Trends in Remedy Selection, Optimization and Green Remediation

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Vitoria-Gasteiz, Spain

EPA United States Environmental Protection Agency

PhytoSUDOE

Agenda

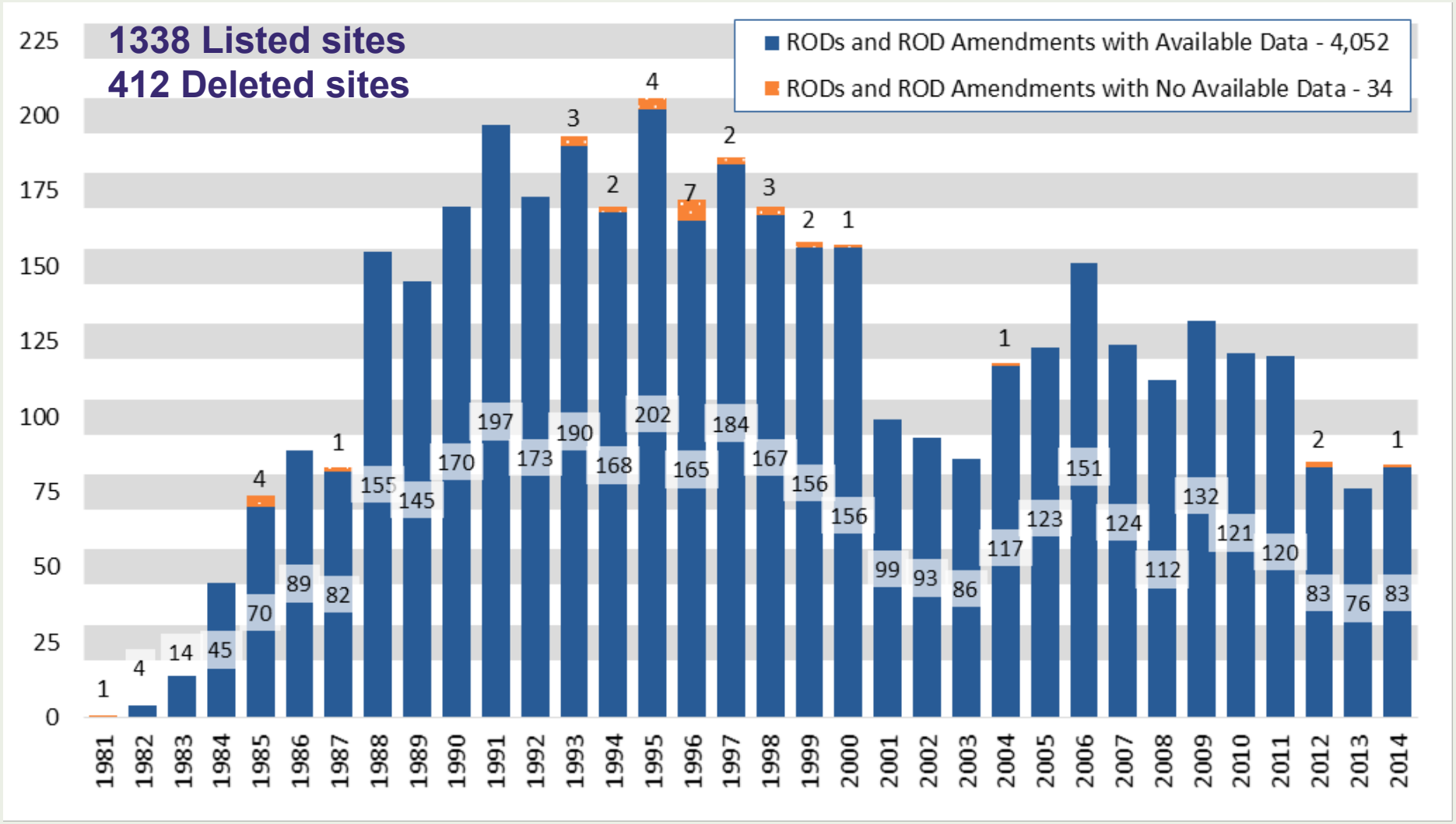
a) Recent trends in the selection of remedies in the Superfund Program
b) High level insights on the selection of phytoremediation technologies in Superfund
c) Green remediation ≠ phytoremediation
d) Lessons learned and best practices in the implementation of remedies
e) Three short field cases summarizing a-c, with a focus on phyto
f) Discussion

Types of Contaminated Site Remedies

- **Treatment *("reduction of toxicity, mobility or volume")***
  - Ex situ (above ground)
    - Such as *pump and treat* of groundwater with solvents
  - In situ (below ground)
    - Such as *soil vapor extraction* to remove solvents from soil or *chemical treatment* to destroy solvents in groundwater
- **Containment**
  - Capping of soil or landfills
- **Off-site Disposal**
  - Excavation and offsite disposal in a permitted landfill
- **Others**
  - Monitored Natural Attenuation
  - Alternative Water Supply
  - Institutional Controls

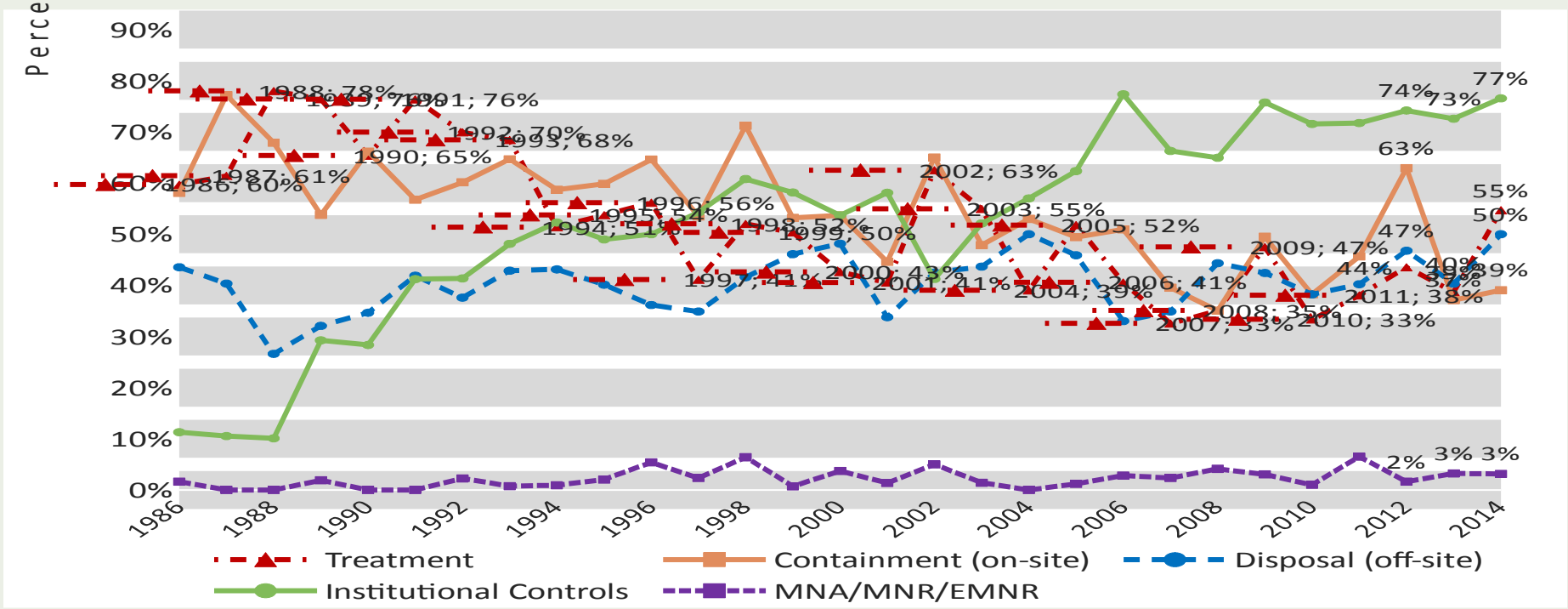
Superfund Law Established a Preference for Treatment in Remedy Selection

Remedy Decisions in the Superfund Program
"Records of Decision" per Year (FY 1981–2014)



