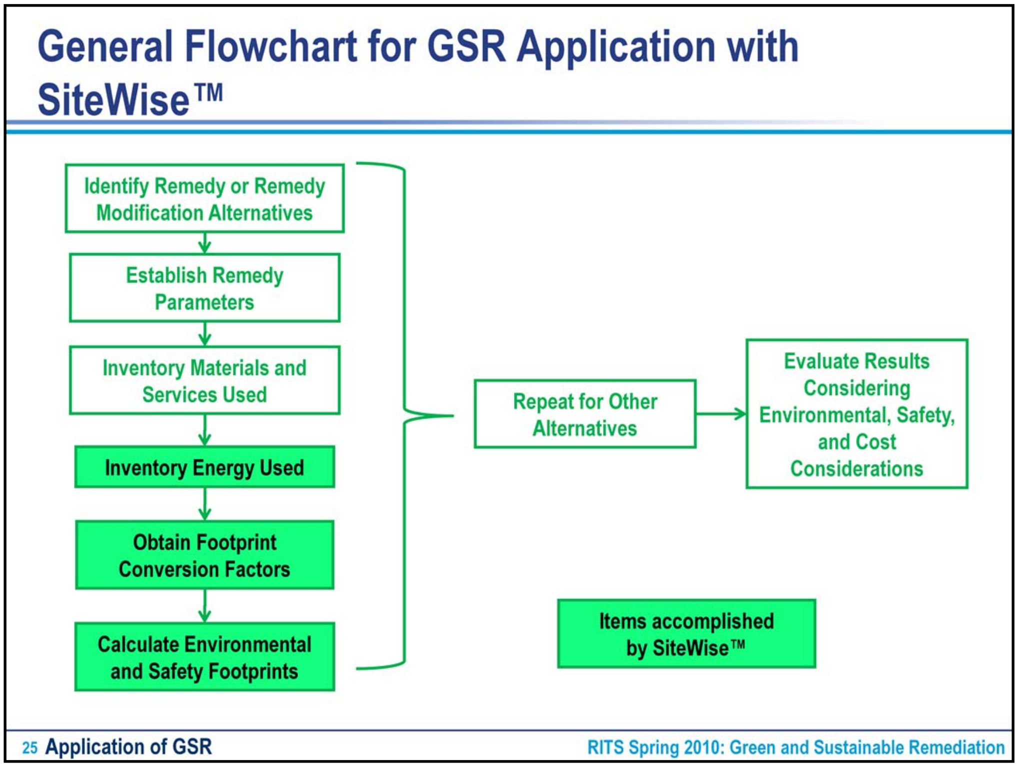


There are a few different ways of performing or implementing GSR.

1. Optimization of a remedy will often lead to a more efficient remedy, which typically translates to a more sustainable remedy
2. There are some things that you can do during a remedy that just make sense. This can be as simple as coordinating vehicle trips or carpooling to reduce mileage and fuel consumption.
3. Use the SiteWise Tool to conduct a footprint analysis. This involves…
    1. determining the footprint of a presumptive, baseline, or existing remedy
    2. identifying the big contributors to the environmental footprints
    3. Brainstorming various modifications that could reduce the footprints
    4. Evaluate the footprints of the remedy after modifications
    5. Evaluate costs, savings, etc.
    6. Make a decision that is based on sustainability, cost, protectiveness, and safety
    7. Can also be used to compare different remedial options during remedy selection.

4. Seek technical support from the optimization workgroup for running SiteWise, interpreting results, identifying methods of reducing the footprints, and making decision on how to move forward.

5. GSR is a great opportunity to involve local stakeholders and the community



So what is the general approach to conducting a GSR evaluation with SiteWise?

1. Begin with identifying the remedies or remedy modifications that you want to evaluate.

2. Establish remedy parameters like monitoring frequency, injection frequencies, injection masses, injection rates, volume to be excavated.

3. Inventory materials and services. How many samples will be analyzed? How much bioremediation nutrient will be purchased and how far does it need to be transported to the site? Where will excavated soil be disposed of? How much will be disposed of? How many hours worked in the field?

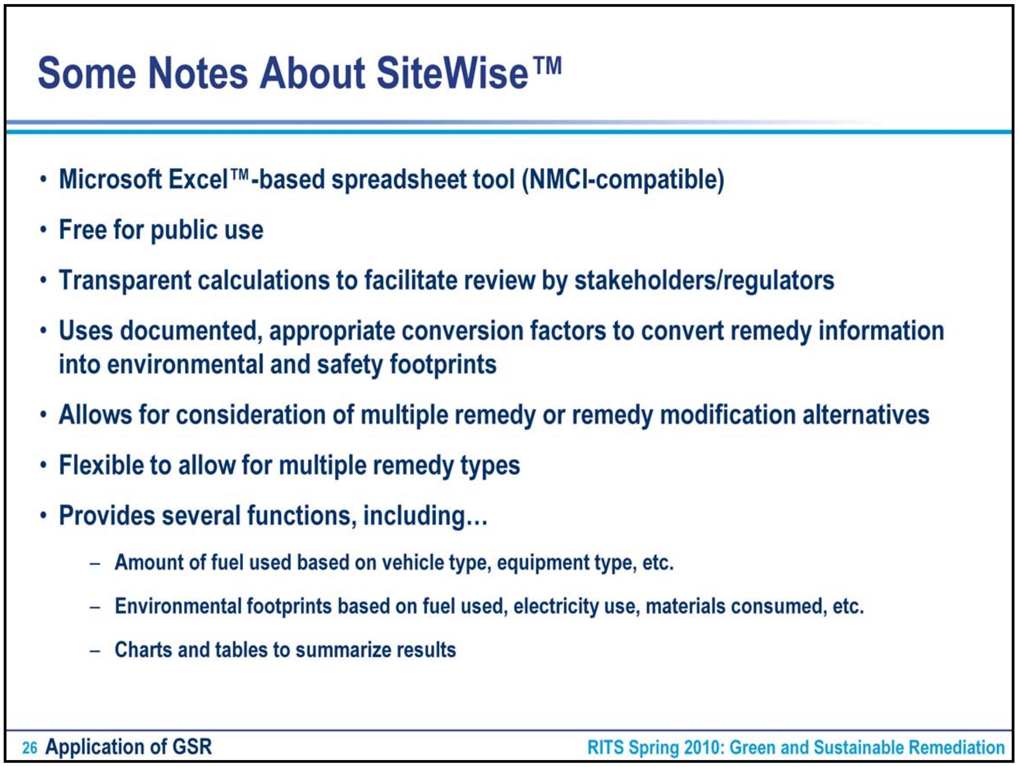
4. A footprint analysis also requires an inventory of how much energy will be used? How much electricity? How much fuel? SiteWise actually does this part for you based on input you give it (e.g., distance traveled and type of vehicle).

You can see the parallels between these steps and the work done during feasibility studies, remedial designs, and optimization evaluations. That is one of the primary reasons to link this effort with these remedial activities.

5. SiteWise then provides the necessary conversion factors to convert these remedial parameters into GSR parameters.

6. SiteWise also applies the conversion factors to the input information to calculate the GSR parameters.

The same approach needs to be repeated for each alternative being considered, and once this is done, the results can be compared.



Some additional notes about SiteWise… Read from slide. Point out that these same features are not necessarily true for other GSR tools. For example, the SRT tool from the Air Force is geared toward specific remedy types and is generally less flexible.

Notes About Other Tools

- There are other GSR tools
  - SRT™ developed for AFCEE
  - Proprietary Life-Cycle Assessment tools (e.g., SimaPro and GaBi)
  - Tools or spreadsheets developed by contractors
  - Tools or spreadsheets available from other footprint evaluations
- Navy and USACE jointly funded SiteWise™ development by Battelle

Navy GSR footprint evaluations will use SiteWise™

- Flexible for multiple remedy types
- Consistent format for evaluations
- Consistent, documented conversion factors and reference information

Read from slide.

Class Exercise: What are Some Primary Contributors to a Remedy's Environmental Footprint?

	Material or Activity	Impact to Environment
Pump and Treat		
In-Situ Bioremediation		
Soil Excavation & Disposal		

One of the key steps to the GSR process is thinking about those aspects of a remedy that impact the environment. Let's take a few minutes to think about the primary materials and activities of these three remedial approaches and consider the environmental impacts associated with them.

