# EPA Session 2 (1C.30S): Evolution of Optimization and other Key Trends in Cleanups: A Superfund Perspective

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Copenhagen, Denmark
June 2015

# Agenda

- Historical trends in remediation technologies and an overview of technical developments
- Optimizing remedies in Superfund: Approaches and findings
- High Resolution Site Characterizations: The basics
- Insights on progress in Superfund groundwater remedies and recent guidance
- Greener cleanups are helping us achieve protectiveness at site cleanups at lower cost and environmental footprint

# Trends in Technologies and Developments in Superfund

# Early Cleanups in Superfund

- Superfund Law Enacted in 1980 in response to a need to protect citizens from the dangers posed by abandoned or uncontrolled hazardous waste sites
- Superfund was a powerful law that resulted in immediate action at many priority sites
- The challenge was new, and the need for action prevailed. Technical solutions were few and we applied what we knew

Superfund Remedies: Early Years (1982-1985)

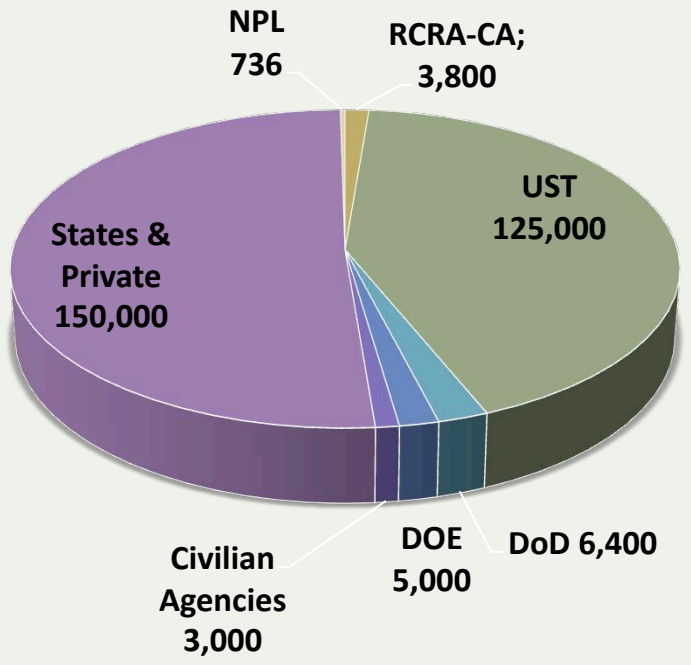
| | Containment | Treatment |
|---|---|---|
| Soil Remedies | 75% | 25% |
| | **Pump & Treat** | **In-Situ Treatment** |
| Groundwater remedies | 90% | 3% |

# EPA Contaminated Site Programs: We Still a Lot of Remediation Work to Do

- We have made great progress cleaning up contaminated sites but…
- National Academies of Sciences estimates 126,000 sites across US still have contaminated groundwater, and their closure expected to cost at least $110 billion to $127 billion
- We continue to invest over $8 billion a year in remediation (USEPA, EBJ)
- We have opportunity to take lessons learned over the past decades, and apply innovations and best management practices to future sites

**Estimated Number of Contaminated Sites (USEPA 2004)**
***(United States, Cleanup horizon: 2004 – 33)***

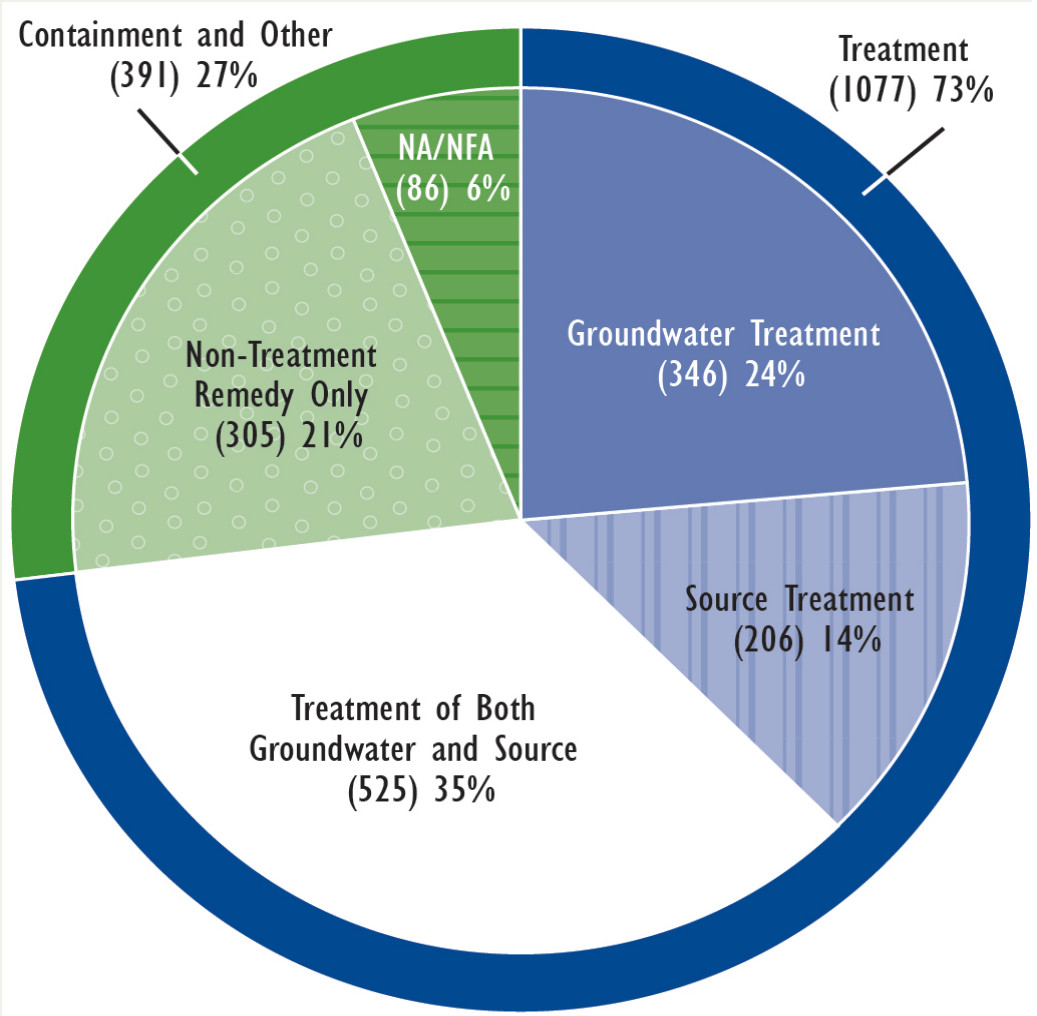
**Total Sites = 294,000**




Sources: www.clu-in.org/market; http://www.nationalacademies.org/ http://www.ebiusa.com/