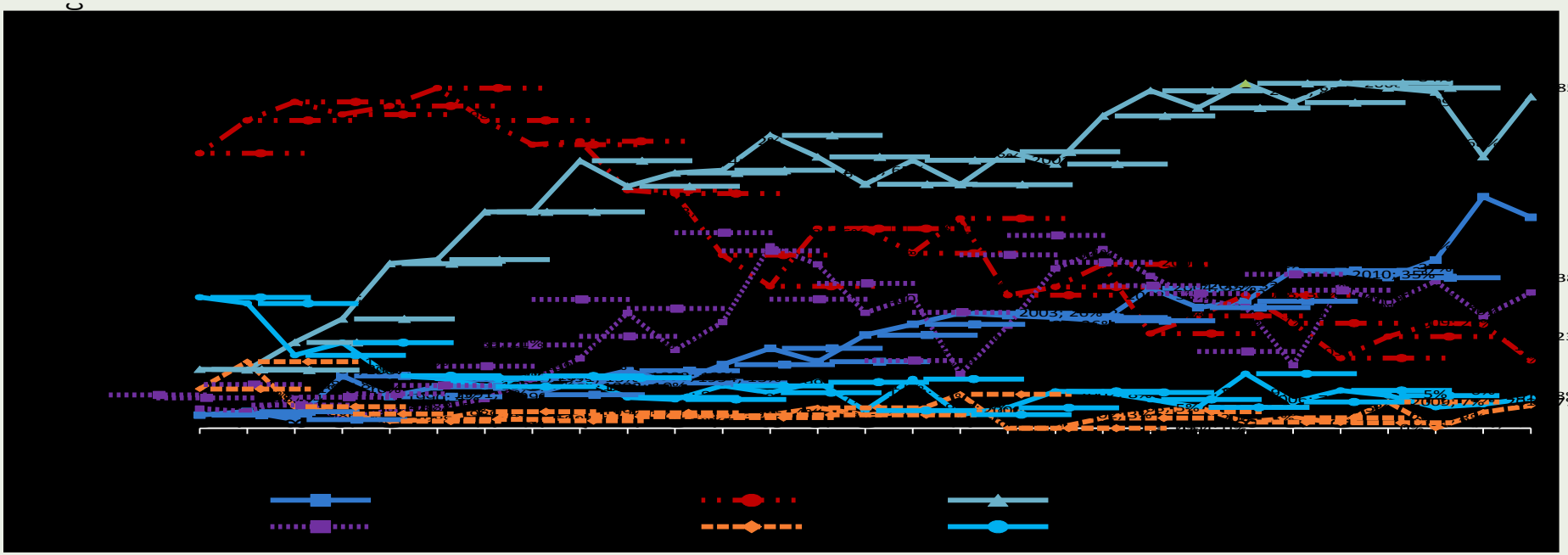
Superfund "Source" Remedy Selection Trends

Decision Documents with the Five Main Remedy Types (1986-2014)



Superfund Groundwater Remedy Selection Trends (FY 1986-2014)

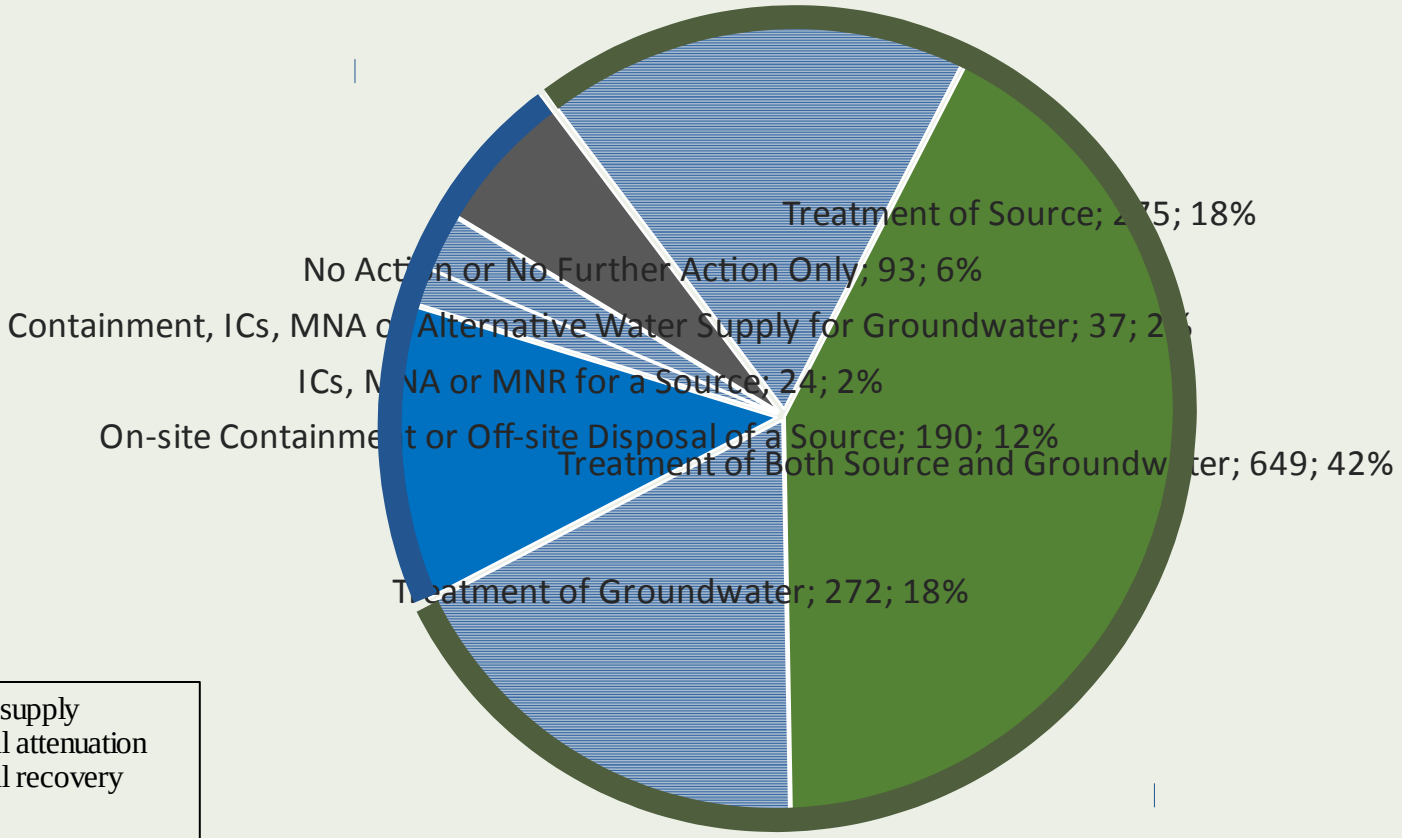
Percentage of Groundwater Decision Documents



Treatment at Superfund Sites (FY 1982-2014)

Non-Treatment, NA or NFA– 344 Sites (22%)

Treatment – 1,196 Sites (78%)

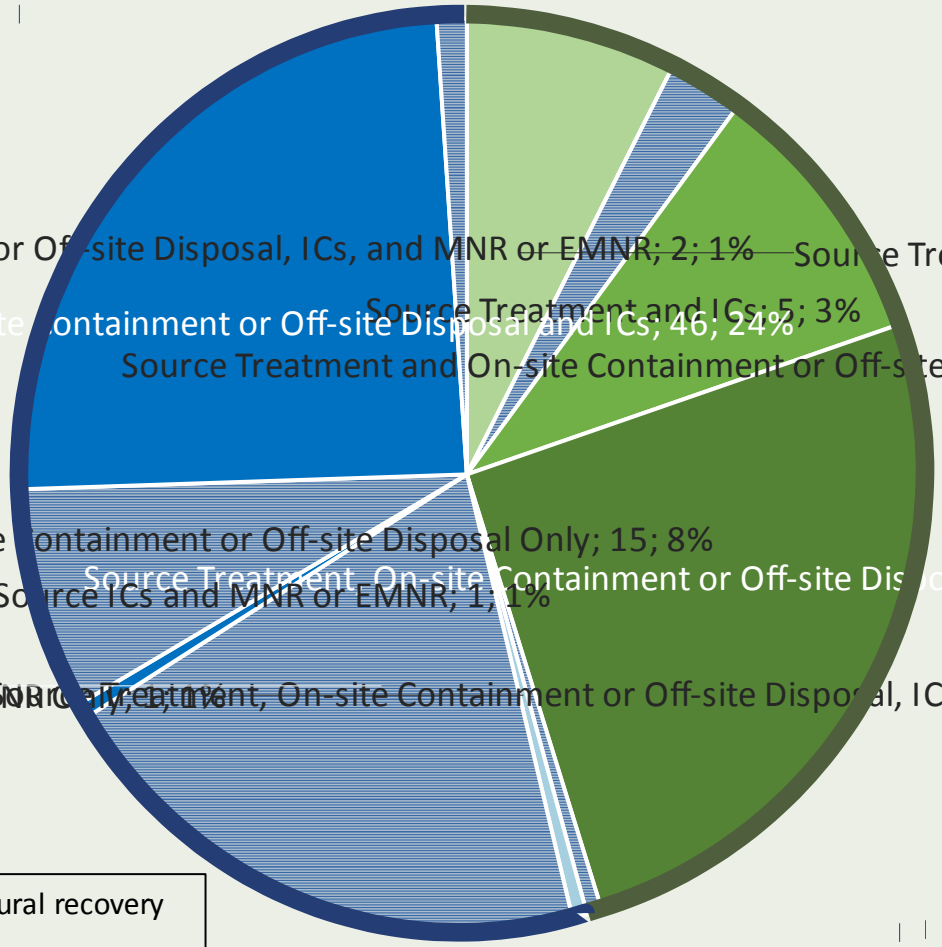


AWS = alternative water supply
MNA = monitored natural attenuation
MNR = monitored natural recovery
NA = No action
NFA = No Further Action

