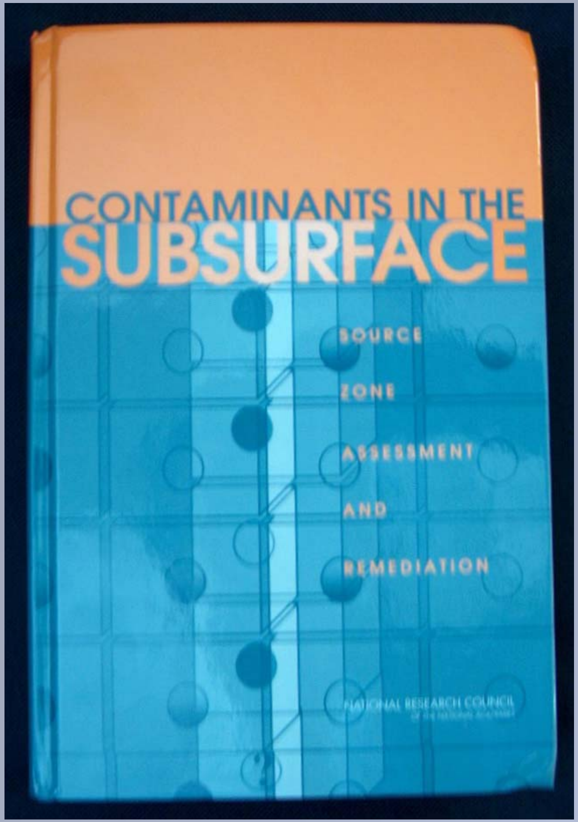
A Summary of Results-
NRC Source Zone Report



Presented to:
Federal Remediation
Technologies Roundtable
Arlington, VA
May 25, 2005

Presented by:
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Marine, Earth and Atmospheric Sciences
North Carolina State University

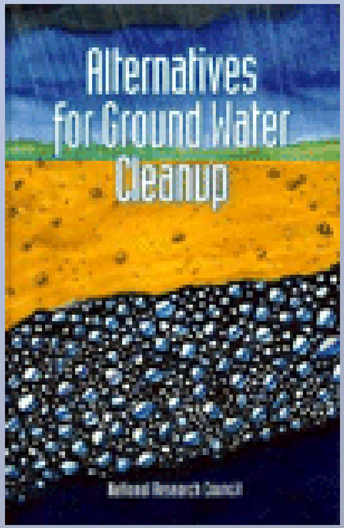
Contaminants in the Subsurface

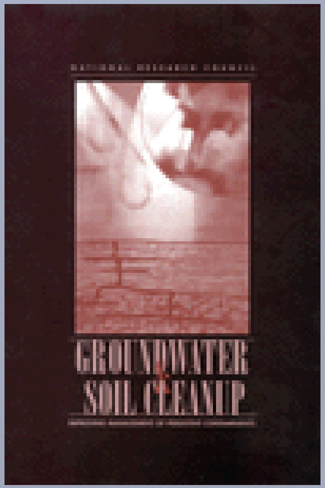
Source Zone Assessment and Remediation

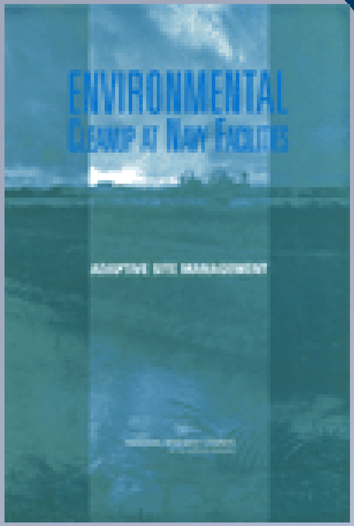
National Research Council
Water Science and Technology Board

http://books.nap.edu/catalog/11146.html

Many Prior Studies







ITRC, 2002. DNAPL Source Reduction: Facing the Challenge

EPA, 2003, The DNAPL Remediation Challenge: Is There a Case for Source Depletion?

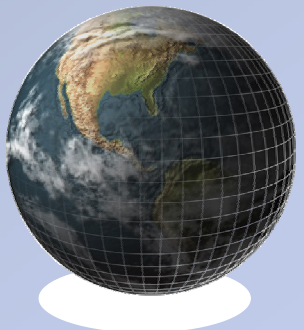
EPA, 2004, DNAPL Remediation: Selected Projects Approaching Regulatory Closure

Environment Agency (UK), 2003, Illustrated Handbook of DNAPL transport and fate in the subsurface

No Consensus that Remediation is Worthwhile

"..there is almost universal concern among groups with diverse interests in groundwater contamination … that the nation may be wasting large amounts of money on ineffective remediation efforts (NRC 1994).