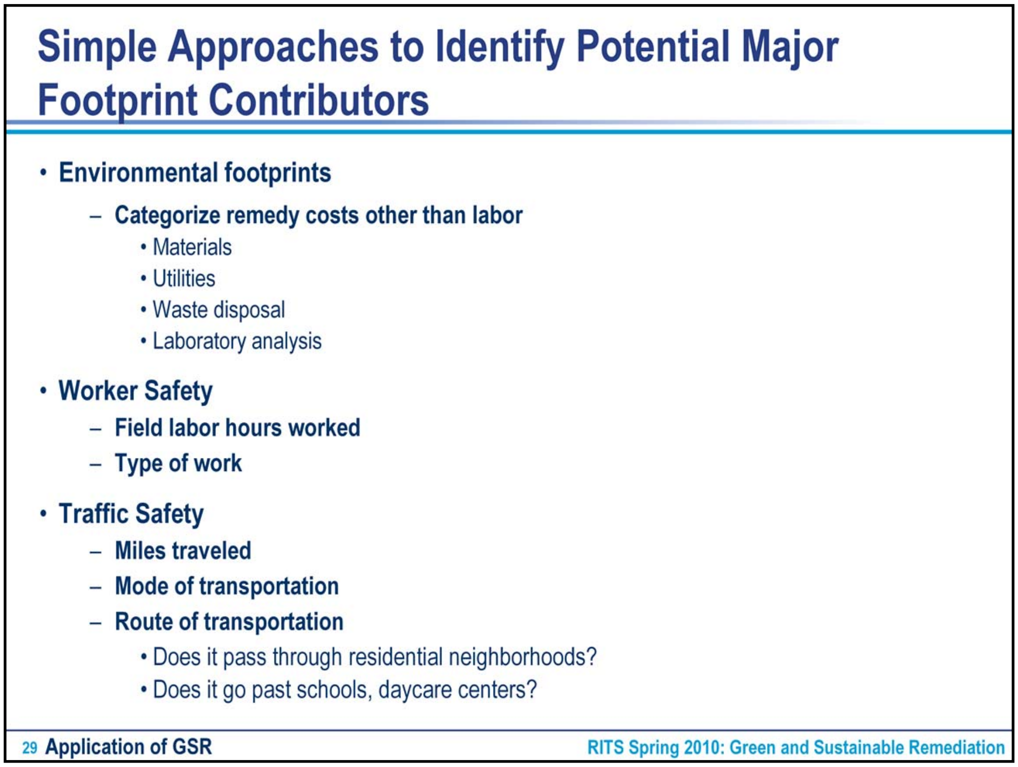
If necessary, ask some of the following questions?

-How do we get water from the ground to the treatment plant? …. Pump it…. Electricity… CO2, Nox, SOx, PM emissions plus other impacts.

-Name two P&T treatment technologies…. Air stripping and GAC… electricity for air stripping…. Transportation and a lot of heating for GAC regeneration…

- What is involved in bioremedation? …… Injecting chemicals or nutrients…. Diesel for injection process… Energy for processing nutrients

- Soil excavation and disposal? Fuel for excavating soil, fuel for transporting soil, fuel associated with landfill activities… land occupied by excavated soil.

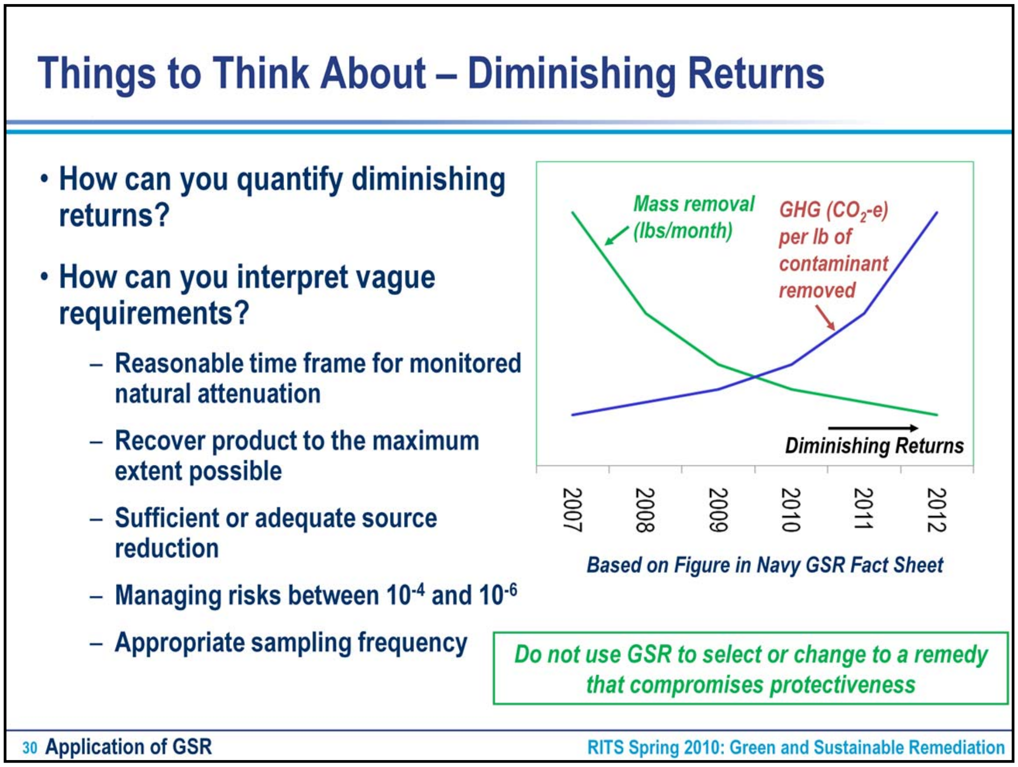


There are some things you can do at the 50,000 foot level to identify big contributors to GSR parameters.

For environmental GSR parameters, many of the footprints are somewhat tied to cost, which makes some sense. Everything we do as a society involves the use of energy…. If you look at the most costly non-labor items, you'll find that they are often the biggest contributors to environmental footprints. For example, the potassium permanganate for and in-situ chemical oxidation remedy will likely overshadow the cost of the disposable gloves and tyvek that might be used for personal protective equipment (PPE). Similarly, the footprint of the permanganate will likely overshadow the footprint of the PPE.

For worker safety, the SiteWise calculations are based on hours worked. The more hours worked, the more likely there will be an injury or accident. You can also see that the likelihood of an accident is based on the type of work. Working in a trench alongside heavy equipment is more likely to result in a serious accident than collecting a groundwater sample with a bailer.

Traffic safety is clearly tied to miles traveled, the type of vehicle, and the route.



GSR provides a new angle at looking at the diminishing returns of some remedial activities, especially those activities with vague requirements. You can envision situations where there is no discernible increase in protectiveness by conducting an specific activity, but that there is a significant and potentially growing environmental impact.

The figure illustrates this concept, but it is important to note that you cannot directly equate the GSR parameters with pounds of contamination removed. More importantly, GSR should not be used as an excuse to compromise protectiveness of a remedy.

Take a look at some of the commonly used vague requirements for some remedial activities. You can envision situations where there is a range in the potential level of effort, that the level of protectiveness does not vary discernibly within that range, but that there are substantial differences in GSR parameters.

Things to Think About – Materials

- Can we use less materials?
- What is the footprint of manufacturing those materials?
  - Are there alternate materials with smaller footprints?
  - Are there options to use recycled materials?
- Where does the stuff come from?
  - Transportation of materials can significantly add to the footprint
  - Is there a more local source for the same materials?
- Reference Navy Green Procurement Program Implementation Guide

Examples of Materials

- Donor for in-situ bio such as vegetable oil or molasses
- GAC for liquid or air treatment (P&T, SVE)
- Chemicals (e.g., sodium hydroxide, sulfuric acid)
- In-situ reactive barriers
- In-situ chemical oxidation such as permanganate or hydrogen peroxide
- Steel (e.g., sheet piling)

Materials inherently have a footprint because they use energy and raw materials in their production and because they need to be transported… often far distances. For this reason it is important to think about the materials we are using at our sites… Here are a few questions to ask yourself.

In addition, the Navy has a green procurement program to help purchase materials that have been manufactured in a more sustainable manner.

Things to Think About – Electricity Usage

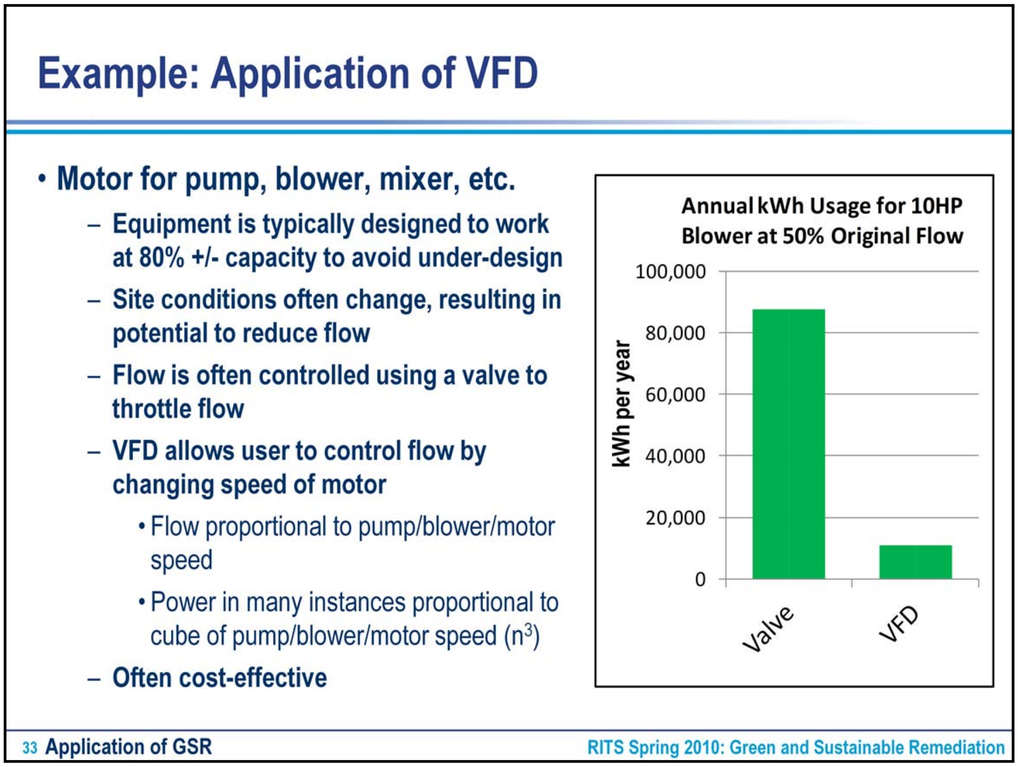
- **Can we use less power?**
  - Motors with Variable Frequency Drives (VFDs)
  - More efficient components
  - Energy efficiency audits
  - Utilize treatment trains that transition to more passive remedies as performance objectives are met
- **What is the source blend for the local electricity grid?**
  - Footprint is different for electricity generated from coal or natural gas than it is for electricity generated from hydropower
- **Footprint reduction from lower electricity usage will depend on the source of the electricity**

Electricity Source	Lbs CO_2-e per Kwh
Coal	1.90
Natural gas	1.30
Nuclear	0.14
Hydroelectric	0.03
Wind	0.05
Solar (PV)	0.20

Electricity is another important consideration and can be a dominant contributor to a remedy’s footprint….