Combinations of Recent Source Remedies (FY 2012-2014)

Non-Treatment -102 (54%)

Treatment - 86 (46%)

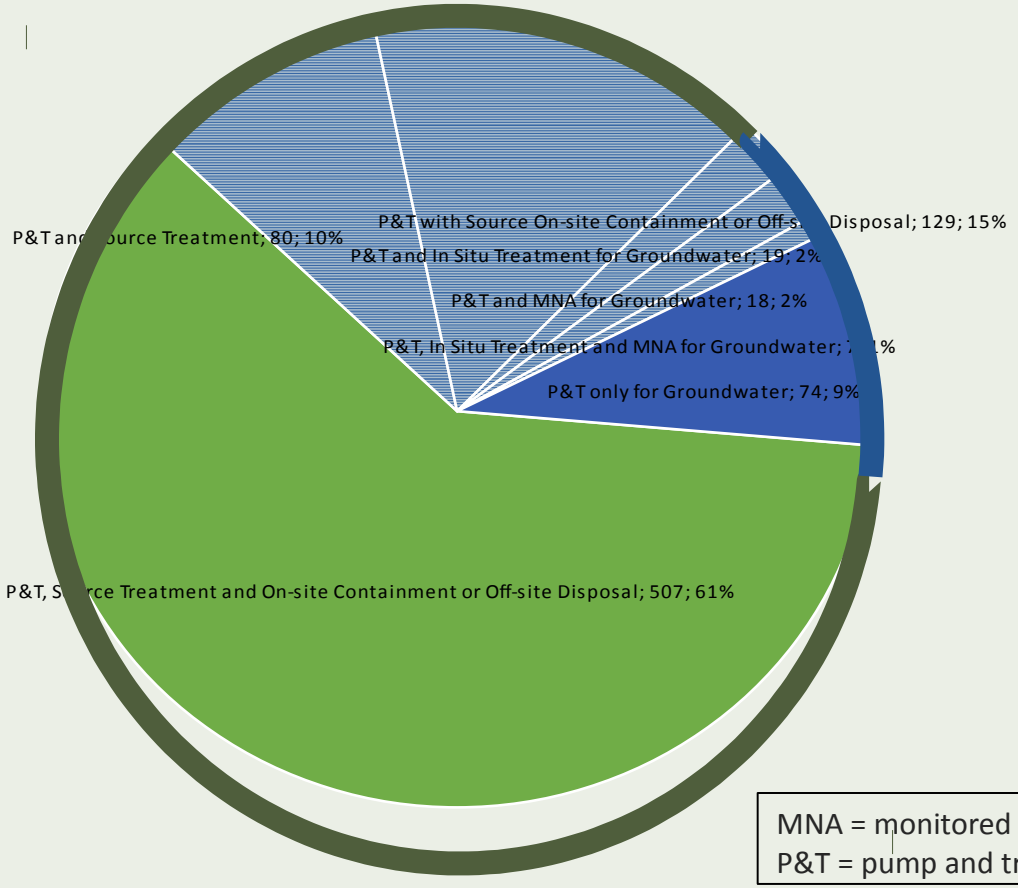


EMNR = enhanced monitored natural recovery
IC = institutional control
MNR = monitored natural recovery

Summary of 834 Groundwater P&T Remedies

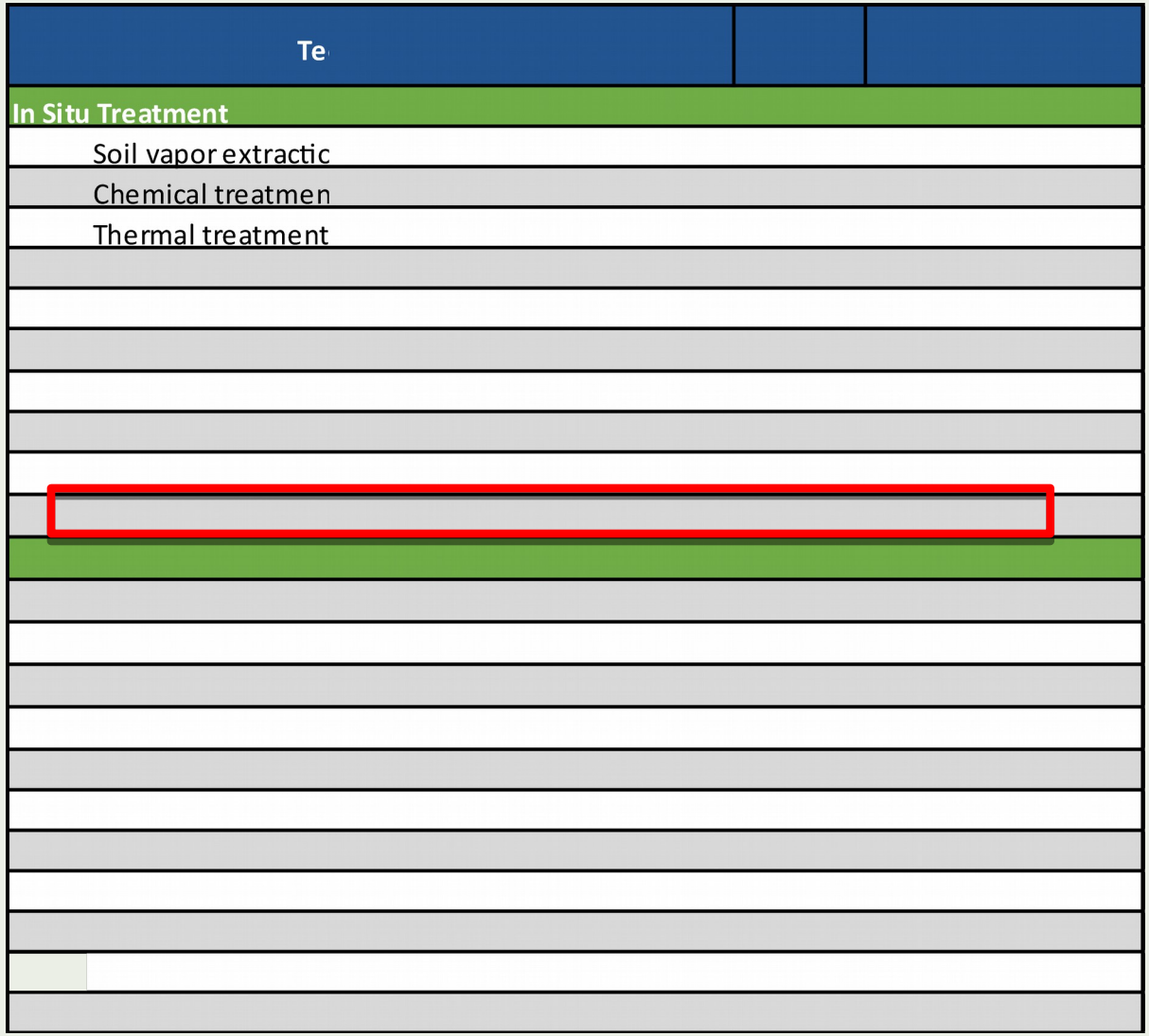
P&T with Source Control - 716
86%

P&T with no Source Control - 118
14%



MNA = monitored natural attenuation
P&T = pump and treat

Source Remedies Selected in Recent Decision Documents 2012-2014 Source Decision Documents = 188