# Remediation: The "Big Picture"- Remedy Types at National Priority List Sites

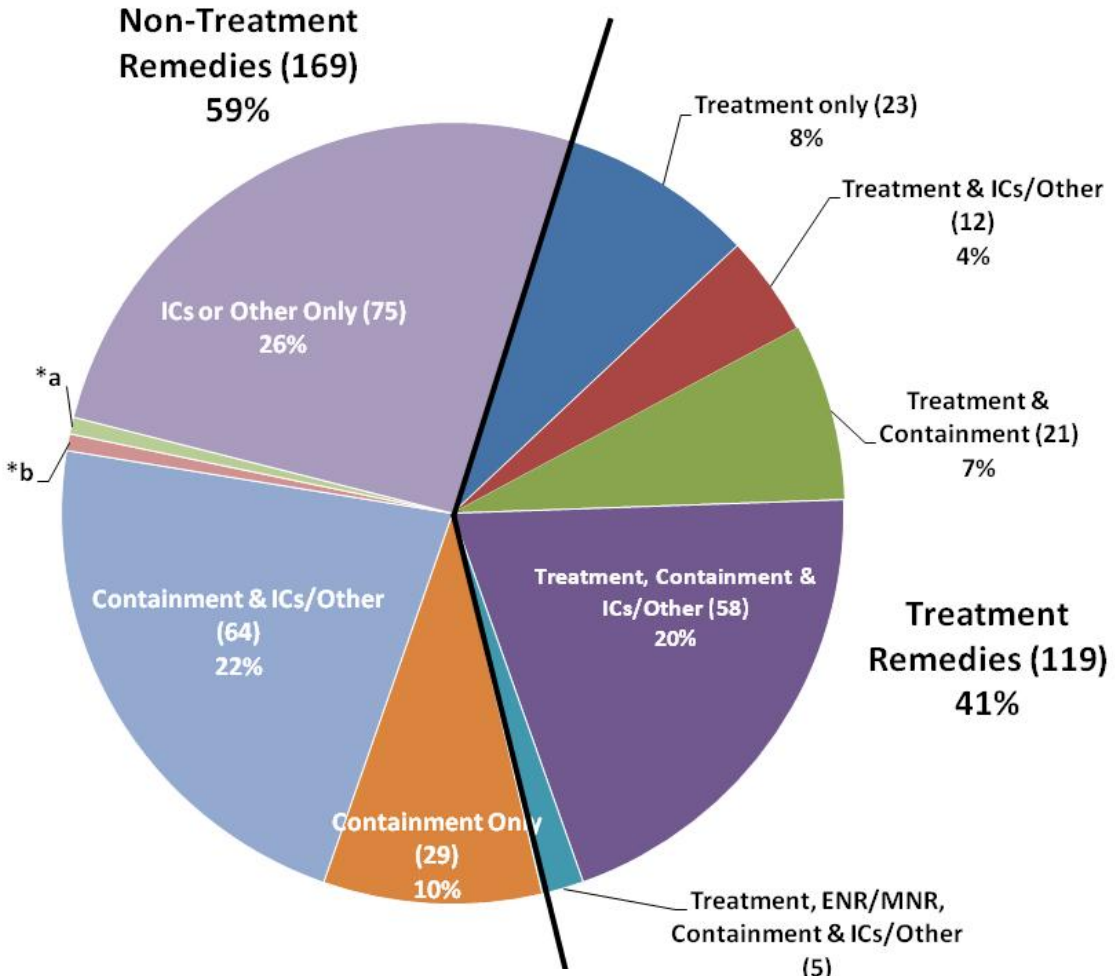
- Superfund law established preference for treatment and permanent remedies
- In early years that was a challenge; we did not have many alternatives to contain, burn, or pump and treat remedies
- Over time Superfund program has succeeded in implementing treatment remedies at over 70% of NPL sites
- At many sites we are treating both soil and groundwater contamination




Total number of sites with remedies = 1,468, 1982-2011

# Superfund Remedies for Sources[1] (2009–2011 )

- Remedies often selected and applied in combination
- For example, over 30% of treatment remedies were selected with other types of remedies
- We now have a rich mix of remedies available and mature consulting and engineering sector to implement them




*a: ENR/MNR & ICs/Other (2) 1%
*b: ENR/MNR, Containment & ICs/Other (2) 1%

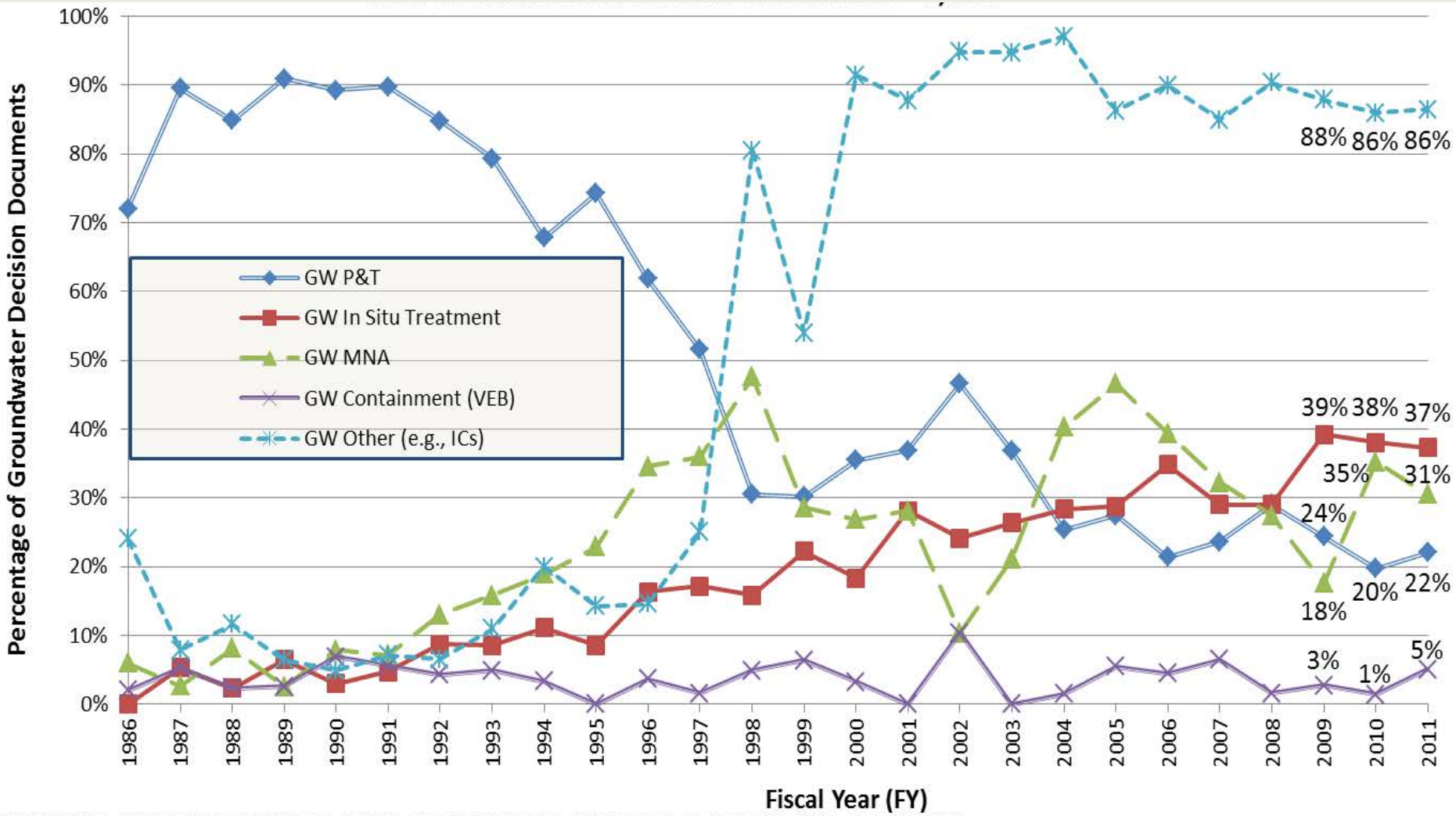
1. "Sources", include soil, sediment, solid waste, NAPL

# In Situ Source Treatment Technologies at Superfund Sites

- About 45% of treatment remedies for source control are currently in situ (in place)
- We are seeing fewer developments in new technologies, and more innovation in design, construction and operation of commercial technologies
- More aggressive remedies used to tackle source areas (such as in situ thermal treatment, chemical oxidation)
- Often coupled with groundwater remedies, treatment and non-treatment

| Technology | Total 2009-2011 | Percent 2009-2011 |
|---|---|---|
| **In Situ** | | |
| Soil Vapor Extraction | 25 | 14% |
| Chemical Treatment | 17 | 10% |
| Solidification/Stabilization | 11 | 6% |
| Multi-Phase Extraction | 9 | 5% |
| In Situ Thermal Treatment | 7 | 4% |
| Bioremediation | 5 | 3% |
| Subaqueous Reactive Cap | 2 | 1% |
| Flushing | 1 | 1% |
| Fracturing | 1 | 1% |
| Phytoremediation | 1 | 1% |
| **Total In Situ** | **79** | **45%** |