The general question to ask yourself is… How can we use less power? And here are some of the common ways to do that.

It is important to note that all electricity is not created equally. As an example, the carbon footprints from various fuel sources are shown here, and there is quite a range, even amongst the traditional fuel sources.



On the previous slide, we mentioned variable frequency drives, and it is worth discussing these in more detail. Read slide.

Things to Think About – Excavation and Disposal

- Where is material being transported?
  - This can be a large part of the footprint
  - Identify more local disposal options
- Is there potential to minimize off-site transport and disposal?
  - Better characterization to reduce volume excavated
  - Segregate material and reuse cleaner stuff on-site for fill
  - Crush and re-use concrete on site for backfill
  - Consider on-site soil treatment options

Some Items to Consider

- Re-use options
- Recycle options
- Biodiesel for excavation and/or transport
- Dust control (particulates, health concerns)

Things to Think About – Water Usage

- **Can we use extracted groundwater for reagent injections instead of potable water?**
  - Conserve potable water
  - Use less refined resource
  - Extraction/injection assists with reagent distribution in subsurface
- **For operating P&T systems, where is the water being discharged?**
  - Surface water
  - Recharge to aquifer ← *Could allow for reduced extraction rates*
  - POTW (sanitary sewer) ← *This discharge adds to the footprint of the POTW*
  - Beneficial re-use of the treated water?

Possible Ecological/Social Issues

- Would P&T pumping dry up a wetlands?
- Would P&T pumping dewater supply wells or irrigation wells?

Examples of Things to Think About – Worker Safety and Effects on Community

- **What causes accidents? How do we avoid them?**
  - Identify potential hazards and appropriate controls to reduce risk
  - Consider time involved in conducting "high hazard" work
  - Consider miles driven, vehicle type, driving conditions, and potential for accidents
- **What are potential positive and negative effects on community?**
  - Positive – potential use of local workers and resources, potential redevelopment of property, etc.
  - Negative – noise, odor, emissions, traffic, landscape changes, worker safety, etc.

Existing Tools, Procedures, Policies

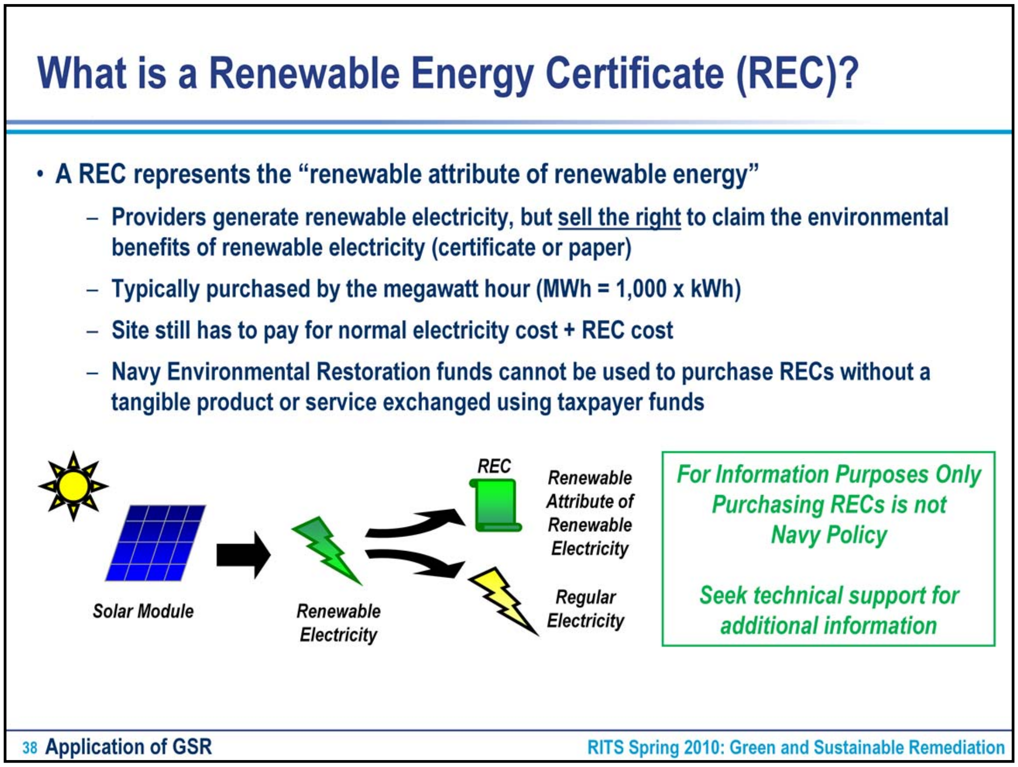
- Health and Safety Plans
- CERCLA Criteria
- Public meetings and other community involvement

The Role of Renewable Energy in GSR

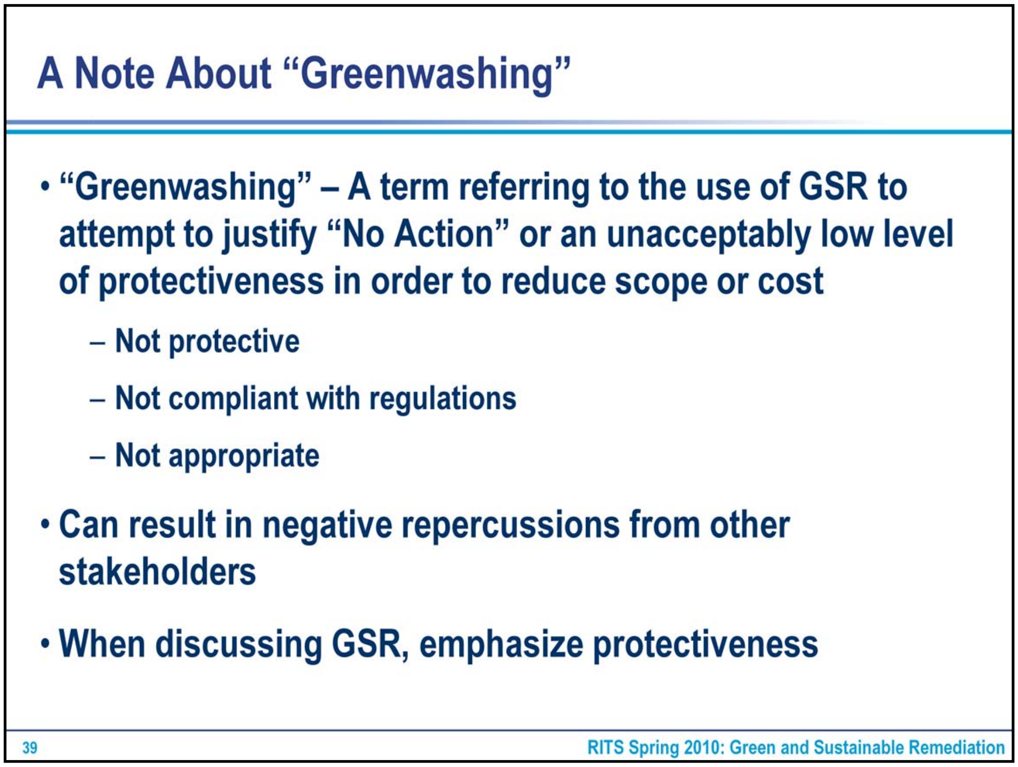
- For remedies that use electricity (e.g., P&T, AS/SVE, etc.), the electricity is a major contributor to many footprints including CO_2-e, NO_x, and SO_x
- Renewable energy has a low footprint for these parameters
- The use of renewable energy can substantially reduce the remedy footprint, particularly for long-term operating systems (i.e., extraction systems for plume containment)

Considerations

- On-site renewable energy generation potential
- Solar
- Wind
- Landfill gas
- Biofuels (e.g., biodiesel)
- Materials from vendors that use renewable energy to lower the footprint of the product
- Renewable energy can be costly; evaluate cost-effectiveness



This slide has been included for informational purposes. It is not Navy policy to purchase RECs, but there use in the field of sustainability and even green remediation is common. For example, EPA Region 2 purchases RECs to offset its footprints from electricity usage at all EPA Region 2 facilities. It is important that you know what they are.



Because less electricity usage, less materials usage, less hours worked, and less miles traveled result in more sustainable remedies, it is important to maintain our focus on protectiveness.

We are not using GSR to achieve less protective remedies, we are using GSR to implement protective remedies in a more sustainable manner.