Phytotechnology Applications: A Broader Window

Application	Media	Mechanisms
Constructed Treatment Wetland/ Aquatic Plant Lagoon	Sediment Surface Water	Phytodegradation Phytoextraction Phytovolatilization Rhizodegradation
Field Crops/ Grass, Forb, Herb, or Fern Gardens	Soil Sediment	Phytodegradation Phytoextraction Phytovolatilization Rhizodegradation
Landfill Cover	Soil Sediment Surface Water	Phytoextraction Phytohydraulics Phytosequestration
Riparian Buffer	Soil Sediment Surface Water Groundwater	Phytodegradation Phytoextraction Phytohydraulics Phytosequestration Phytovolatilization Rhizodegradation
Tree Hydraulic Barrier	Groundwater	Phytoextraction Phytohydraulics Phytosequestration
Tree/Shrub Plantation	Soil Sediment Groundwater	Phytodegradation Phytoextraction Phytovolatilization Rhizodegradation

Source Remedies Selected in Recent Decision Documents (FY 2012-2014)
Source Decision Documents = 188

Te		
In Situ Treatment		
Soil vapor extractic		
Chemical treatmen		
Thermal treatment		

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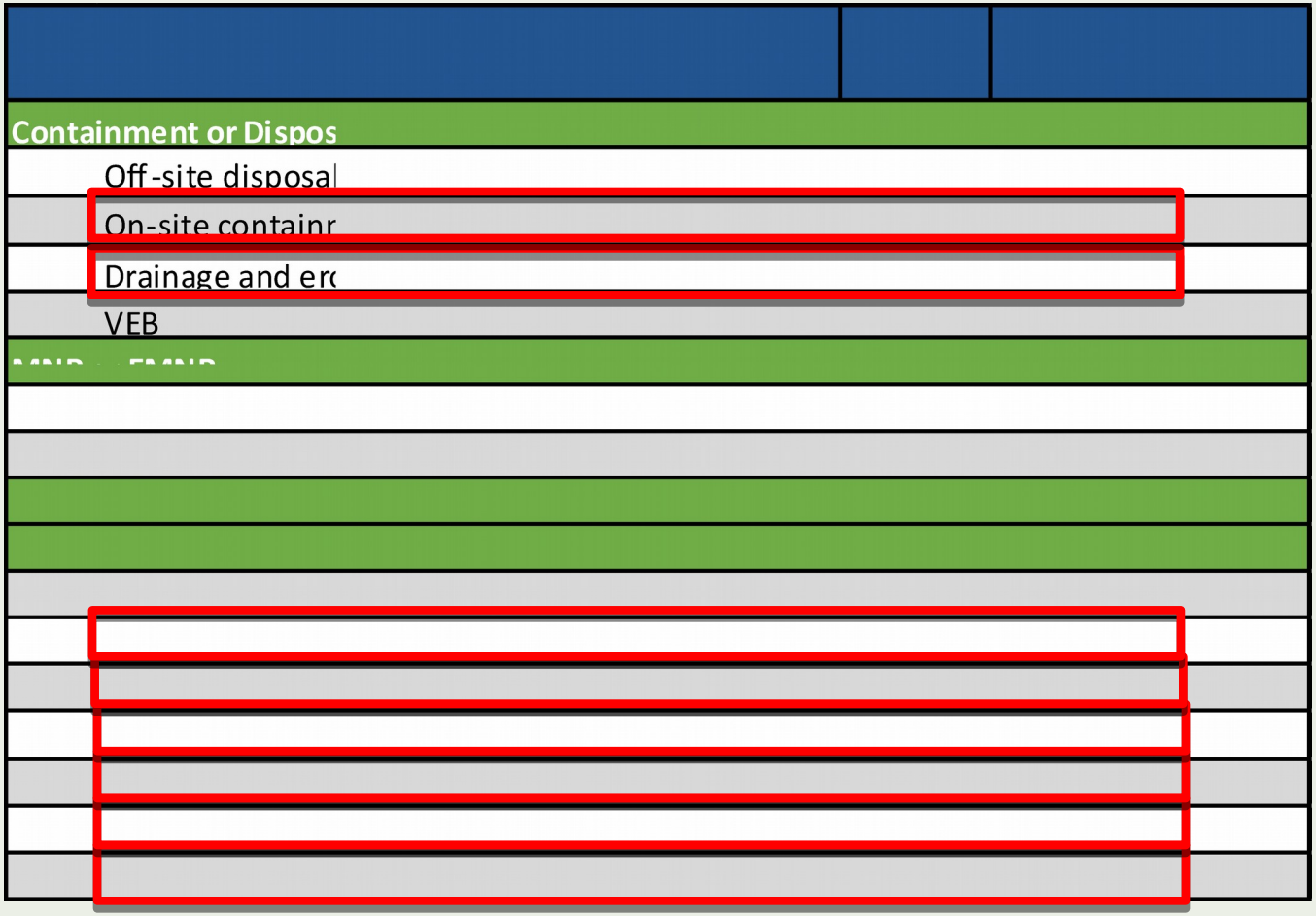
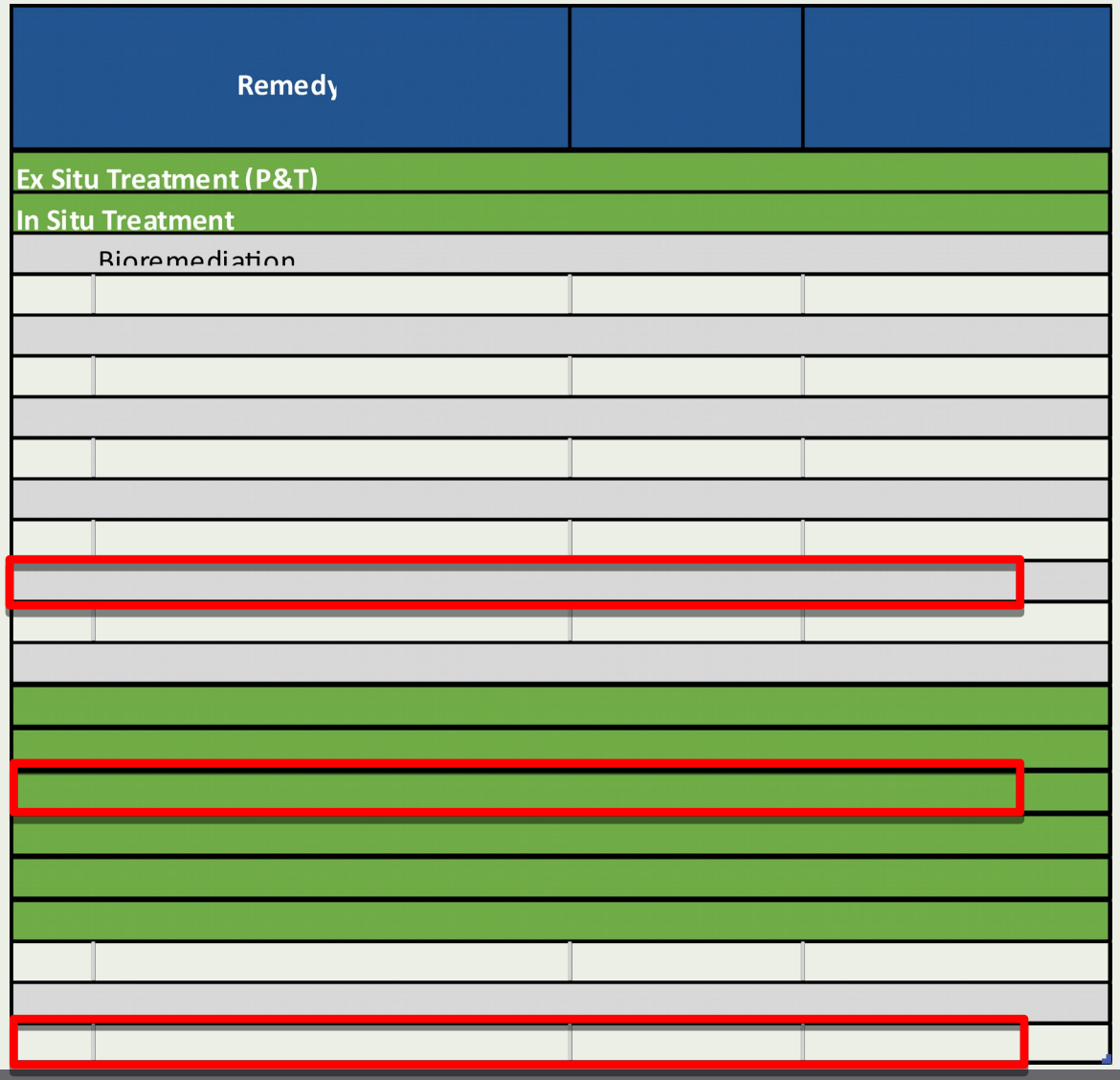
Source Remedies Selected in Recent Decision Documents 2012-2014 (cont'd) Source Decision Documents = 188