# Trends in Superfund Groundwater Remedies Selection (1986–11) Total Groundwater Decision Documents = 1,912

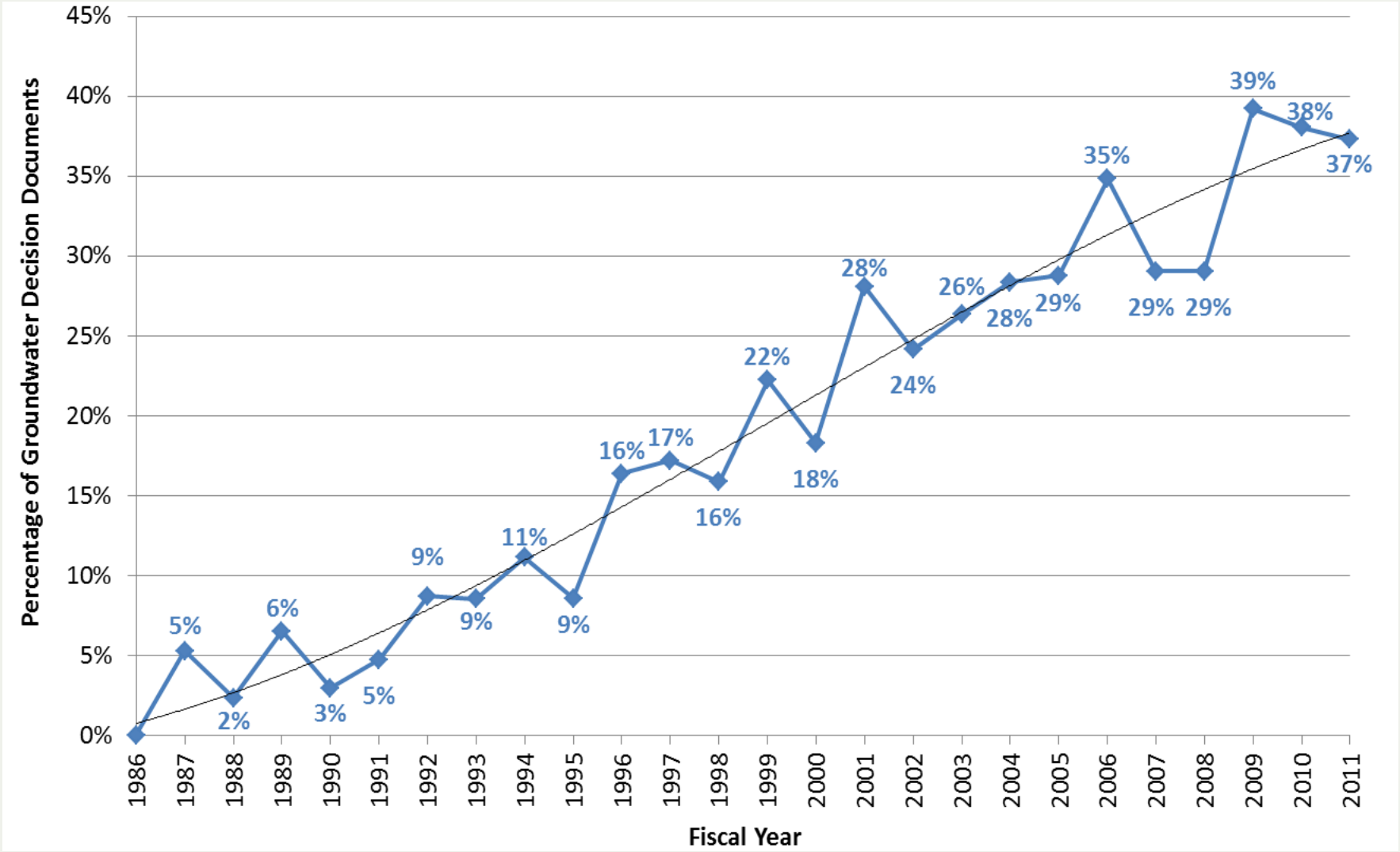


# Groundwater Remedy Types Recently Selected in Superfund

- Groundwater pump and treat still common, but we see more in situ treatment remedies
- Monitored natural attenuation is used either alone or in combination
- Concept of "adaptive management" gaining ground: Actively monitoring operating systems to determine optimal transition time and place between remedy components

| Remedy Type and Technologies | Total (FY09–11) | Percent (FY09–11) |
|---|---|---|
| **Groundwater Pump and Treat** | **44** | **12%** |
| **In Situ Treatment of Groundwater** | **78** | **21%** |
| Bioremediation | 49 | 13% |
| Chemical Treatment | 27 | 7% |
| Air Sparging | 14 | 4% |
| Permeable Reactive Barrier | 8 | 2% |
| In-Well Air Stripping | 2 | 1% |
| Multi-Phase Extraction | 2 | 1% |
| **MNA of Groundwater** | **56** | **15%** |
| **Groundwater Containment (VEB)** | **6** | **2%** |
| **Engineered (Constructed) Wetland** | **3** | **1%** |
| **Other Groundwater** | **177** | **49%** |
| Institutional Controls | 173 | 48% |
| Alternative Water Supply | 13 | 4% |
| Engineering Controls | 2 | 1% |

# In Situ Groundwater Treatment: Increasing Use in Superfund






Total number of groundwater decision documents = 1,912

# New Technologies Drive Project Management Changes

- Use of improved field sampling and analytical technologies yield abundant, reliable, and relatively inexpensive field data
- Traditional cycle of demobilizing to update the conceptual site model negates benefits of real-time information
- A dynamic work strategy (DWS) is needed to identify and eliminate data gaps and test the CSM, in the field
- So we now begin with systematic planning to develop baseline CSM, identify data gaps, and develop DWS

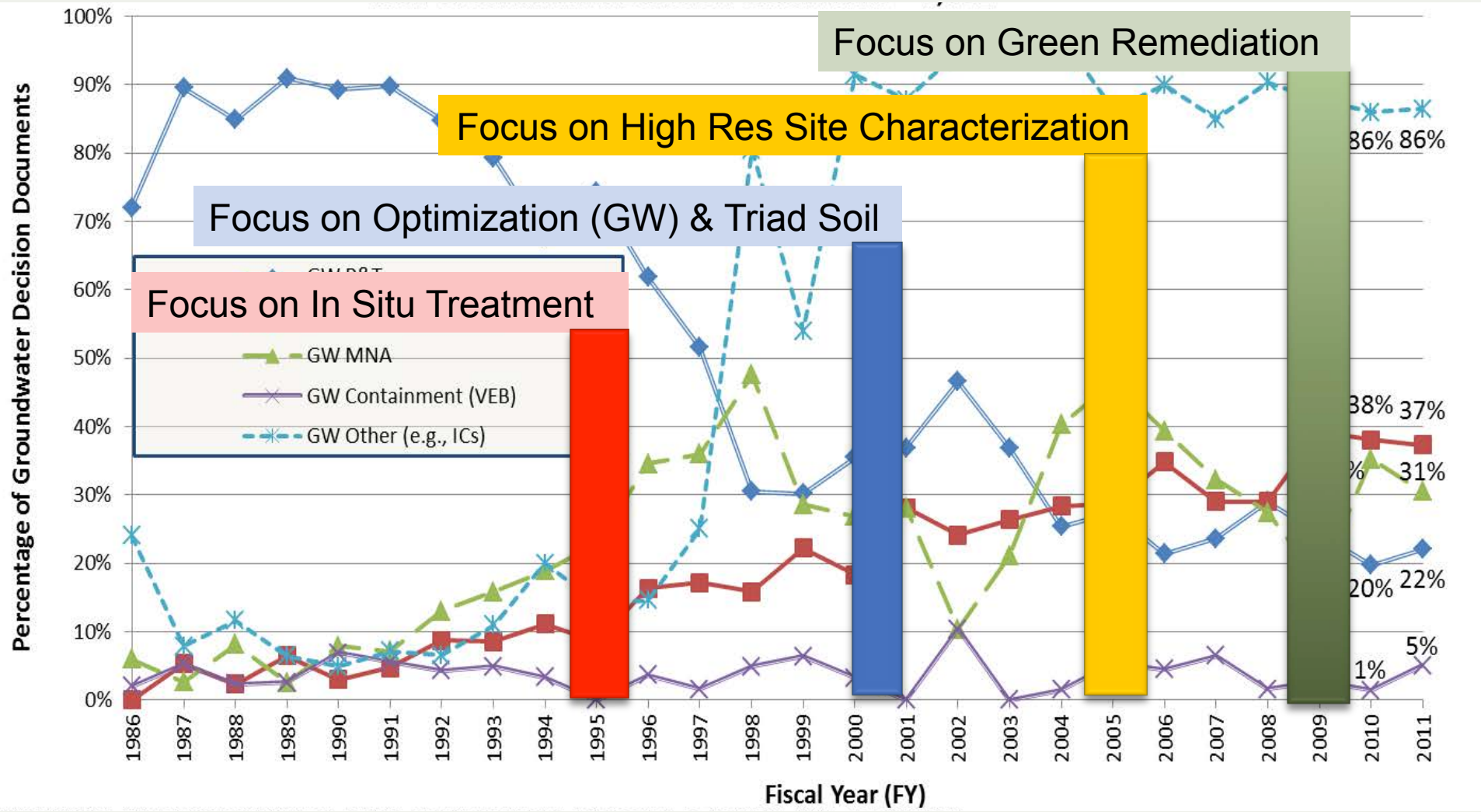
# Developments Beyond New Remediation Technologies

- Integrating field sampling and analytical technologies to address uncertainty and inform active remedy operation decisions
- Improving our understanding of in situ processes to better design, operate, and monitor remedy performance
- High resolution site characterization - a necessary tool for more effective in situ remedies, enabling adaptive management and reducing remedy footprints
- Optimizing remedies in long-term operation phase
- Green remediation in EPA's programs