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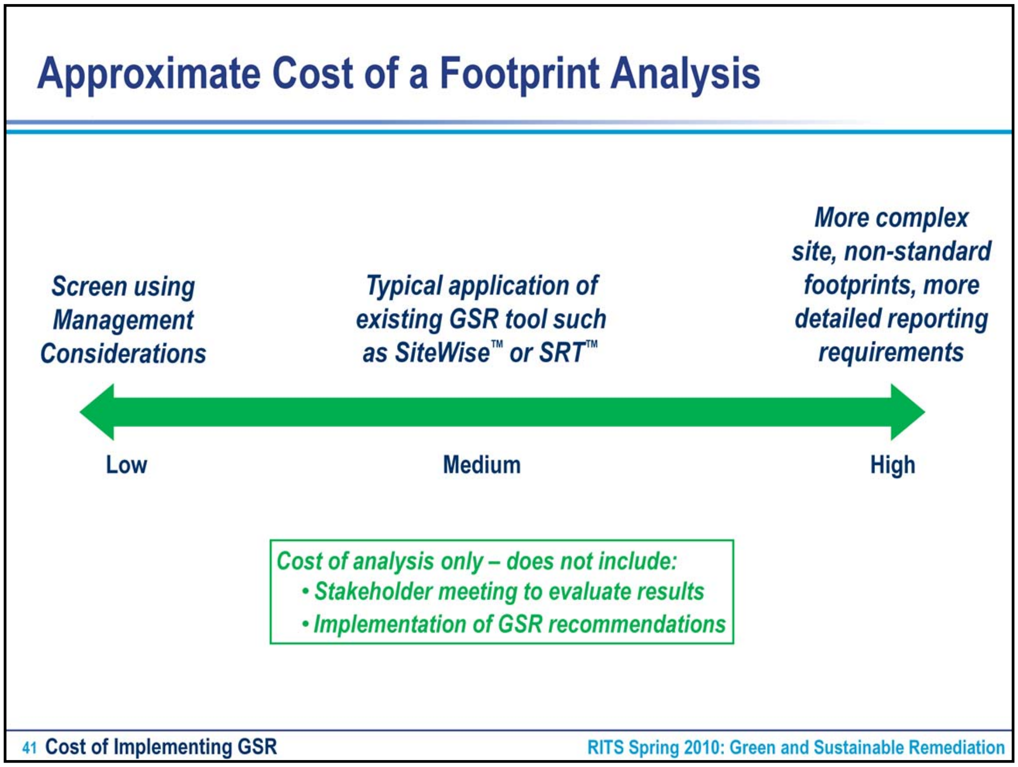
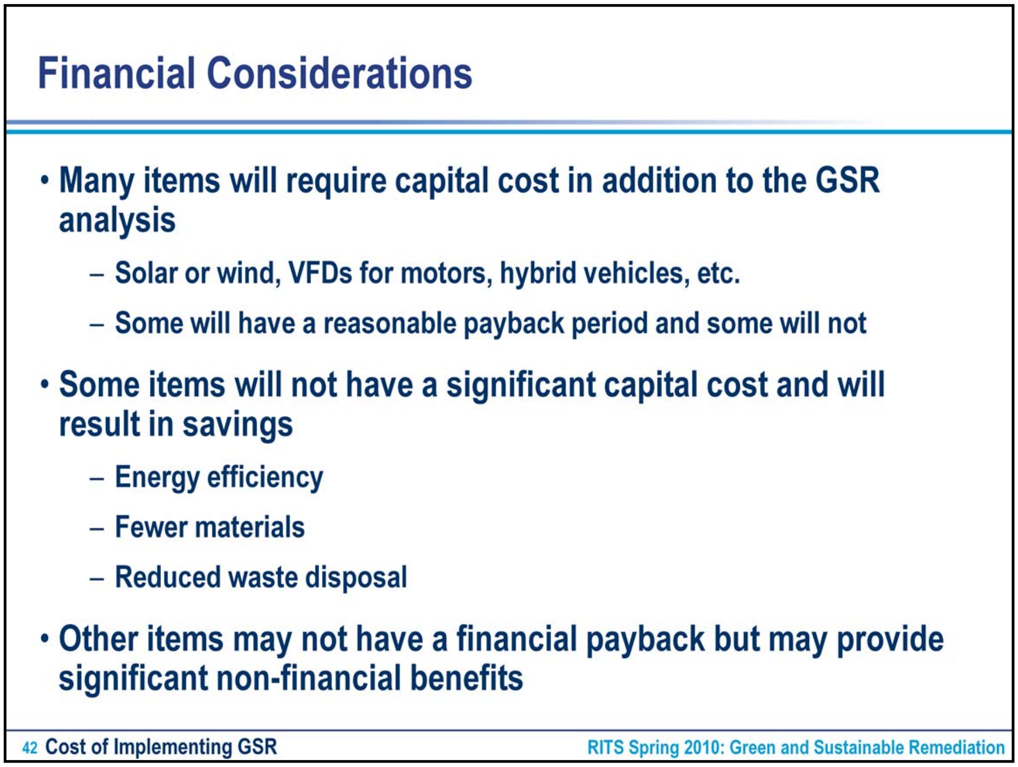


This is an important question, but I'll give you the typical answer….. "It depends"

There is a range in both the level of detail of the analysis and in the site complexity.

Personally, I like to think that for the typical site, a good evaluation conducted with a refined GSR tool like SiteWise and accompanied by a decent report should around $10K. Simply screening some common GSR practices and then recommending application at a site should cost significantly less than this, and conducting a very detailed study at a very complex site should cost more.

The cost of stakeholder meetings and of actually implementing the GSR recommendations are note included in the $10K that I just mentioned.



Referring back to the DoD Memorandum, it specifically mentions cost effectiveness.

Some items will have a capital cost and cost effectiveness will be a function of the payback.

Some items will not have a significant capital cost and will directly result in savings.

Other items may not have a direct financial payback but may provide significant non-financial benefits that will indirectly make the remedy more cost-effective. For this type of situation, seek technical support from the optimization work group.

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GSR Benefits

- Consistent with Executive Orders and Related DoD Goals/Policy
- Results in lower energy use, lower GHG and criteria pollutant emissions, lower water use, etc.
- Provides a means for quantifying footprint reductions
- Contribution from a specific site may seem small in the big picture, but each incremental reduction is part of the solution across the DoD and the Government
- Helps quantify the environmental and safety costs of activities
- Helps engage local community and better address their concerns
- Provides an additional perspective when developing remedy options and optimizing remedies

Read from slide

Challenges to Performing GSR

Challenge	Meeting the Challenge
Estimates for energy, materials, etc. are sometimes uncertain	Same uncertainties are encountered during cost estimating, consider sensitivity analysis
Sparse or conflicting values for footprint conversion factors	SiteWise™ provides documented, consistent conversion factors for Navy evaluations
Interpreting footprints that are of local concern vs. those that are of global concern	Site stakeholders can provide clarification of what is important to them and the site
Interpreting footprints for different parameters (e.g., safety vs. water vs. CO_2)	Technical support can provide valuable input
Absence of current regulatory guidance	Navy GSR guidance and GSR Web site provide some answers. Technical support can provide "real-time" guidance.

There are several challenges associated with performing GSR, but for each challenge there is a way to meet that challenge.

Read from slide.