Groundwater Remedies Selected in Recent Decision Documents 2012–2014 Groundwater Decision Documents = 160



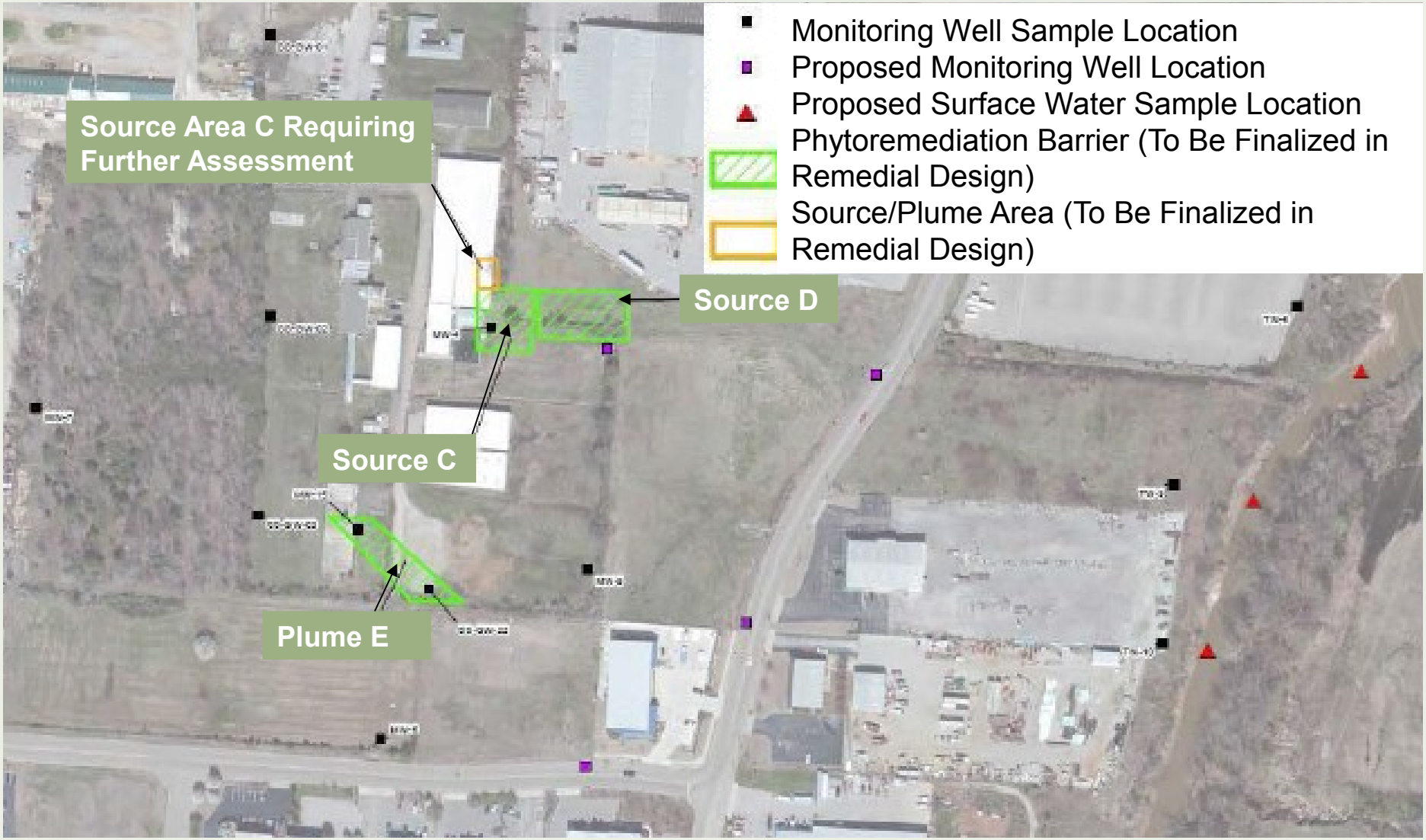
Broader Perspectives on the use of plants at Contaminated Sites Cleanup Projects

- **There is a continuum in the degree to which plants contribute to the remediation of a contaminated site**
  - » Core treatment (*"reduction of toxicity, mobility or volume"*) of the contaminated media, traditional concept of phytoremediation
  - » Non-treatment, but critical role, in a combined remedy (for example hydraulic control)
  - » Supplemental functions, such as storm water management
- **In any of the above roles, plants are an important providers of ecosystem services at remediation projects**
- **Climate change resilience in remedies is driving the incorporation of plant centered technologies, such as narural drainage systems**

Field Example 1: National Fireworks Superfund Site, OU2

- **Site Background**
  - 260-acre site in Cordova, Tennessee.
  - Manufactured munitions for the U.S. Army and Navy.
  - In 1986 the site was redeveloped as an industrial park
  - A time-critical removal action conducted in 2010-2011 removed contaminated soil, debris and live pin flares.
  - Site is being addressed under a Superfund Alternative Approach Agreement
- **Operable Unit 2**
  - Interim remedy addresses groundwater and subsurface soil contamination on the north-central portion of the site.
  - Primary contaminants include tetrachloroethene (PCE) and its degradation products.

Field Example 1: National Fireworks Superfund Site, OU2



Field Example 1: National Fireworks Superfund Site, OU2

- **Remedial Approach**
  - Install trees within the footprint of Plume C (100 trees), Plume D (130 trees) and Plume E (100 trees)
  - Promote aggressive root development to depths up to 30 feet or more by developing borehole to the depth desired, inserting a sleeve or liner to direct root growth, then backfilling the borehole with soil and planting the selected tree species.
- **Treatment Mechanism**
  - Most of the absorbed VOCs will be transferred in the water uptake to the leaves through the xylem (the primary vascular tissue of trees).
  - Dechlorination of the chlorinated VOCs occurs in both the root zone and in the leaves

Field Example 1: National Fireworks Superfund Site, OU2

- **Current status**
  - Site is currently in the remedial action phase.
  - Monitoring of the surface water and groundwater will continue to evaluate the effectiveness of the remedy.
  - A final remedy will be selected to address additional source areas and Plume A and Plume B remediation.
- **Phytoremediation is not typically the primary treatment remedy but can be used effectively as a primary treatment or part of an overall strategy.**

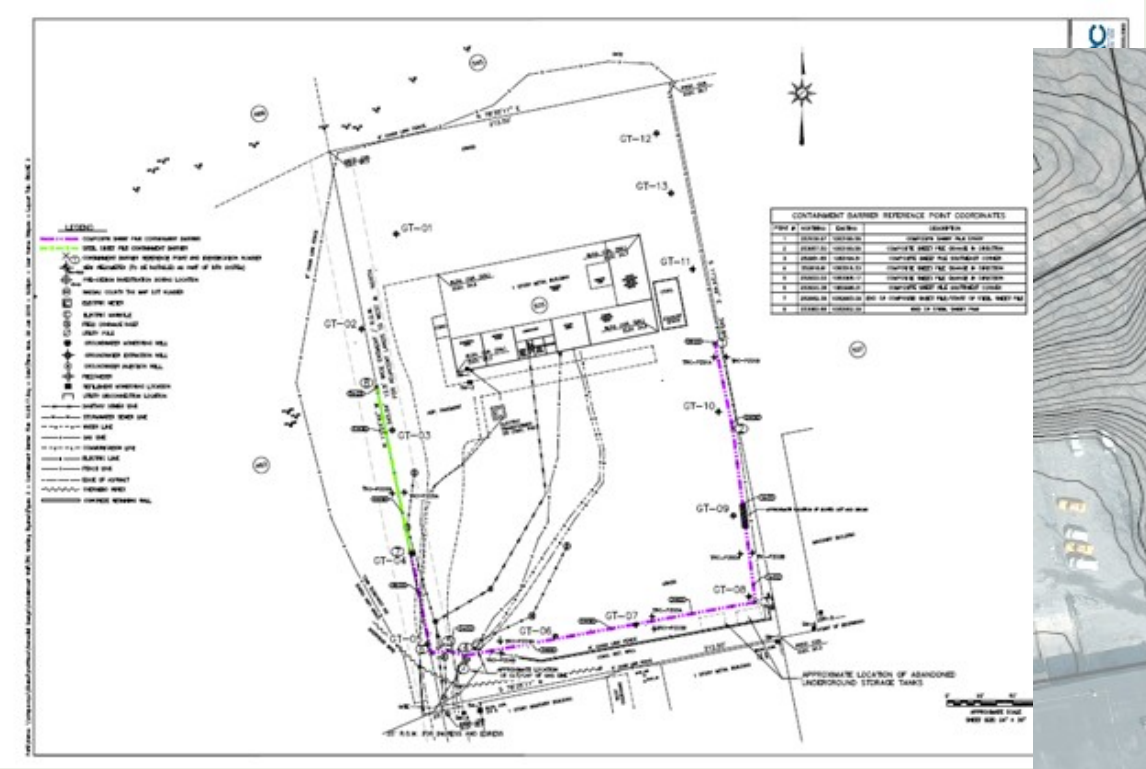
Field Example 2: Mattiace Petrochemical Co., Inc., Superfund Site