# Managing Superfund in a Changing Landscape

- Decreasing budgets: $105 million reduction in Superfund annual remedial budget, and loss of 70 FTE, since 2011
- Program and Agency Priorities include:
  - Working Toward a Sustainable Future
  - Embracing EPA as a High-Performing Organization
- Administrator interest in statutory/regulatory/policy ideas that would leverage capabilities, demonstrate progress sooner, and make more efficient use of Superfund resources to maintain program accomplishments
- Maintain core mission functions with lower environmental footprints

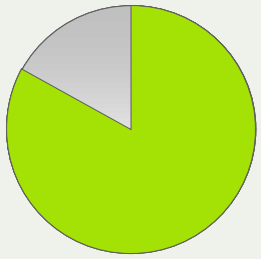
# Recent Technical and Policy Trends in Superfund Groundwater Remedies
## (Underlying Chart = Superfund Groundwater Remedy Selections)



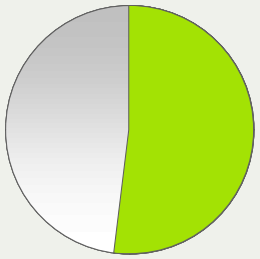
# Remedy Optimization in EPA's Superfund Program

# Optimization: Revisiting long-term remedies
## Analysis of 52 of 150 optimized sites in Superfund

- Cost savings



83% cost savings opportunities

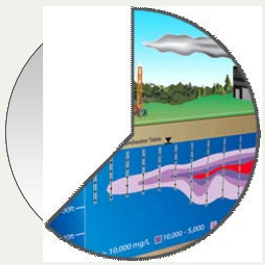


52% cost savings opportunities > $1 million

- Improved protectiveness

19% eliminate or confirm no ecological exposures

33% eliminate or confirm no human exposures

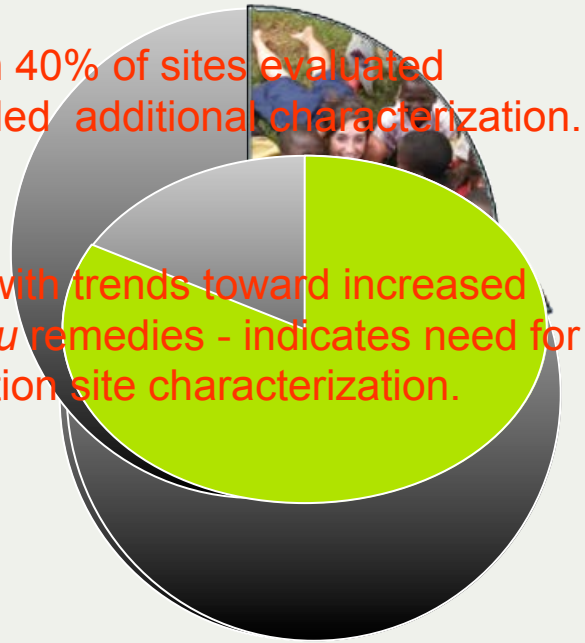


62% improve or confirm control of plume migration

***Similarly positive findings for the other 98 optimized sites…***

***and >$350M in potential cost savings/avoidance for all 150 sites.***

**More than 40% of sites evaluated recommended additional characterization.



Combined with trends toward increased use of *in situ* remedies - indicates need for high-resolution site characterization.

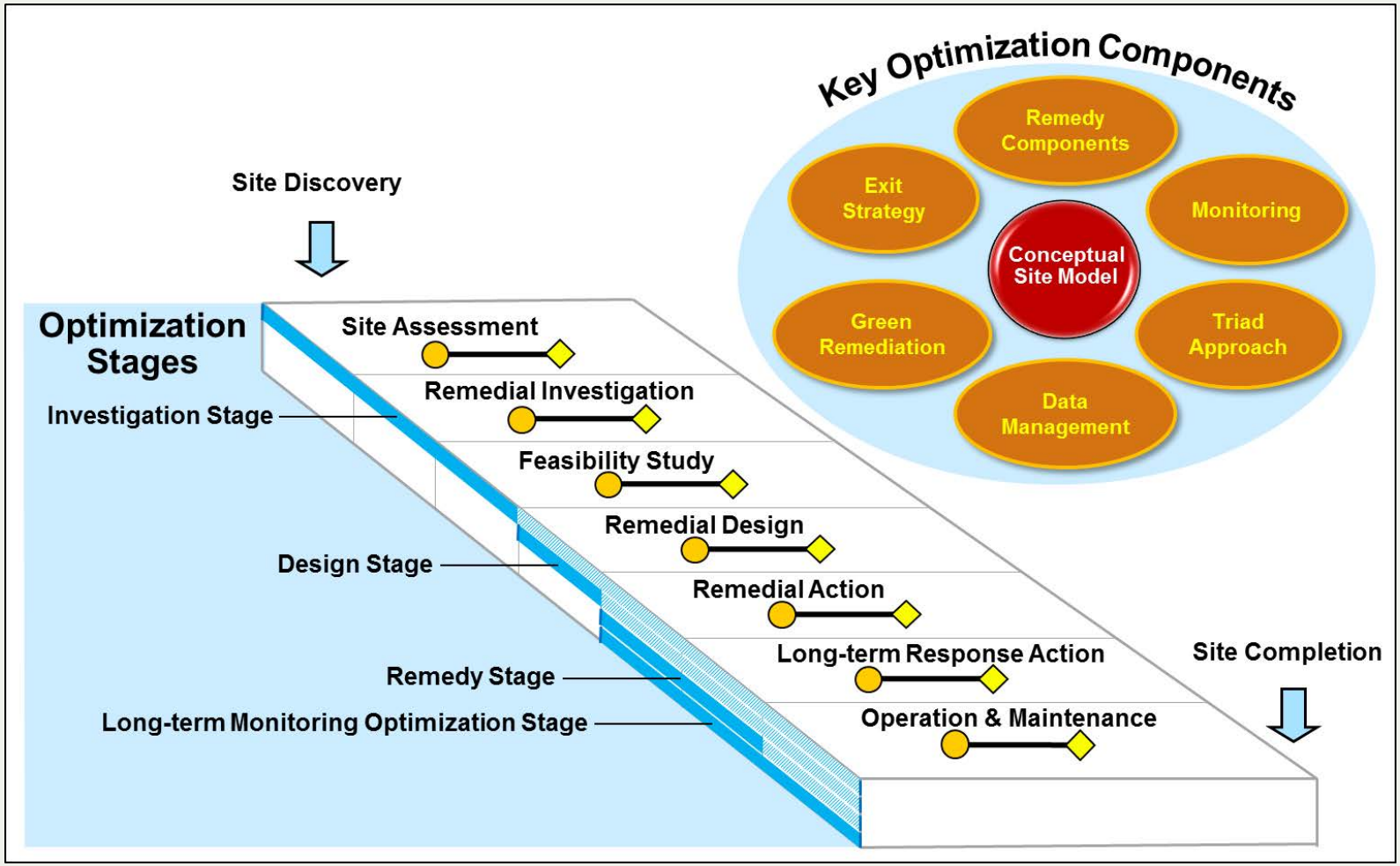
83% of sites had cost savings opportunities

33% eliminate or confirm no human exposures

# Working Definition of "Optimization"

***Systematic site review by a team of independent technical experts, at any phase of a cleanup process, to identify opportunities to improve remedy protectiveness, effectiveness and cost efficiency, and to facilitate progress toward site completion.***

# From Discovery to Completion



# Optimization During The Investigation Stage

- **Historical information and data**
  - » Geology / hydrogeology / chemistry / operations
  - » Data quality / usability / net information value
  - » 3-D visualization and analysis
- **CSM status / alignment with project life cycle needs**
  - » Plume delineation; plume core & migration pathways
  - » Source identification
- **Technologies previously applied / may apply in future**
  - » Analytical, sampling and measurement tools
- **Key stakeholder needs**
- **Exit strategy considerations**

# Frequent Review Findings & Recommendations

- **Data**
  - » Numerous prior data collection efforts, data not leveraged
  - » Low data density = high spatial uncertainty
  - » Non-existent or inadequate CSM
  - » Improve CSM
  - » Use HRSC approaches
  - » Develop collaborative data sets
- **Strategy & Technologies**
  - » Static vs. dynamic work strategies
  - » High cost, conventional methods
  - » Scale of measurement ≠ heterogeneity
  - » Design investigation around CSM gaps
  - » Apply systematic project planning
  - » Scale of measurement = heterogeneity
- **Decision ability**
  - » End data users not adequately considered
  - » Plan for and collect collaborative data to support risk assessment, remedy selection and design

# Optimization - The Design and Construction Stages

## Why Optimize

- Concerns regarding protectiveness or cost
- Concerns regarding current CSM
- Differences in opinion among members of site team
- Concerns or uncertainty regarding key conclusions or findings from site consultant
- Unexpected monitoring results