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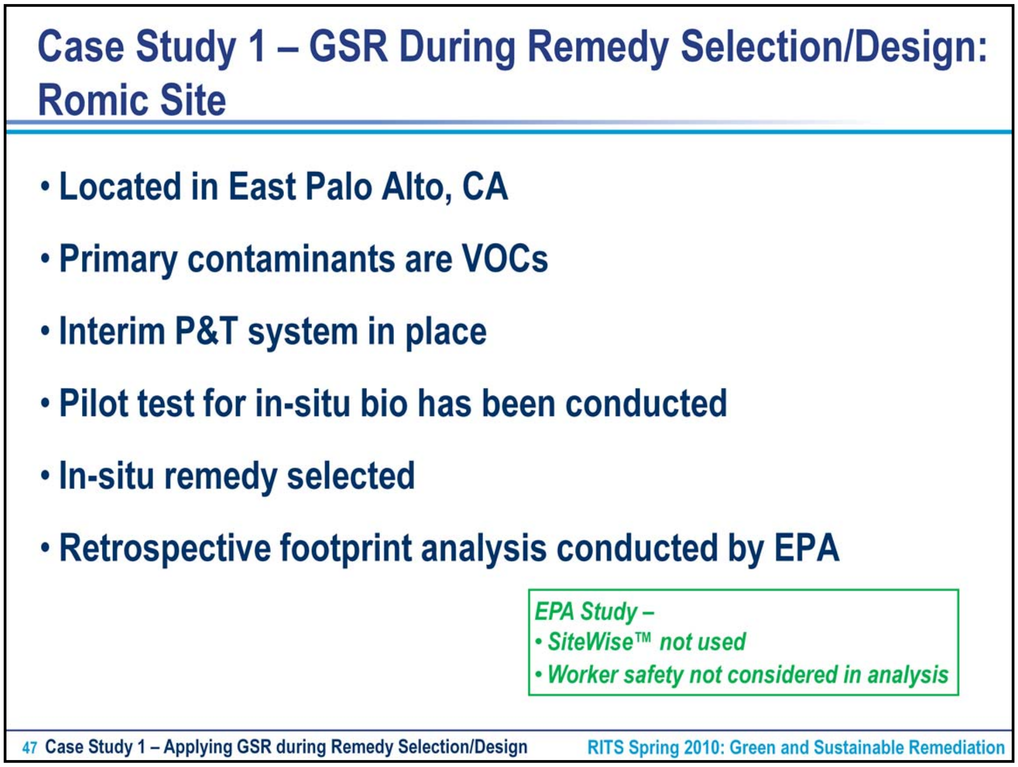
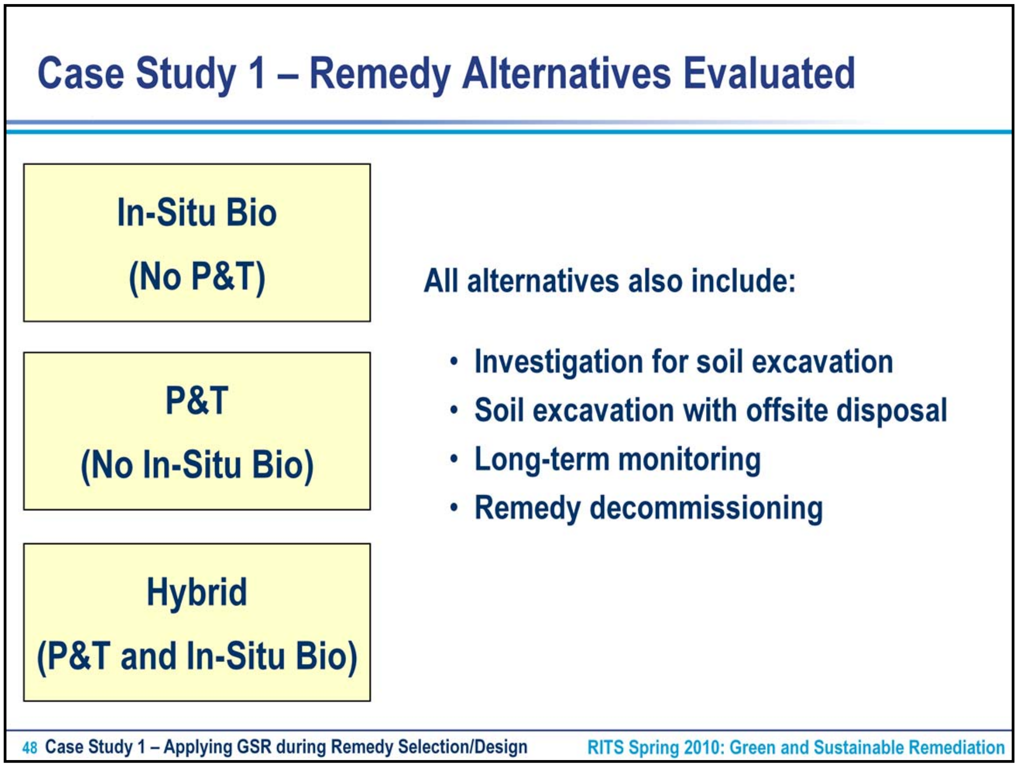


This evaluation at the Romic site is an example of a green remediation evaluation that EPA conducted at a willing PRP site.

Read slide.



Three remedy alternatives were evaluated as part of the retrospective analysis. For each alternative, the these other four remedial components were also included. The scope for these additional four components were the same for each of the three remedy alternatives except for a slight modification to the long-term monitoring program.

Case Study 1 – Approach

- Considered 4 of the 5 EPA "core elements"
  - Energy, air, water, and materials/wastes
  - Fifth core element (ecology) considered equivalent for each alternative
- Calculated footprint contributions from:
  - On-site activities (e.g., on-site fuel combustion)
  - Transportation (e.g., personnel, freight)
  - Off-site activities (e.g., waste disposal, material manufacture, laboratory analysis, electricity generation)
- All calculations performed in MS-Excel spreadsheets
  - Developed for this project
  - Constructed for more general use
  - Will be available to the public
- Most footprint conversion factors obtained from government sponsored life-cycle inventory databases, some (e.g., GAC, laboratory analysis) developed by evaluation team

Read from slide.

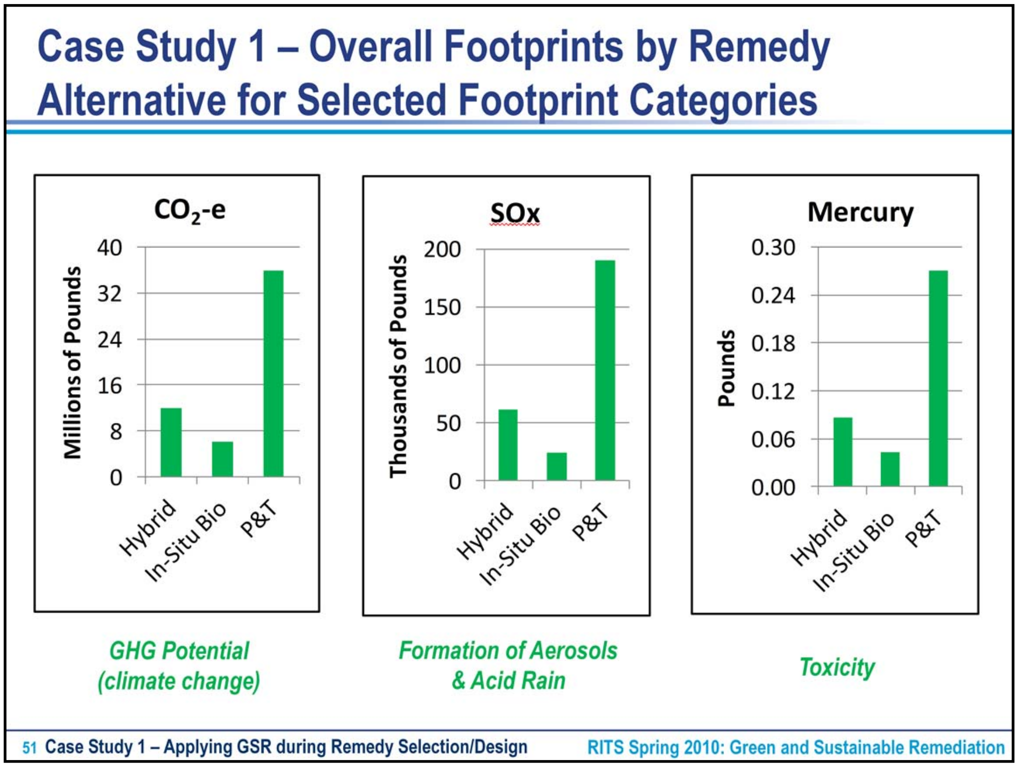
Case Study 1 – Footprint Categories Calculated

On-Site	Off-Site
Energy	Energy
Electricity	Electricity
All water	All water
Potable water	
Local groundwater extracted	
Carbon dioxide equivalents (CO_2-e)	Carbon dioxide equivalents (CO_2-e)
Nitrogen oxide (NO_x) emissions	Nitrogen oxide (NO_x) emissions
Sulfur oxide (SO_x) emissions	Sulfur oxide (SO_x) emissions
Particulate matter (PM) emissions	Particulate matter (PM) emissions
Solid (non-hazardous) waste generated	Solid (non-hazardous) waste generated
Hazardous waste generated	Hazardous waste generated
Air toxics emitted	Air toxics emitted
Mercury released to the environment	Mercury released to the environment
Lead released to the environment	Lead released to the environment
Dioxins released to the environment	Dioxins released to the environment

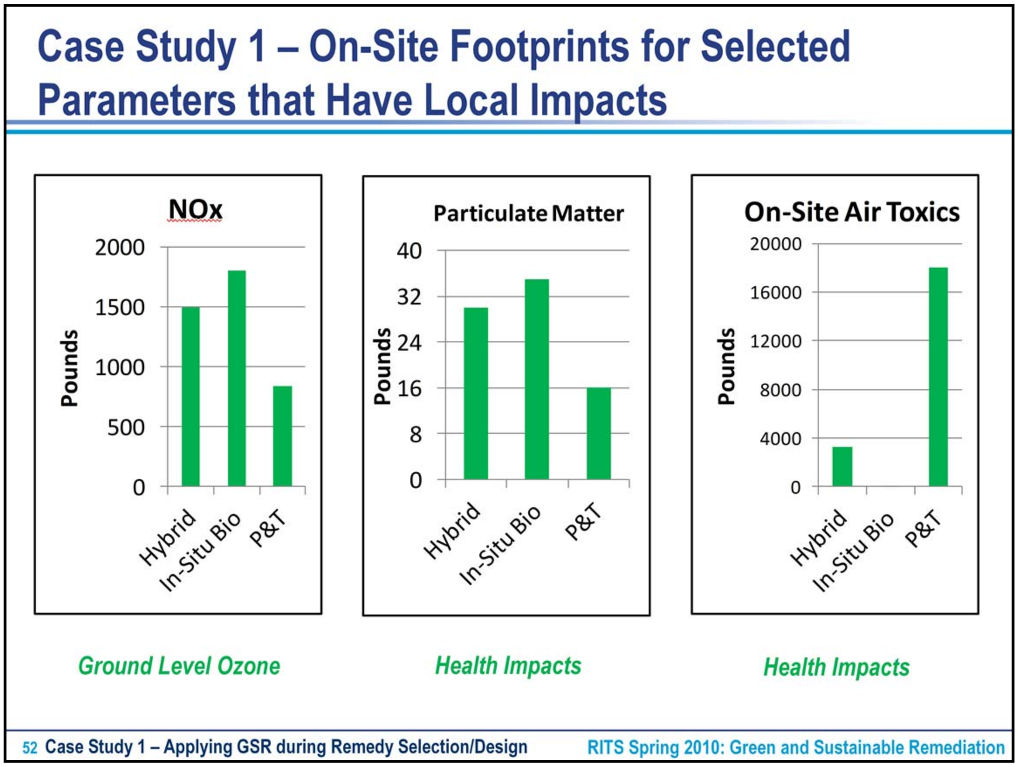
The study involved a very comprehensive list of parameters and distinguished between on-site and off-site parameters. EPA attaches importance to the on-site parameters because remedies are by definition local activities within a community. The on-site and off-site parameters are the same except that when looking at the offsite water usage, there was no effort to determine if the water used was groundwater potable water, or some other water resource.