- **Site Background**
  - 2.5-acre site in Glen Cove, New York
  - Chemical distribution facility from 1960s until 1987
  - Drum cleaning activities until 1982
  - Removal action in 1988 to remove 100,000 gallons of hazardous liquids
- **Remedial Approach**
  - P&T, SVE and LNAPL recovery selected in 1990/1991
  - Optimization performed in 2000 provided suggestions for improvement of existing systems and recommended further delineation of LNAPL
  - Remedial action amended in 2014 to address newly identified LNAPL plume

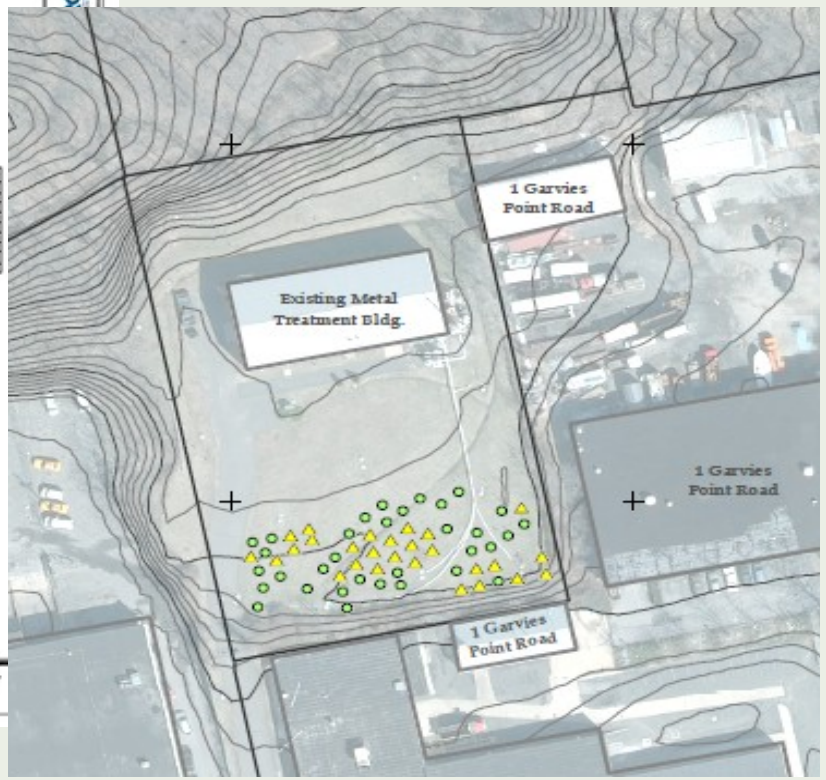
Field Example 2: Mattiace Petrochemical Co., Inc., Superfund Site

- **Amended Remedy**
  - Remedy changed from P&T to combined remedies:
    - ISTT
    - Bioventing (aerobic)
    - Enhanced reductive bioremediation (anaerobic)
    - Partial vertical engineered barrier (VEB) and phytoremediation (for hydraulic control)
  - Hydraulic control via phytoremediation to address water level increase behind the partial VEB
  - Phytoremediation may extract some VOC contaminants, although hydraulic control is the main purpose
  - Phytoremediation will contribute to meeting remedial action objectives

Field Example 2: Mattiace Petrochemical Co., Inc., Superfund Site



Partial VEB (purple line)



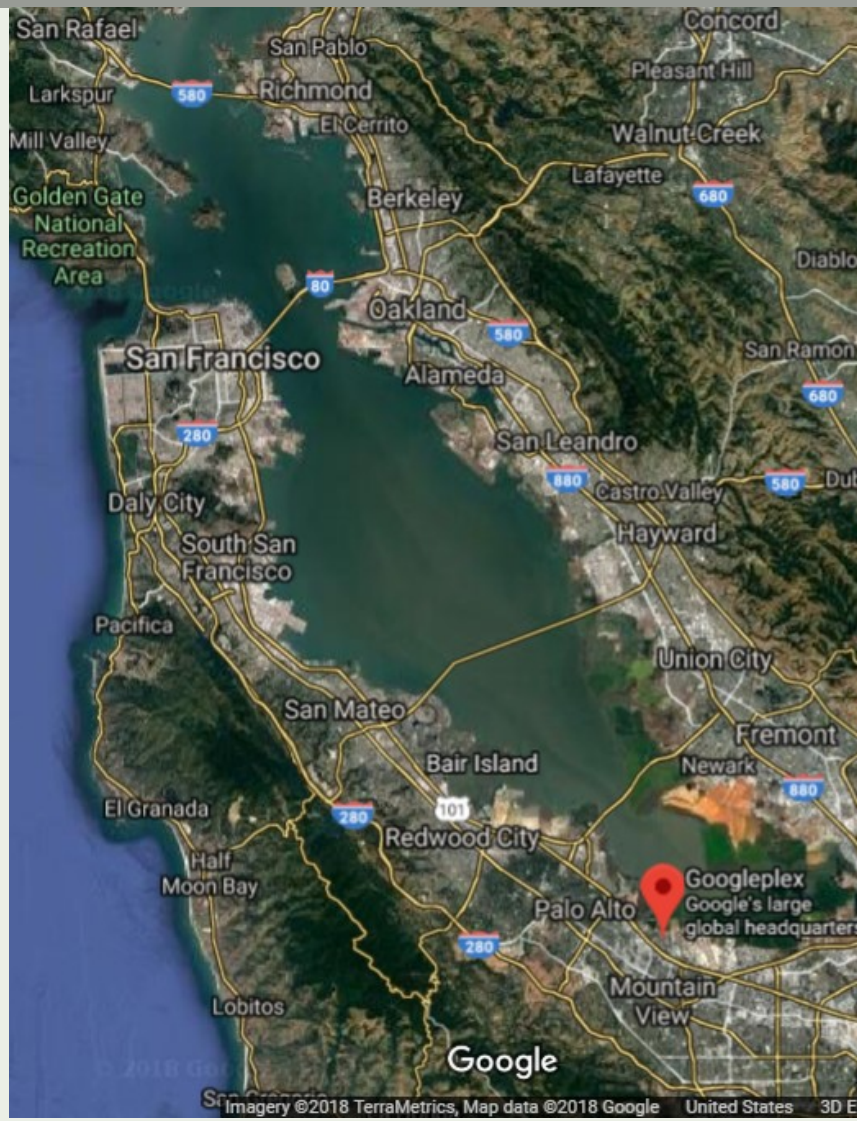
Phytoremediation conceptual design
Willow, cottonwood tree (yellow triangle)
Poplar tree (green dot)

Field Example 2: Mattiace Petrochemical Co., Inc., Superfund Site

- **Current Status**
  - In remedial design phase
  - VEB construction completed Sept 2017 (purple line shown on next slide)
  - Conceptual site design will include a proprietary engineered approach to promote aggressive root development in the targeted horizon
  - Tree species chosen based on robustness, ability to extract large amounts of water, rapid growth potential and water-seeking root growth
    - Willow and cottonwood trees (yellow triangles)
    - Poplar trees (green dots)

Field Example 3: Moffett Field Phyto-barrier with Endophyte Inoculated Hybrid Poplars

- MEW Superfund Area (includes 4 NPL sites – Fairchild Semiconductor, Intel, Raytheon, and portions of NAS Moffett Field). A high profile site in Silicon Valley, CA
- Primarily TCE groundwater contamination (+2km plume). 1989 GW and Soil remedy: P&T, slurry wall, SVE, excavation. 2010 - Vapor Intrusion remedy.
- 2008 Optimization report recommends treatability study of additional technologies, including phyto
- 2013 Feasibility study chosen using phytoremediation to address shallow plume
- 2015-2018 treatability study initiated by NASA using phytotechnology to address shallow TCE plume.
- EPA anticipates incorporating Phyto findings in EPA 2019 Shallow Zone FFS.