## Sources of Information

- Remedial Investigation and Feasibility Study Reports
- Decision documents
- Design submittals (including tech memos)
- Pilot test results
- Work plans for future work
- Implementation reports (such as construction, start-up, performance monitoring)
- And many other potential documents as appropriate

# Frequent Review Findings

- **Alternative approaches or technologies are available for implementing selected remedy**
  - Example 1 – Carefully designed permanent injection wells instead of direct-push injections
  - Example 2 – Pre-fabricated system instead of on-site building
  - Example 3 – Treatment and reinjection instead of discharge to POTW
  - Example 4 – Use of extracted groundwater instead of potable water for reagent blending, injection, and circulation

# Frequent Optimization Recommendations

- Refinements to CSM through additional monitoring or testing
- Suggestions for improving numerical model
- Suggestions for reducing/streamlining costs and cost estimates
- Phase remedial components so later components benefit from results of earlier phases
- Consider specific alternative approaches or technologies

# Optimization: Long-term remedies

## Why Optimize

- Remedy not achieving goals in time-frame
- Cost issues
- Questions of long-term protectiveness
- Property re-development or transfer to state – expedited time frame
- Energy, efficiency and effort
- Exit strategies

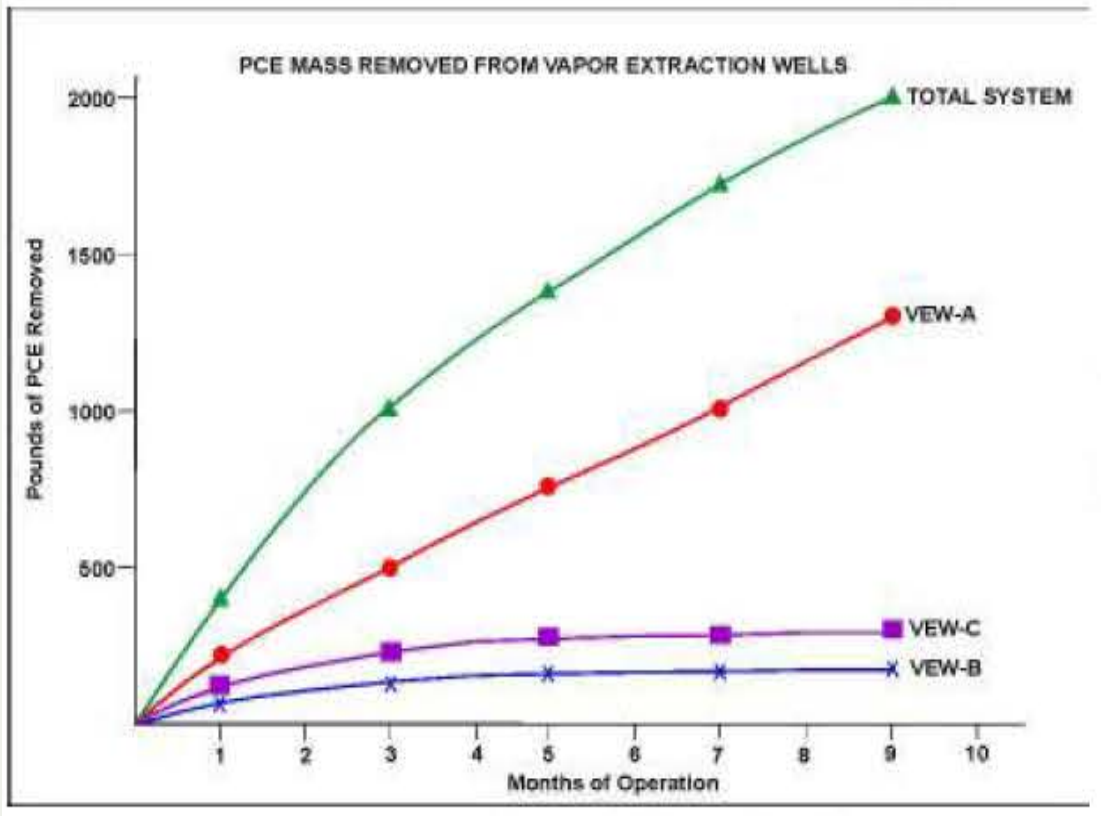
## What we review

- **CSM – all of it**
  - » Original CSM at time of design
  - » Changes to CSM since design
- **Remedies**
  - » Remedial Objectives
  - » Original Remedial Design
  - » Identify Performance Criteria
  - » Performance data -- *Correlate treatment performance with cost*

**Goal: Improve Protectiveness, Efficiency (cost, carbon, effort) and Time to completion.**

# What is Frequently Reviewed

- Changes in COC concentrations
- Rate of mass removal
- Effluent discharge
- Evaluate costs/ effort/ carbon/
- Containment
- Monitoring network



# What is Frequently Reviewed

- Extraction and monitoring well locations
- Amendment injection amount/location
- Groundwater extraction performance
- Re-injection, release, reuse
- Air stripping – GAC – ion exchange
- Chemical feed and storage

- Conditions since end of active remedy

# Frequent Optimization Findings & Recommendations

## Findings

- **Improve CSM**
  - » Sources
  - » Low and high permeability zones
  - » NAPL
- **Data management**
  - » Tracking and reporting performance
  - » Spatial data
  - » Historic data (paper → electronic)

## Recommendations

- **Remedy system components**
  - » Operational improvements
  - » Update current system
  - » Monitoring optimization (LTMO)
- **Change Remedy Strategy**
  - » P&T to MNA
- **Exit strategy**
  - » How close are we to cleanup?
  - » What data do we need to show attainment?

# High Resolution Site Characterization: The Basics

# High Resolution Site Characterization: A Working Definition

**A subsurface investigation appropriate to the scale of heterogeneities in the subsurface which control contaminant distribution, transport and fate, and that provides degree of detail needed to understand:**

- **Exposure pathways**
- **Processes affecting the fate of contaminants**
- **Contaminant mass distribution and flux by phase and by media (mobile and immobile)**
- **How remedial measures will affect the problem**