For example, potable water from on-site was used for the bioremediation injections. Some form of water, the quality and source of which is unknown, is used off-site for regenerating the GAC associated with the P&T remedy.

“released” to the environment means released to air or water.

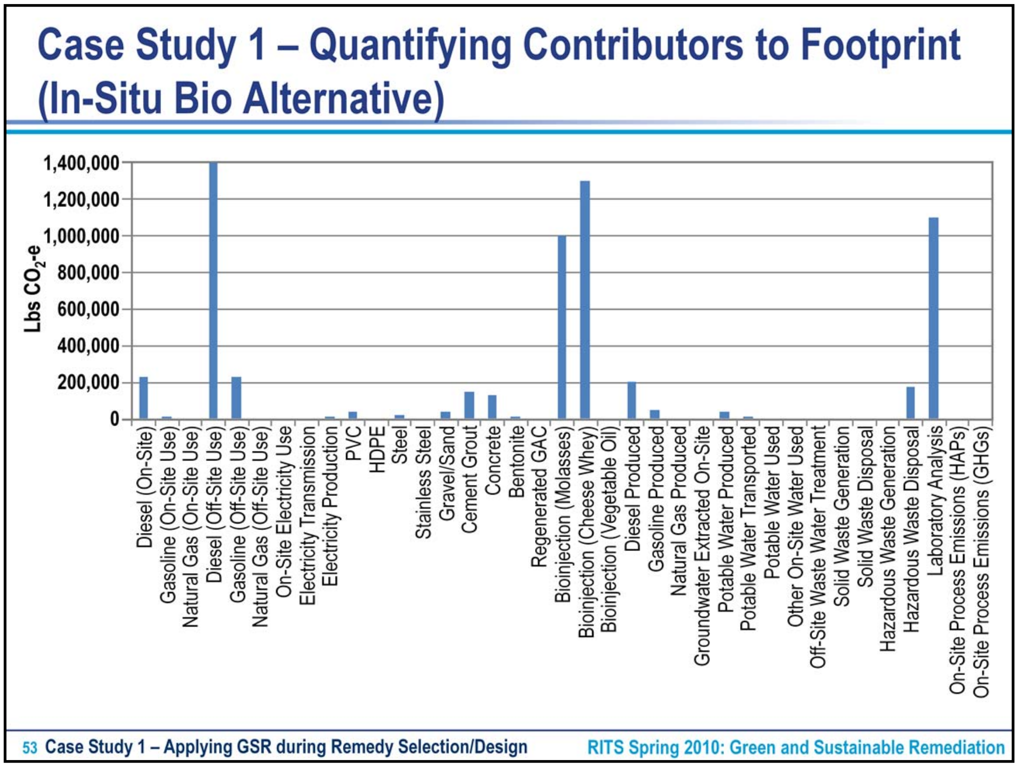


The initial analysis suggested that the P&T remedy had a significantly higher overall or total footprint for many parameters relative to the bioremediation remedy. The hybrid remedy was obviously a blend of the two other remedies. Overall or total refers to the sum of both on-site and off-site CO2, SOx, or mecury emitted.



The on-site picture is a bit different. The bioremediation option has a higher footprint for many categories because of the on-site work necessary to inject all of the bioremediation nutrients. An important note is that the footprint associated with electricity is considered and “off-site” contribution because the electricity is generated at a power plant some distance from the site.

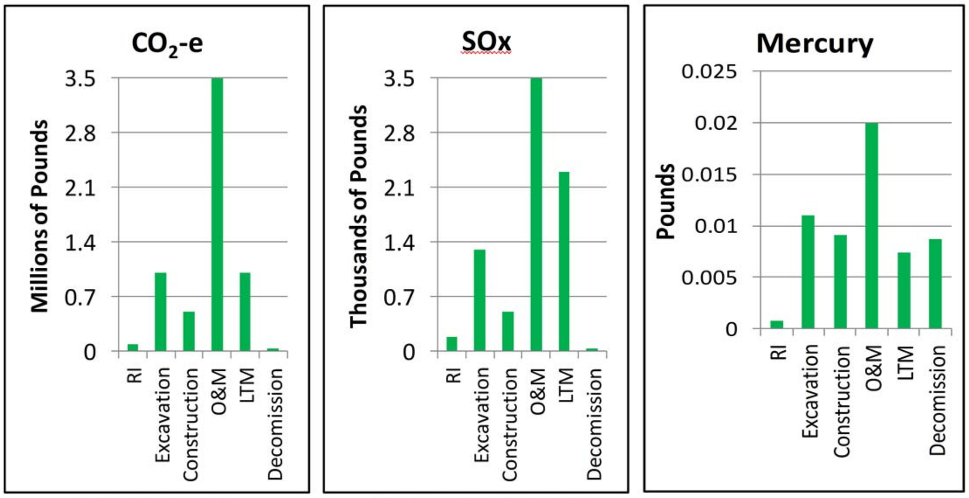
The relatively high air toxics for the P&T alternative is from air stripper off-gas that is not effectively treated by the vapor phase GAC.



Here is a breakdown of the contributors to the carbon footprint for the bioremediation remedy. It is evident that the big contributors are off-site diesel usage, molasses production, cheese whey production, and laboratory analysis. Some of the off-site diesel usage was for hauling waste from the soil excavation, but the majority of it is associated with transporting the molasses and cheese whey to the site.

You can see from this chart that a remedy footprint cannot be effectively derived by looking at direct energy consumption only.

Case Study 1 – Example of Overall Footprint by Remedy Component (In-Situ Bio Alternative)

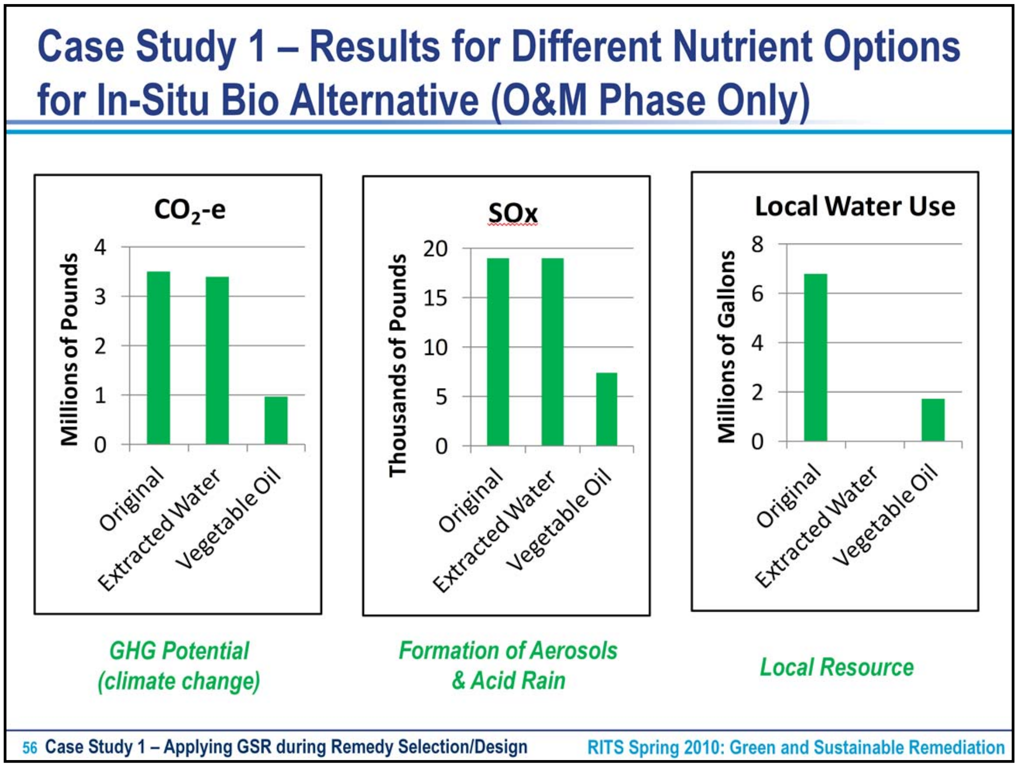


GHG Potential (climate change) | *Formation of Aerosols & Acid Rain* | *Toxicity*

Case Study 1 – Example of Using GSR to Identify Potential Improvements to a Remedy Alternative

- **Footprinting for in-situ bio alternative identified large contributors to footprints**
  - Production of nutrients
  - Transportation of nutrients
  - Long-term monitoring (particularly laboratory analysis)
  - Use of potable water for blending/injecting nutrients
- **Explore other options to target those footprints**
  - Original: molasses and cheese whey injected with potable water
  - Modification #1: Inject same nutrients with extracted water rather than potable water
  - Modification #2: Replace use of molasses and cheese whey with emulsified vegetable oil (injected with potable water)

The footprinting exercise helped identify the big contributors to the bio remedy. As a result, we ran a second analysis on a modified bio remedy in which extracted groundwater was used for blending and injecting nutrients and where emulsified vegetable oil was used in place of cheese whey and molasses.