Field Example 3: Moffett Field Phyto-barrier with Endophyte Inoculated Hybrid Poplars

- Project goal: Enhanced degradation of groundwater VOCs at a Superfund site using endophyte-assisted Poplar tree phytoremediation
- Initial findings after 4 growing seasons: Inoculated trees show improved growth rates & greater indications of TCE breakdown
- Findings published in Environmental Science & Technology, 2017

EPA

Summary of Phytoremediation Field Examples

- Phyto is rarely the prime treatment remedy, but in certain situations it can meet cleanup goal
- We continuously evaluate remedies and adapt as we learn. At field case 2 & 3 we transitioned from P&T to a combined remedy approach, with phytotechnologies helping in hydraulic control
- Innovations continue, particularly for volatiles, such as use of endophyte inoculated trees for increased phytotoxicity resistance and enhanced biodegradation of TCE
- Use of phytotechnologies to treat metals is a continuing challenge
- There is a broad continuum of opportunities in the use of plants to treat and restore contaminated sites

Phytotechnologies

Overview

- Overview
- Guidance
- Application
- Training
- Additional Resources
- Technology Focus Home
- Suggest Resource
- Comments

Phytotechnology is broadly defined as the use of vegetation to address contaminants in soil, sediment, surface water, and groundwater. Cleanup objectives for phytotechnologies can be contaminant removal and destruction, control and containment, or both. Phytoremediation (i.e., contaminant removal and destruction) is a phytotechnology subset (ITRC 2009). EPA has developed a fact sheet, Phytotechnologies for Site Cleanup, as well as a layman's discussion of plant-based remediation in A Citizen's Guide to Phytoremediation, which is also available in a Spanish translation.

While phytotechnologies generally are applied in situ, ex situ applications (e.g., hydroponics systems) are possible. Typical organic contaminants, such as petroleum hydrocarbons, gas condensates, crude oil, chlorinated compounds, pesticides, and explosive compounds, can be addressed using plant-based methods. Phytotechnologies also can be applied to typical inorganic contaminants, such as heavy metals, metalloids, radioactive materials, and salts (ITRC 2009).

Six major plant mechanisms enable phytotechnologies to remove, destroy, transfer, stabilize, or contain contaminants:

- Phytoextraction
- Phytodegradation
- Phytovolatilization
- Rhizodegradation
- Phytosequestration
- Phytohydraulics

> Phytohydraulics is the ability of vegetation to evapotranspire sources of surface water and groundwater. Water interception capacity by the aboveground canopy and subsequent evapotranspiration through the root system can limit vertical migration of water from the surface downward. The horizontal migration of groundwater can be controlled or contained using deep-rooted species, such as prairie plants and trees, to intercept, take up, and transpire the water. Trees classified as phreatophytes are deep-rooted, high-transpiring, water-loving organisms that send their roots into regions of high moisture and can survive in conditions of temporary saturation. Typical phreatophytes include species such as cottonwoods, poplars, and willows (ITRC 2009).

Additional information specific to uses of plants for soil and groundwater cleanup, and constructed wetlands is available in the Federal Remediation Technologies Roundtable's Remediation Technologies Screening Matrix and Reference Guide.

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Green Remediation: Meeting Cleanup Objectives With a Smaller Environmental Footprint

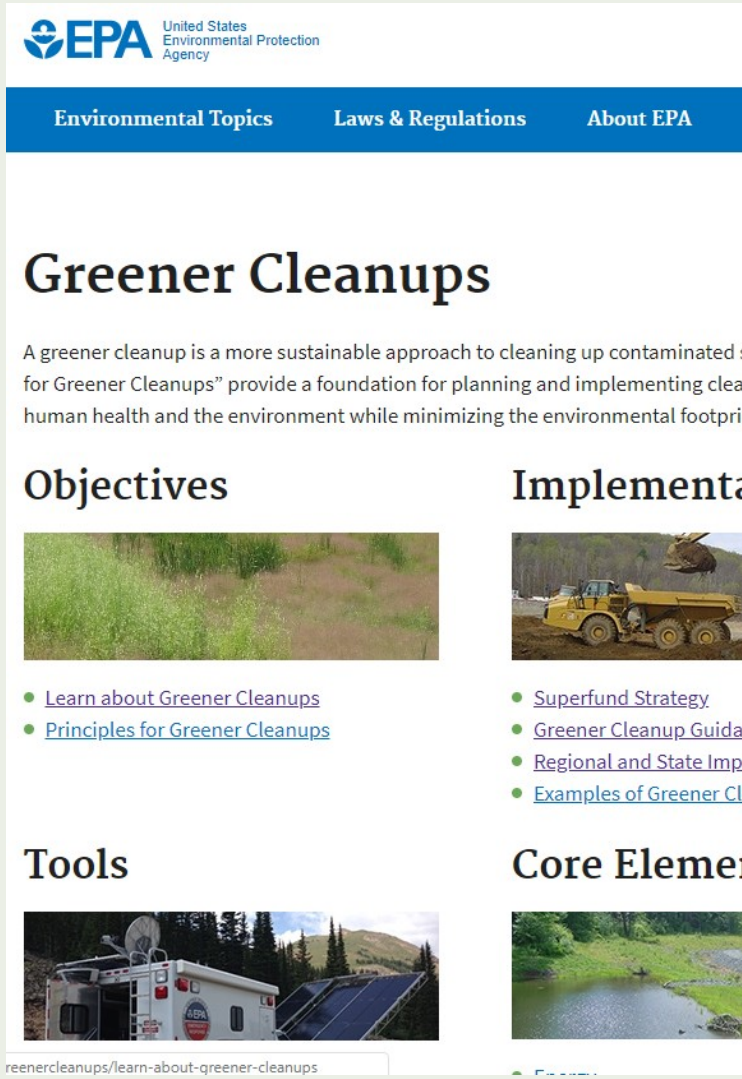
Myths, Truths & Tools

Greener Cleanups Are….

- NOT just about GHG
- NOT about the greenest technology
- The same as green remediation
- Integral to more sustainable cleanups

Recommended Project Level Tool: ASTM Standard Guide for Greener Cleanups

https://www.epa.gov/greenercleanups



Examples of Best Management Practices

Recycled concrete for erosion control

A mobile solar system to power tools

Wetlands for stormwater & habitat

http://clu-in.org/greenremediation/profiles

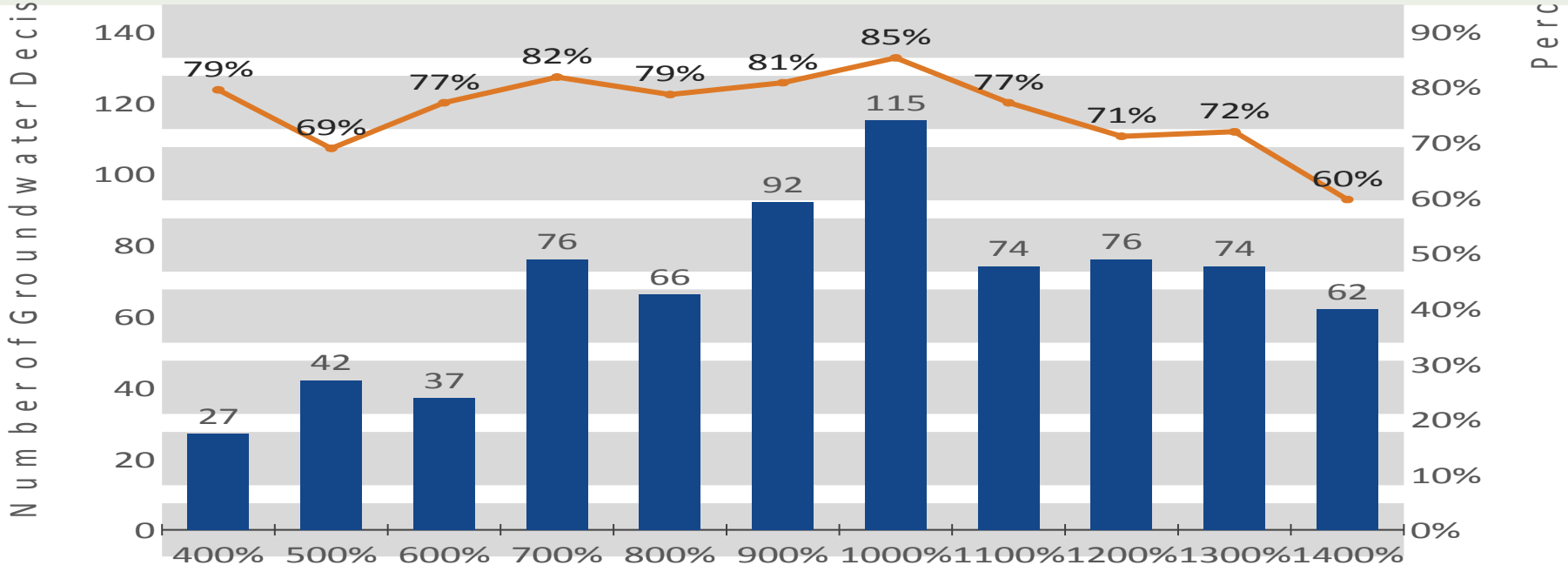
EPA's Working Definition of Optimization