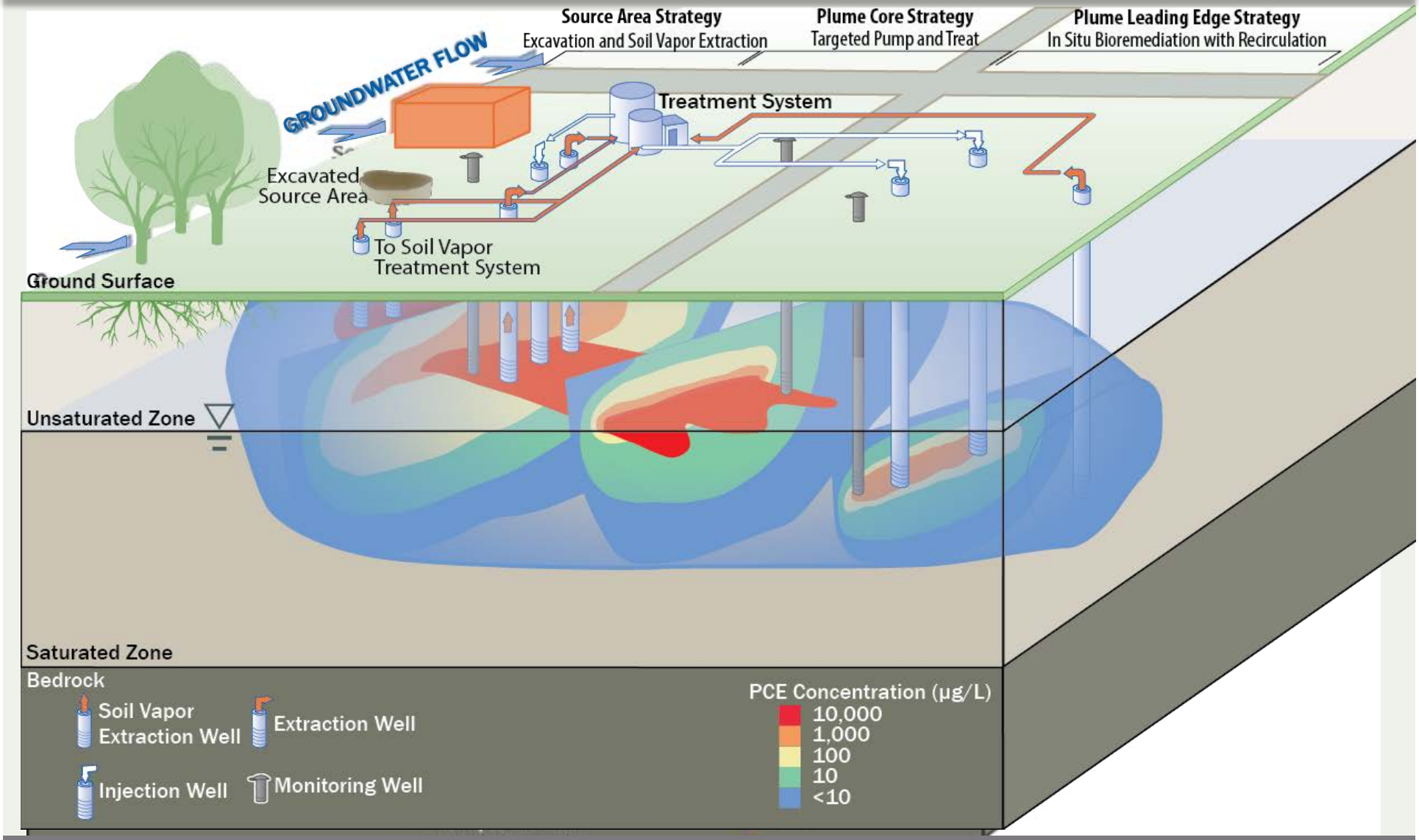
# Key Priorities of HRSC

- **HRSC Addresses Scale First**
  - » If measurements are made at the wrong scale it is very hard to understand that which is being measured no matter how many measurements are made
- **HRSC Addresses Measurement Spacing, Density and Placement Second**
  - » Measurements made at the right scale will not help unless a sufficient number of measurements are made at the right spacing and in the right places
- **Collaborative data – "multiple lines of evidence"**
- **Clearer picture of subsurface heterogeneities**

Porosity Geochemistry Capillary pressure

Hydraulic Conductivity Hydraulic Head/Hydraulic Gradient

# HRSC: Improved site characterization and remedy design, operation and performance tracking



# Cost of Remedies vs. Cost of Characterization

- Remedies based on a flawed CSM may not perform as expected, increasing the time it takes to achieve remedial action objectives and the overall cost
- HRSC makes the investment upfront to obtain a more complete and realistic CSM
- Pay a little more now to avoid paying a lot more later
  - » Until the CSM reflects reality, investigation and cleanup will be costly –pay the costs upfront and get the CSM right the first time in order to avoid paying more late - conceptually….
- +50% Characterization, design, monitoring +$150,000
- -10% remedy operation & closure - $1,000,000

# HRSC Summary

- **HRSC uses transects of vertical profiles to overcome challenges of subsurface heterogeneity**
  - » Improved tools allow this approach for shallow and deep unconsolidated environments
  - » Monitoring wells are not optimal characterization tools because they are making measurements at too large of a scale
- **HRSC results provide the detailed information necessary to design and implement targeted in situ and ex situ remedies**
  - » HRSC can find the 75% to 95% of contaminant mass discharging in 5 to 25% of an unconsolidated aquifer, allowing the selected remedial action to target those zones
- **HRSC is applicable to the characterization of shallow and deep unconsolidated environments and fractured bedrock environments**

# Analysis of Superfund Groundwater Cleanups

# Groundwater Remedial Action Objectives (RAOs) and Cleanup Levels*

- **Numeric cleanup levels (restoration RAO)**
  - » Federal or state drinking water Maximum Contaminant Levels (MCLs)
  - » Risk-based contaminant concentrations
- **Containment of plume (nonrestoration RAO)**
  - » Prevent migration (horizontal & vertical)
  - » Protect surface water bodies
  - » Protect drinking water wells

* Analysis conduced on 43 Superfund projects in 2013. Original briefing provided by Linda Fiedler, 2015 REMTEC, Westminster Colorado.

# GW Contaminants Addressed

| Contaminant Group* | Number of Sites/OUs |
|---|---|
| Chlorinated VOCs (e.g., TCE) | 31 sites/OUs |
| Metals (e.g., Cr+6, As, Cd) | 21 sites/OUs |
| Nonchlorinated VOCs (e.g., BTEX) | 12 sites/OUs |
| PCBs, Pesticides, Dioxins and/or Furans | 11 sites/OUs |
| PAHs, SVOCs, and/or CSVOCs (e.g., creosote, pentachlorophenol) | 11 sites/OUs |

*28 of 43 GW sites (65%) had more than one contaminant group

*13 sites had observed or suspected dense nonaqueous phase liquids (DNAPLs)

# GW Cleanup Progress (Analysis of 43 Projects)

**Out of 34 projects with restoration goals:**

- **18 met restoration RAOs**
  - » All have reduced contaminant concentrations by 2 to 4 orders-of magnitude
- **16 restoration sites made significant progress**
  - » 6 within 10 ppb of cleanup level
  - » 3 of these have only 1 well that exceeds cleanup levels
  - » Half have reduced contaminant concentrations by 2 orders-of-magnitude
- **All 9 nonrestoration GW sites met RAOs**

# Examples of GW Remedy Performance

- ***Norton AFB, CA*****,** reduced TCE from 4,630 ppb to below MCL (5 ppb)
- ***Gold Coast Oil, FL*** remedy reduced PCE from 48,000 ppb to <3 ppb (EPA MCL 5 ppb)
- ***Western Processing, WA*** remedy reduced DCE conc. of 10,000 ppb in offsite plume to ND (EPA MCL 70 ppb)
- ***Island Chemical, VI*** remedy reduced total toluene/ ethylbenzene/xylene conc. from 176,000 ppb to 13 ppb (all individual contaminant conc. below EPA MCLs)

# GW Remedy Findings

- In general, multiple treatment methods often combined to address:
  - » different media,
  - » different contaminants in the same media, or
  - » different contaminant concentrations
- GW remediation often preceded by or combined with source control remedies (e.g., excavation & removal, capping, vertical engineered barriers)
- GW restoration achieved with only P&T at some sites
- Remedy optimization or changes often occurred

# Remedy Findings Related to Hydrogeologic Complexity

- Range of hydrogeology (from homogeneous to fractured)
- Traditional technologies (such as P&T, SVE, air sparging) effective at sites with dissolved phase plumes (e.g., cVOCs) in permeable homogeneous & layered/interbedded aquifers
- Other supplemental technologies (such as ISCO and in situ thermal treatment) necessary for sites with non-VOC contaminants in same subsurface environments

# GW Remediation Time Frames

- Sites with more homogeneous and permeable subsurface, smaller plumes and lower initial concentrations usually required less time to meet GW RAOs/cleanup levels
  - » Homogeneous – 4 to 6 years (3 sites)
  - » Heterogeneous – 9 years (1 site)
  - » Layered/Interbedded – 6 to 24 years (6 sites)
  - » Fractured – 10 years (1 site)

# New Suite of Groundwater Guidance

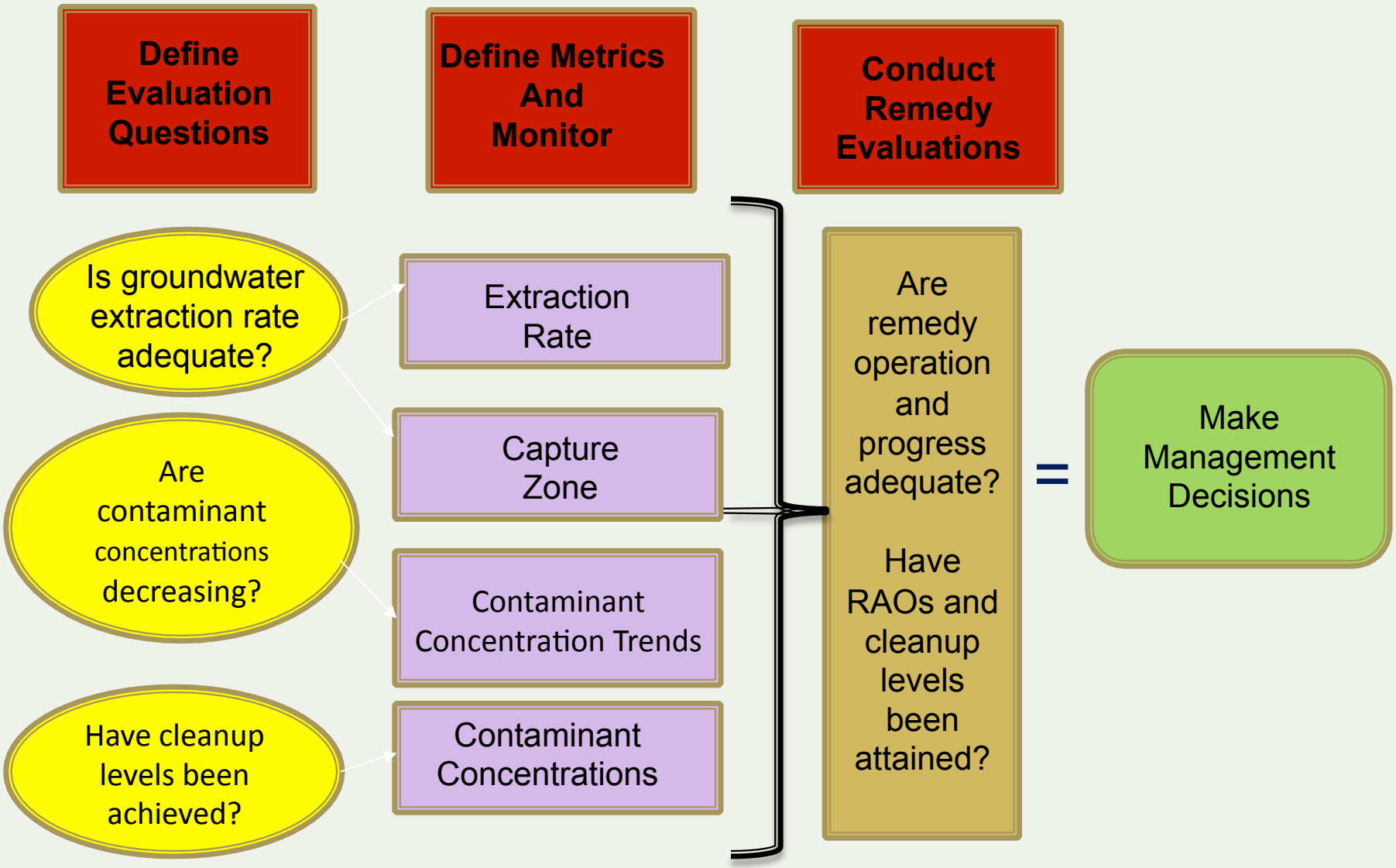
- ***Groundwater Remedy Completion Strategy*** (May 2014)
- ***Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions*** (Nov. 2013)
- ***Recommended Approach for Evaluating Completion of Groundwater Restoration Remedial Actions at a Groundwater Monitoring Well*** (August 2014)
- ***Groundwater Statistics Tool*** (August 2014)