Here are the results. There is almost no change in the carbon and SOx footprints from using extracted water, but there is an obvious big influence on the water footprint. The move to vegetable oil had a significant change. This is partially due to needing less vegetable oil (greater nutrient content), a slower/more even burn of the vegetable oil which results in less frequent injections, and a less mass to transport to the site.

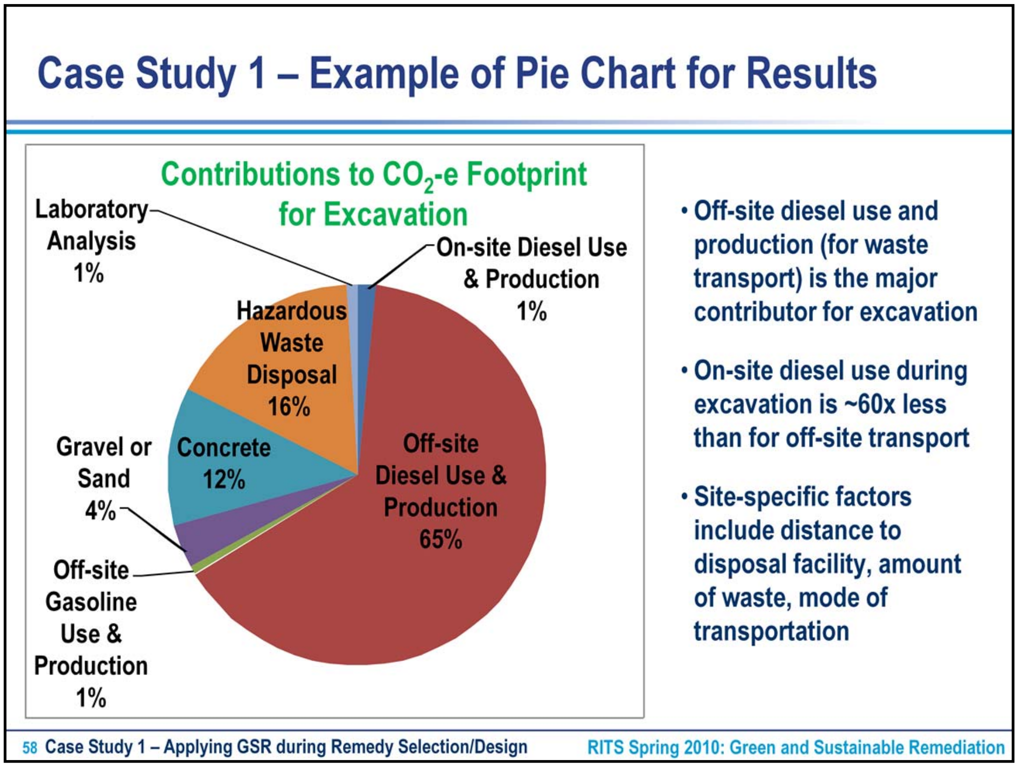
Case Study 1 – Findings Related to Remedy Design

- Choice of electron donor can significantly reduce footprint
- Also evaluated potential alternative configurations to P&T
  - Optimization of P&T can significantly lower footprint
    - Original P&T design included air stripping, GAC, and sanitary sewer discharge
    - GAC and sanitary sewer treatment contribute significantly to footprints
    - Optimized/alternative P&T design
      - Increases air-to-water ratio of air stripping
      - Eliminates GAC
      - Eliminates POTW discharge
      - Offsets electricity usage with renewable energy
  - Optimized P&T has total footprint comparable to in-situ bio footprint

We also took a second look at an “optimized” version of the P&T alternative.

The original P&T design included several redundant processes: Air stripping, GAC, and sanitary sewer discharge. Each of these steps has a big footprint associated with it.

Optimization of the system found that the contaminants were more efficiently treated with air stripping than with GAC. As a result, it made sense to increase the air-water ratio of the air stripper and eliminate the need for the GAC and sanitary sewer discharge. We then chose to offset the electricity usage with RECs. The optimized P&T remedy had a very similar footprint to the in-situ bio remedy, which demonstrates that the design plays as much or more of a role in sustainabilty as remedy selection does.



We took a look at the excavation remedy as well and found that the bulk of the carbon footprint results from transportation of the waste (off-site diesel usage), disposal at a hazardous waste facility, and the concrete used for resurfacing the excavation. The on-site heavy equipment made a very small contribution to the footprint.

This suggests that minimizing waste removal, identifying close disposal facilities, or using an alternate surface cover all would have a greater effect than using biodiesel or idling heavy equipment engines.

Navy Case Studies

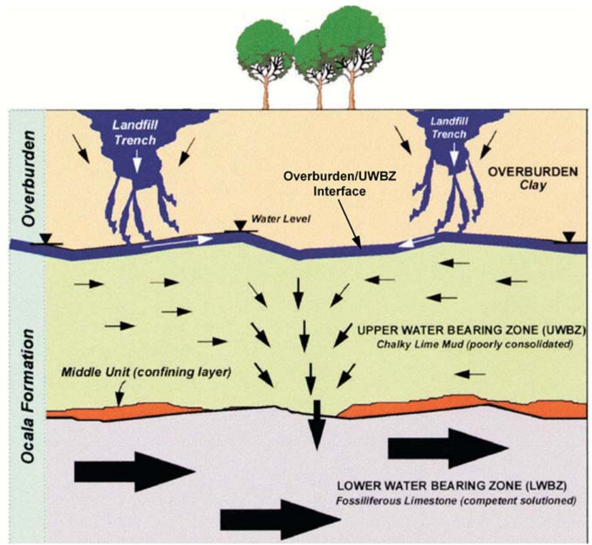
Case Study 2 – MC Logistics Base Albany OU6 Conceptual Site Model

PSC 3 – Landfill

- Landfill trenches act as source of contaminants
- Trash to maximum depth of 10 to 15 ft bgs
- Chlorinated VOCs
- Upper Water Bearing Zone (UWBZ) wells screened in a range of 90 to 150 ft bgs

PSC 26 – Containment Berm

- Location of contaminant sources unknown
- Most significant contaminants are CT and TCE



Case Study 2 – MC Logistics Base Albany OU6
Summary of Original Remedy (Scenario 1)

Case Study 2 – Albany OU6 Sustainability Evaluation Scenarios

- Sustainability Remedial Evaluation was performed for the following:
  - Scenario 1 (Original Remedy with 20 year LTM): 190 Injections (ZVI and $KMnO_4$), $16.9 M
  - Scenario 2 (Optimized Remedy with 30 year LTM): 39 Injections (ZVI and $KMnO_4$), $7.6 M
  - Scenario 3 (Optimized Remedy and Optimized 30 year LTM): 39 Injections (ZVI and $KMnO_4$) and optimized LTM sampling approach, $5.2M

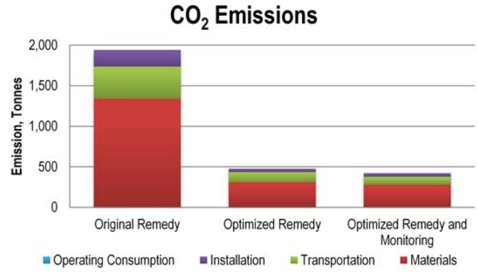
Case Study 2 – Albany OU6 Sustainability Evaluation Approach

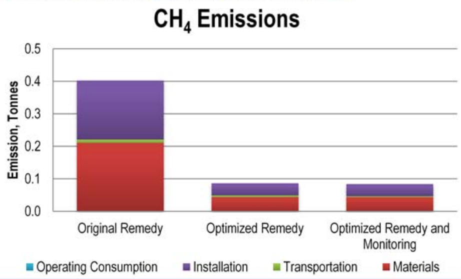
- **Parameters Evaluated:**
  - GHG: CO_2-e (CO_2, N_2O, CH_4)
  - Primary Pollutants: NO_x, SO_x, PM_{10}
  - Energy Consumption: Electricity and fuel use
  - Water Consumption: Implementation requirements, energy production, and material production
- **Calculated life-cycle impacts from implementation of remedy components and manufacture of consumable materials**

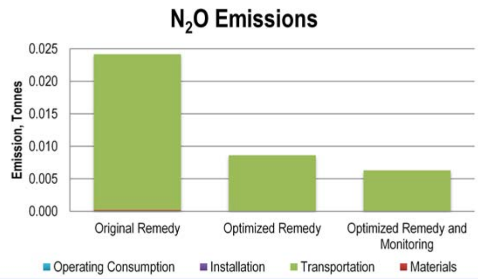
Case Study 2 – Albany OU6 Sustainability Evaluation Results

- Largest contribution to GHG emissions from production of injection reagents and nitrogen gas
- Scenario 1 has significantly higher GHG emissions, due to increased materials, installation, & transportation requirements
- CO_2 (1x), CH_4 (21x), N_2O (310x)*

*CO_2-equivalent multiplication factor in parentheses

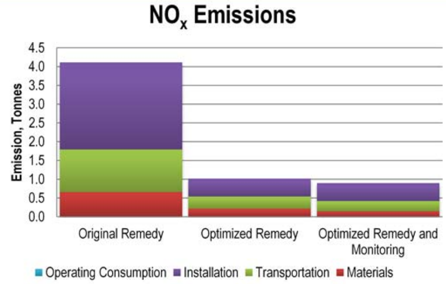


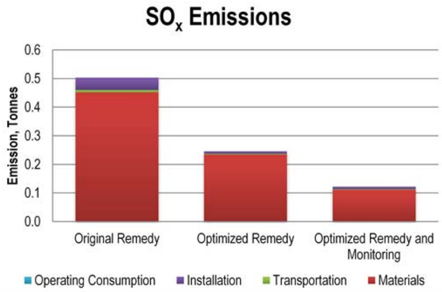


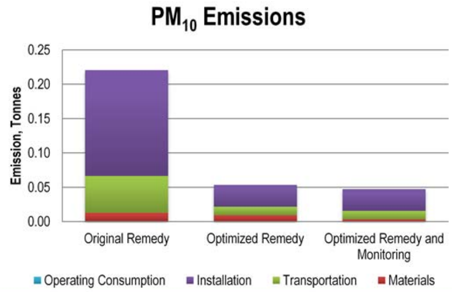


Case Study 2 – Albany OU6 Sustainability Evaluation Results (cont.)