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

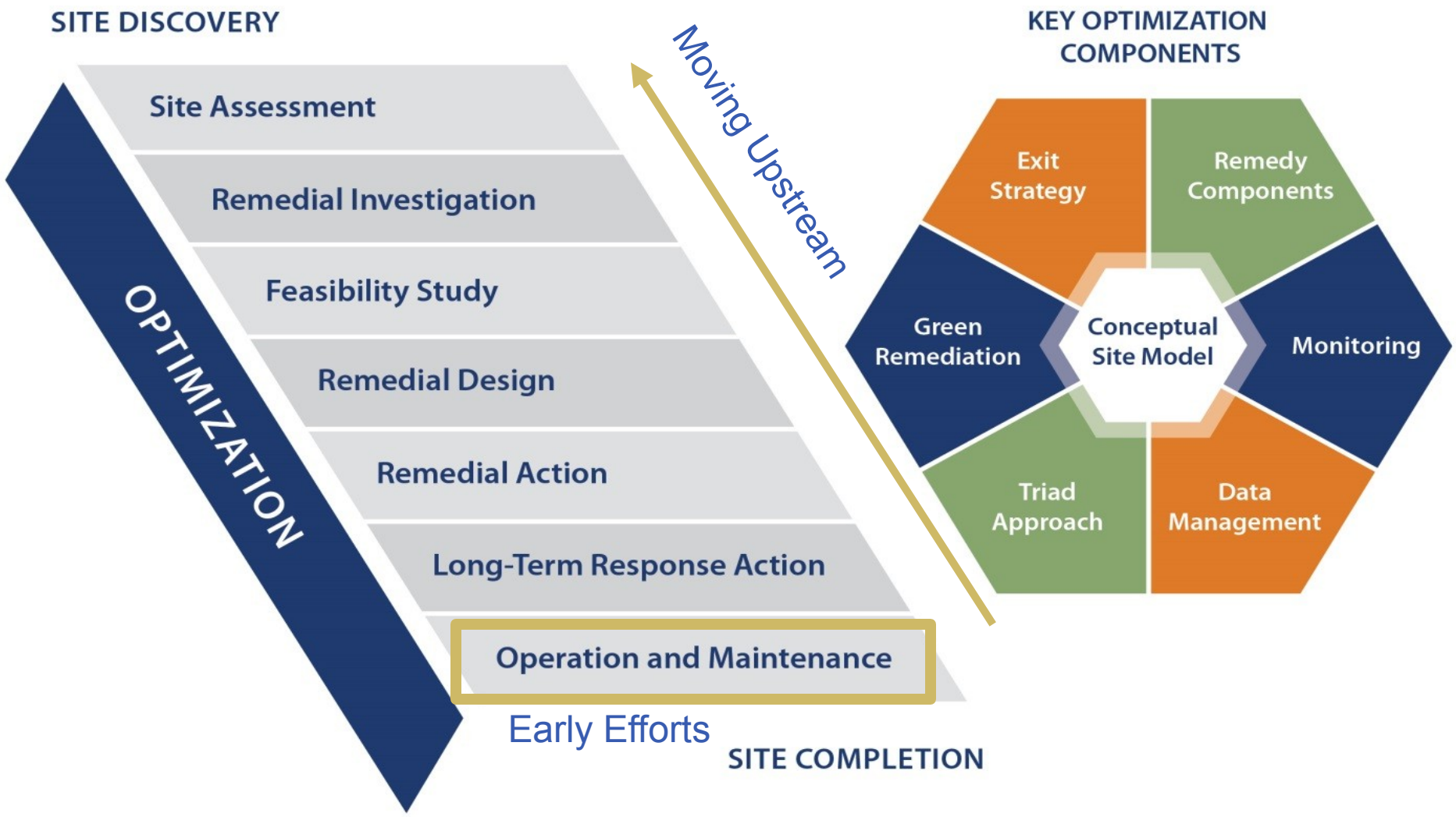
and cost efficiency, and to facilitate progress toward site completion.

EPA's National Optimization Program revolves around third-party evaluations

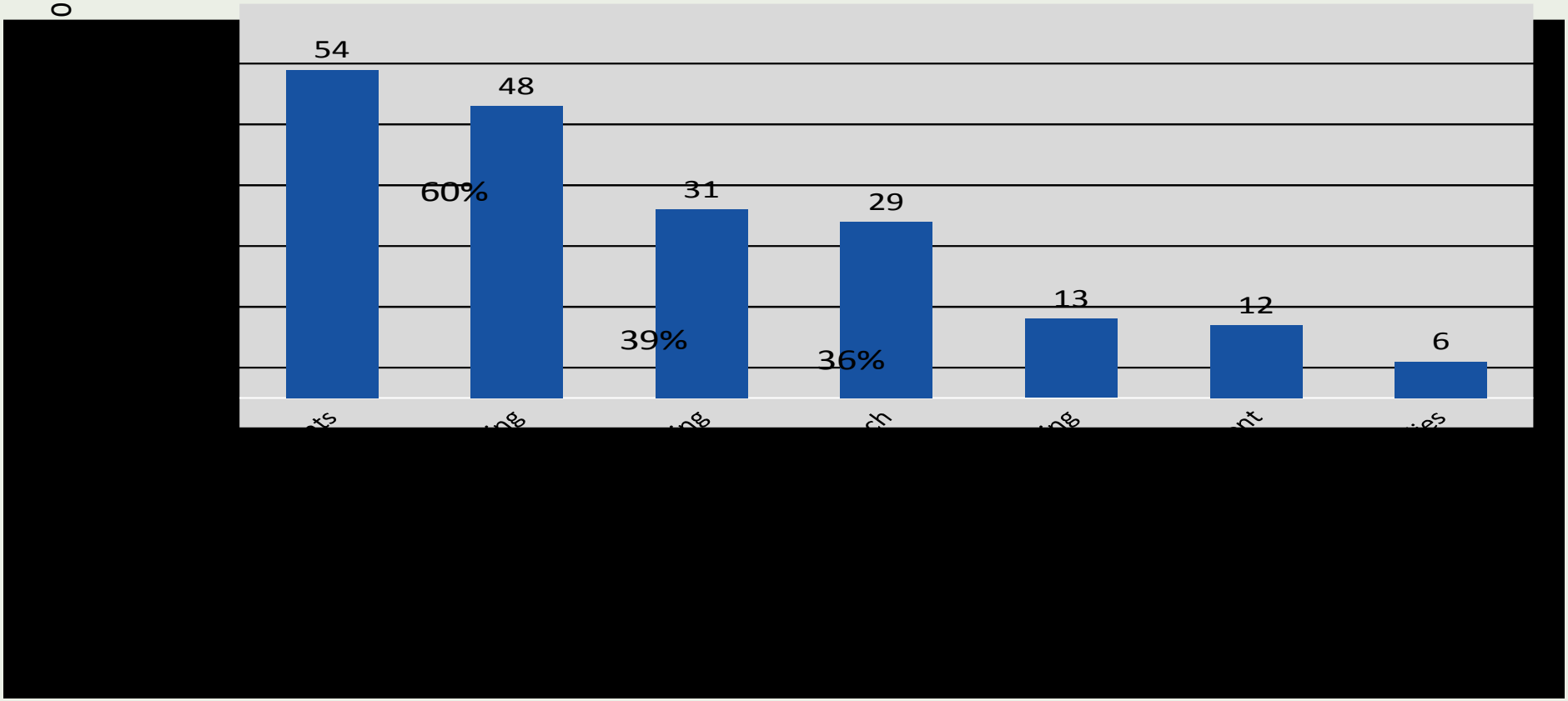
P&T Selection for Decision Documents with Groundwater Remedies (FY 1985-1995)



Key Optimization Components and Superfund Pipeline Activities



Number of Implemented Tools and Techniques
Total Number of Optimization Events = 80



Summary Conclusions

- The remediation services sector provides a broad suite of options to remediate contaminated sites
- Technologies are often use in combination to address different contaminants and media at a site
- Phytoremediation is rarely the main treatment remedy, but often is a part of the solution at many sites
- Green remediation helps us build and operate any chosen remedy with a lower environmental footprint
- Optimization allows us to capture lessons learned and build them into existing or new treatment systems

Thank you!

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