# Groundwater Remedy Completion Strategy
## (May 2014, OSWER 9200.2-144)

- Recommends step-wise planning and decision-making processes for evaluating groundwater remedy operation and progress toward achieving groundwater RAOs and cleanup levels
- Process to focus resources toward effective and efficient completion of groundwater remedies
  - Understand current site conditions
  - Design site-specific remedy evaluations
  - Develop performance metrics and collect monitoring data
  - Conduct remedy evaluations using site-specific metrics
  - Make management decisions

# Example Groundwater Remedy Completion Strategy

***Assumes a current conceptual site model*



# The recommended strategy does NOT…

- Alter Agency approach for setting RAOs or cleanup levels
- Change existing guidance or policy on remedy selection
- Address groundwater classifications or use designations
- Request that states or tribes alter existing groundwater classification or use designations

# Guidance for Evaluating Completion of Groundwater Restoration Remedial Actions (November 2013, OSWER 9355.0-129)

- **Recommends evaluating contaminant of concern (COC) concentration levels on a well-by-well basis**
- **Well-specific conclusions used with conceptual site model to demonstrate that:**
  - » Groundwater has met and
  - » Will continue to meet cleanup levels for all COCs in the future

# Groundwater Statistical Tool
(August 2014, OSWER 9283.1-46)

- **Supports EPA's recommended approach for evaluating groundwater restoration actions**
- **Tool uses statistics to evaluate completion of a groundwater remediation action at a specific well for a specific contaminant**
  - » Remediation Monitoring Phase
  - » Attainment Monitoring Phase
- **May also be used to evaluate data trends during cleanup**

# Groundwater Remedy Analysis - Conclusions

- Superfund has successfully cleaned up hard-to-remediate GW sites to achieve RAOs/cleanup levels in many different settings
- Superfund has used multiple remediation approaches, especially for challenging sites
- Remedy optimization and changes have resulted in cleanups
- Superfund has used and achieved nonrestoration RAOs
- Superfund striving to focus resources on information and decisions needed to effectively complete groundwater remedies

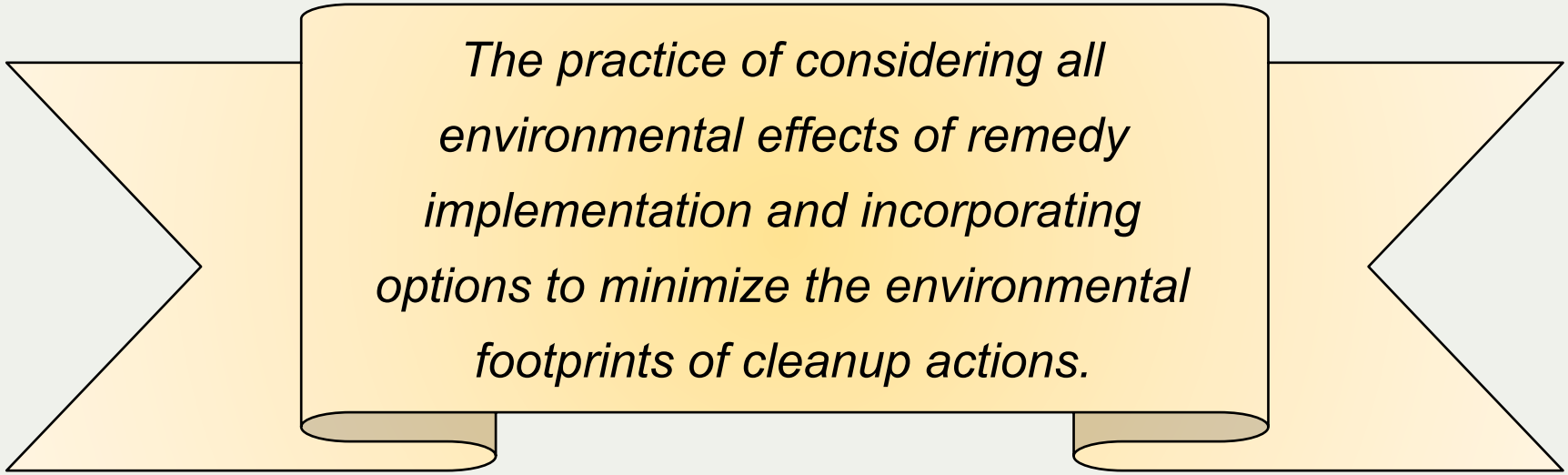
# Greener Cleanups & Sustainability in Superfund Cleanups: Completing the Sustainability

# Sustainability in Superfund Site Remediation

- **Social:**
  - » Engaging communities in site cleanup decisions
  - » Turning contaminated sites into community assets
- **Economic:**
  - » Redevelopment in blighted areas (aligns with smart growth goals)
  - » Fostering employment opportunities in communities where sites are cleaned up
  - » Rising property values in communities
  - » Remediation in the U.S.: A $7billion/year economic engine
- **Environmental:**
  - » Protecting Human Health and the Environment
  - » Liberating contaminated sites for reuse (1 remediated acre redeveloped = 4 acres of green field development)
- **Challenge: A smaller environmental footprint cleaning up sites**

# Challenge: Lowering the Environmental Footprint of Site Cleanup Projects

## Green Remediation




*as defined by US EPA, *a.k.a.* greening response actions, greener cleanups, etc.

# Addressing the Environmental Leg of Sustainability: Core Elements of Green Remediation

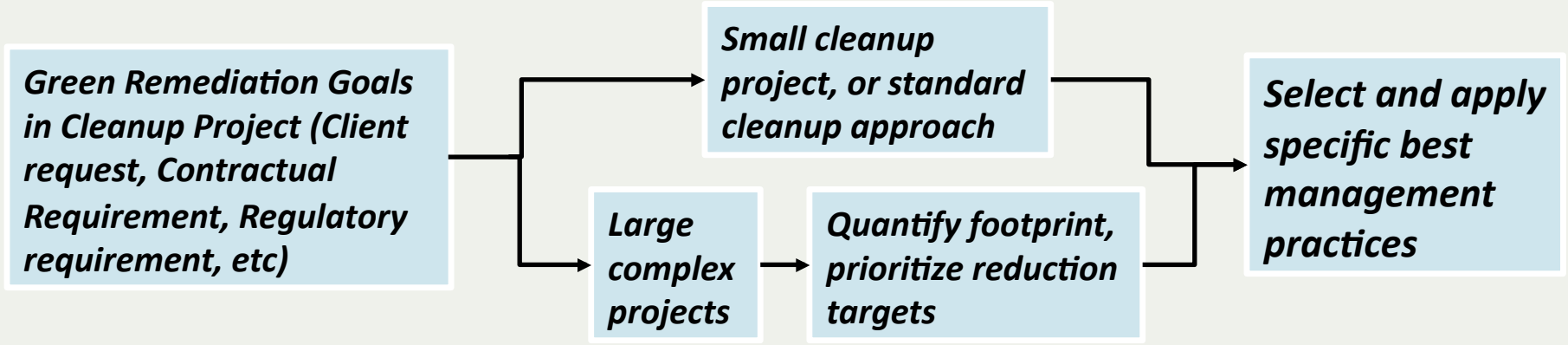
# Implementation of GR in EPA Contaminated Site Programs