- Emissions of NO_x and PM_{10} primarily from operation of injection equipment
- SO_x emissions largely driven by material production
- Scenario 1 has the highest emissions, due to increased material & installation requirements



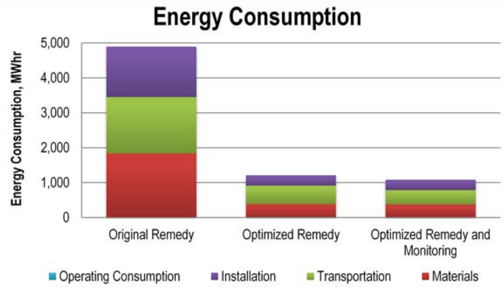


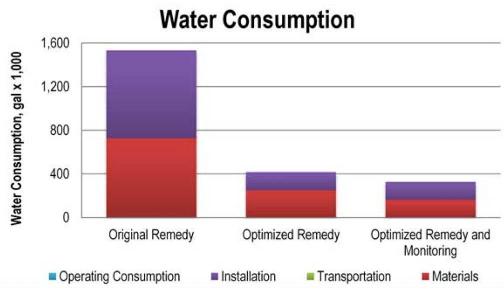


Case Study 2 – Albany OU6 Sustainability Evaluation Results (cont.)

- Energy consumption similar for installation, transportation and material manufacture categories

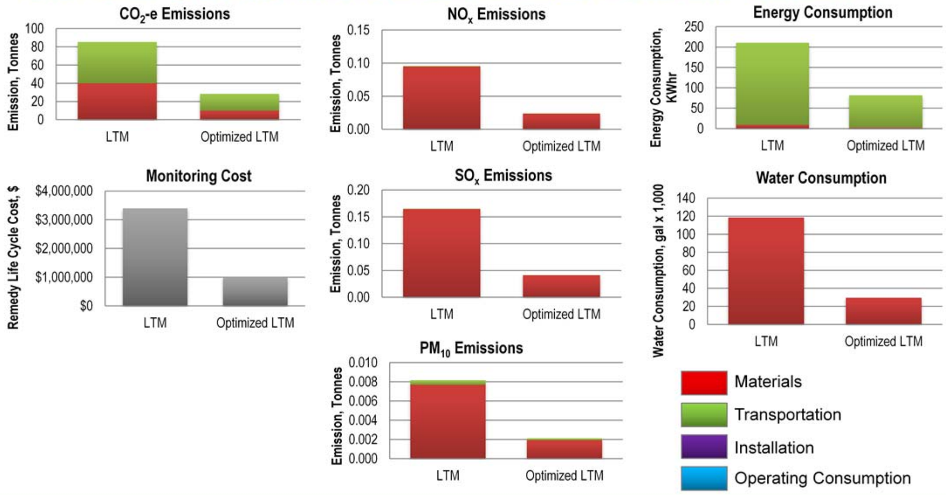
  (materials>transportation>installation)
- Water consumption primarily from the production of ZVI and $KMnO_4$ and dilution of reagents prior to injection
- Scenario 1 has the highest energy and water consumption due to the increased material demands, specifically reagents and dilution water, and 20 yrs of monitoring





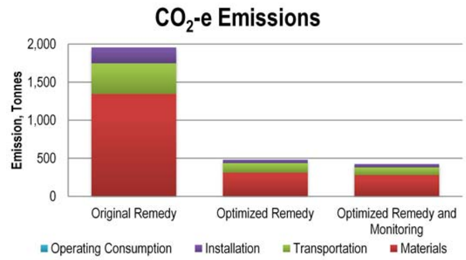
Case Study 2 – Albany OU6 – Affects of Long-Term Monitoring Optimization

- Optimization of the monitoring program will decrease emissions and energy usage. Below is life-cycle footprint comparison of LTM prior to and after optimization:



Case Study 2 – Albany OU6 Sustainability Evaluation Conclusions

- The results of the Sustainability Evaluation clearly illustrate that continued optimization, in accordance with Navy policy, not only reduces lifecycle costs, but also increases the environmental benefit of the project
- Optimization prior to remedy implementation and continued optimization throughout the lifecycle of the project is an effective means to reduce overall emissions and energy usage

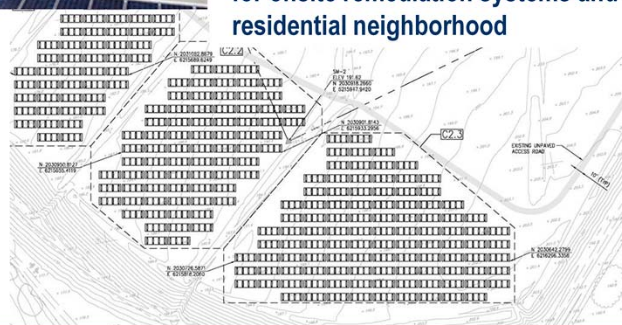


Case Study 3 – Former Live Impact Area (LIA) Vieques, Puerto Rico

- Hundreds of acres, landfill, remote open space
- Photovoltaics used
- Wind turbines used
- 15.2 million lbs of metals accumulated and 11.5 million lbs recycled

Case Study 4 – MCB Camp Pendleton, Landfill – Site 7

- 23 ac landfill, large amount of unused open space
- 6 to 12 ac of photovoltaics planned; 2 MW capacity
- Installation of landfill gas collection system planned
- Microturbine & photovoltaics will generate power for onsite remediation systems and nearby residential neighborhood



Case Study 4 – MCB Camp Pendleton, Landfill – Site 7 (cont.)

- Excavated 120,000 yd^3 of impacted soil
- Sustainable Remediation planning led to:
  - Use of clean diesel technologies
  - Retrofitted equipment w/air scrubbers
  - Required use of ultra-low-sulfur diesel fuel and biofuels onsite
  - Relocated endangered Southwest Arroyo Toads away from site
  - A portion of excavated soils were shipped to landfill by train, keeping 100s of trucks off congested CA highways
- Honored by the USEPA Cleanup-Clean Air Initiative

Case Study 5 – Former Adak Naval Complex, AK

- Remote area, multiple sites, free product
- Mobile wind turbines used to generate power for remediation systems
- Some units were damaged when gale force winds unexpectedly hit site
- Whether temporary or permanent, plan for what is reasonably expected

Presentation Overview

- Defining Green and Sustainable Remediation (GSR)
- Policy, Guidance, and Standards
- Application
- Cost of Implementation
- Benefits and Challenges
- Case Studies
- Summary and Conclusions

Take-Home Points

- GSR is a growing "hot topic"
  - EO 13423 and EO 13514 outline energy conservation initiatives
  - DoD memorandum on GSR (8/10/09) expands environmental stewardship
  - Navy guidance and tools will continue to evolve with input from many other groups (EPA, ITRC, SuRF)
  - Builds on practices that Navy already follows, especially environmental protection, while including social, economic, community, and safety aspects
- GSR is intended to be used as a set of optimization practices to help analyze remedial alternatives so they are more sustainable and environmentally-friendly while maintaining the protectiveness of the remedy
  - Footprinting allows consideration of sustainability into existing criteria for making remedy decisions and for optimization of remedies at every phase
  - Navy will not use GSR to support "No Action" alternatives to avoid responsibility

Take-Home Points (cont.)

- GSR can be performed during the remedy selection, remedy design, and remedy operation phases
  - Footprint estimates during design can be particularly valuable to identify largest potential contributors to footprint
  - Design can then seek to reduce the remedy footprint
- GSR is a natural fit with remedy optimization
- Footprints result from on-site activities, transportation, and off-site activities (e.g., manufacturing of materials)
  - All can potentially contribute significantly (depends on remedy)

Take-Home Points (cont.)

- Footprint calculations can depend on where the site is located (e.g., local source blend for that electricity)
- Uncertainties (e.g., materials usage estimates) can be evaluated with sensitivity analysis
- Standard approaches needed to combine results for multiple footprint categories
  - Work with NAVFAC technical support staff and stakeholders
  - Encourage stakeholders to provide input into process

Take-Home Points (cont.)

<u>Many principles are presented here that an RPM can apply</u>

- Seek to reduce energy, water, and materials usage
- Consider renewable energy options, as policy or finances allow
- Determine if materials can be replaced by others with lower footprint due to manufacturing, transport, and/or disposal
- Minimize wastes requiring off-site disposal
- Look for opportunities to recycle and reuse
- Continue to emphasize safety, community involvement, and cost considerations

References

- Navy GSR Fact Sheet
- Navy GSR Web Portal
- AFCEE Sustainable Remediation Website
- U.S. EPA Web Site and GR Documents
- ITRC GSR website
- SuRF – Sustainable Remediation Forum