- Define internal policies, strategies and program action plans:
  - Cross-Agency Principles for all cleanup programs
  - Superfund green remediation strategy & 40 action items
  - Update contracting language to reflect new practices
- Develop technical guidance for practitioners
  - Best management practice fact sheets (13 to date)
  - Environmental footprint evaluation methodology
- Leverage voluntary market driven options
  - ASTM Standard Guide for Greener Cleanups

# The Role of the ASTM Guide in Greener Cleanups

→ ***ASTM Standard Guide for Greener Cleanups (E2893):***

- ***Codifies best practices and defines a process for reducing environmental footprint***
- ***Includes over 160 BMPs and outlines process for straight BMP application or use of quantification***
- ***Useful protocol for contracting purposes***
- ***Results in a transparent documented process that is reported publicly***

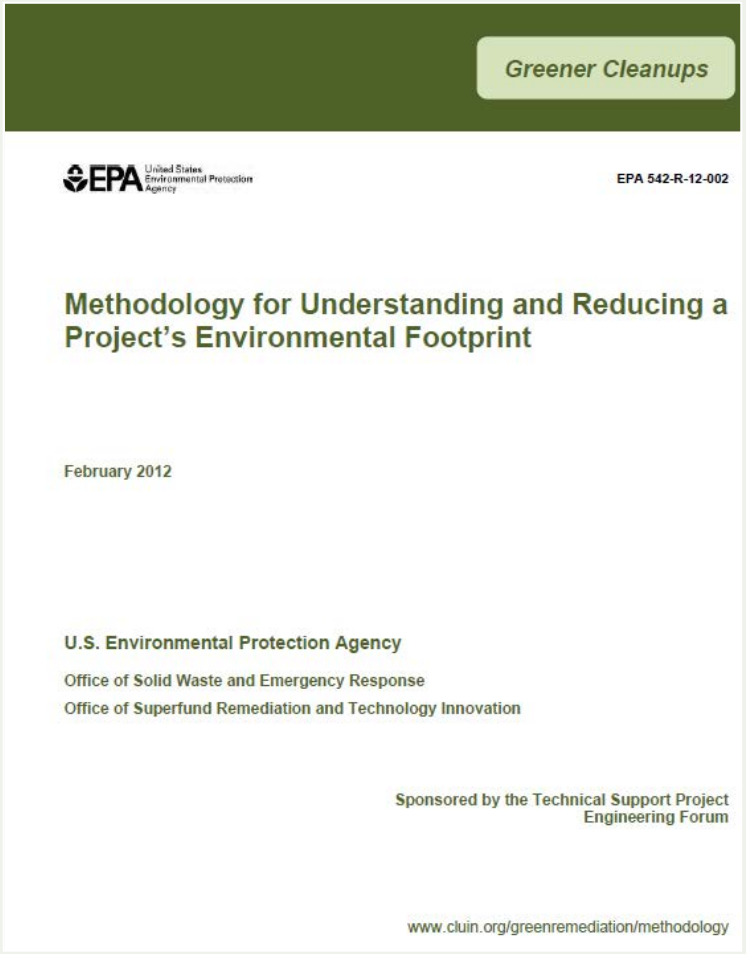


# Options for Implementing Green Remediation

- **Direct Use of Best Management Practices (BMPs)**
  - Excavation and Surface Restoration
  - Site Investigation
  - Pump and Treat Technologies
  - Bioremediation
  - Soil Vapor Extraction & Air Sparging
  - Clean Fuel & Emission Technologies for Site Cleanup
  - Integrating Renewable Energy into Site Cleanup
  - Sites with Leaking Underground Storage Tank Systems
  - Landfill Cover Systems & Energy Production
  - Mining Sites
  - Implementing In Situ Thermal Technologies
  - Overview of EPA's Methodology to Address the Environmental Footprint of Site Cleanup

www.cluin.org/greenremediation/

- **For Complex Projects – Apply Footprint Methodology**



# Standard Guide for Greener Cleanups : Integrating Greener Cleanup Goals at Sites

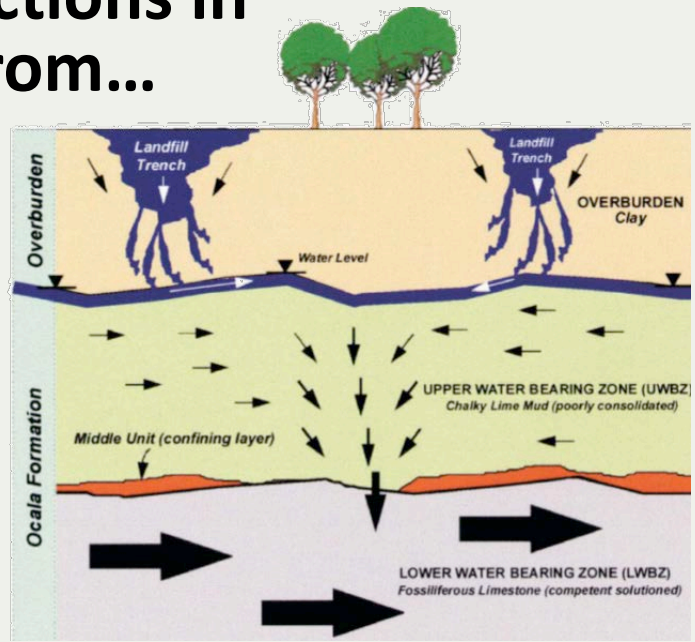
- **Provide clear definitions, methods and expectations for all stakeholders**
- **Leverage private sector resources**
- **Harness corporate responsibility**
- **Incorporate new approaches**
- **Build upon state and local incentives**
- **Minimize green-washing**

# What the Standard Guide Does

- **Codify best practices**
- **Define a process for reducing environmental footprint**
- **Provide a protocol for contracting purposes**
- **Provides "brand recognition" for greener cleanups**
- **Results in a transparent documented process that is reported publically**

# Summary: Leveraging innovation efficient remedies with a lower environmental footprint

- **Cost effectiveness and large reductions in environmental footprints come from…**
  - » Accurate CSM
  - » Well-characterized source areas and contaminant plumes
  - » Optimal remedial strategy
  - » Adaptive management
  - » Streamlined performance monitoring




- **Further environmental footprint reductions are achieved applying green remediation best management practices**
- **As a result, we sustainably protect human health and the environment prepare sites for reuse**

# Overview

- We have made significant progress in pollution prevention and remediating legacy contaminated sites, but we still have work to do
- Remediation sector is benefiting from years of investments and technology developments. Once "innovative approaches" are now mainstream
- Several evolving concepts are helping us achieve protectiveness at lower cost and environmental footprint
- EPA seeks to further reduce the environmental footprint of cleanups, while integrating community interests, and supporting economic growth

# Thank You!

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**Presentation available at - http://cluin.org/global**

# EPA Information and Resources

**Superfund Remedies Report:**
http://www.epa.gov/superfund/remedytech/srr/

**Key EPA Superfund Groundwater Policies:**
http://www.epa.gov/superfund/health/conmedia/gwdocs/

**Groundwater Remedial Action Completion Guidance(s):**
http://epa.gov/superfund/health/conmedia/gwdocs/remedial.htm

**Remedy Optimization:**
http://www.cluin.org/optimization/

**Green Remediation:**
http://cluin.org/greenremediation

**High Resolution Site Characterization:**
http://cluin.org/hrsc

# Federal and State Links to Optimization Resources

- **EPA's Remedy Optimization**
  - » www.epa.gov/superfund/cleanup/postconstruction/optimize.htm
- **CLU-IN Optimization**
  - » www.cluin.org/optimization
- **U.S. Army Corps of Engineers**
  - » www.environmental.usace.army.mil/rse_checklist.htm
- **U.S. Army Environmental Command**
  - » www.aec.army.mil/usaec/cleanup
- **U.S. Air Force Center for Engineering and the Environment**
  - » www.afcee.af.mil/resources/restoration/rpo/index.asp
- **U.S. Naval Facilities Engineering Command**
  - » www.ert2.org/T2Opt/
- **Federal Remediation Technologies Roundtable**
  - » www.frtr.gov/optimization/
- **Interstate Technology Regulatory Council**
  - » www.itrcweb.org/teampublic_RPO.asp