The NRC study, as well as several of the others just cited, attempted to update this conclusion in regards to source zones



Committee on Source Removal

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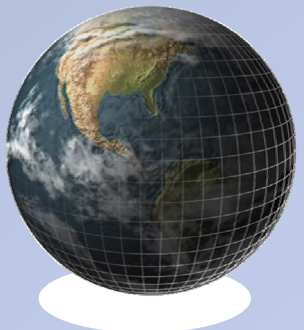
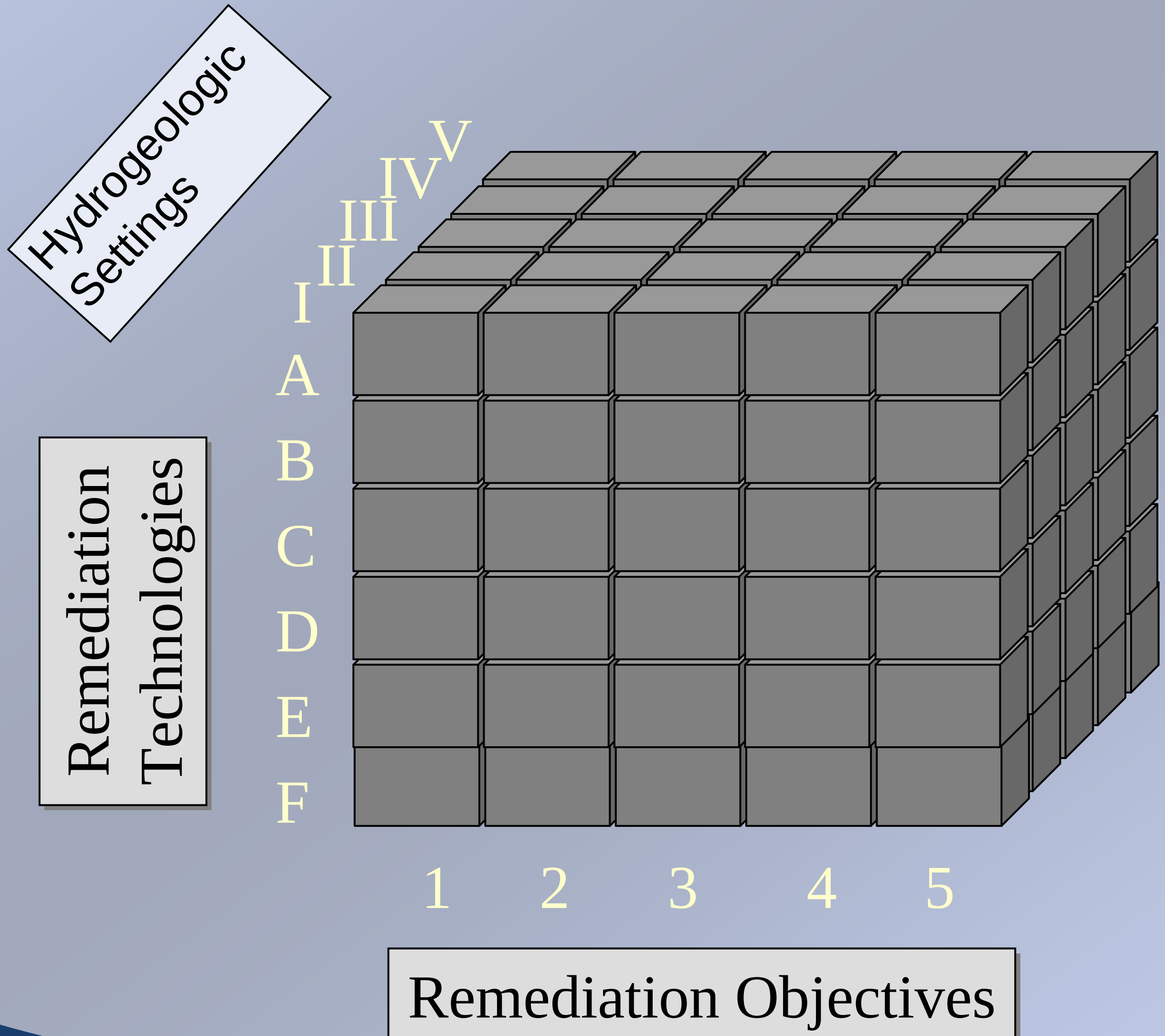
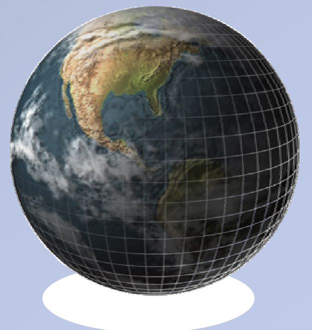
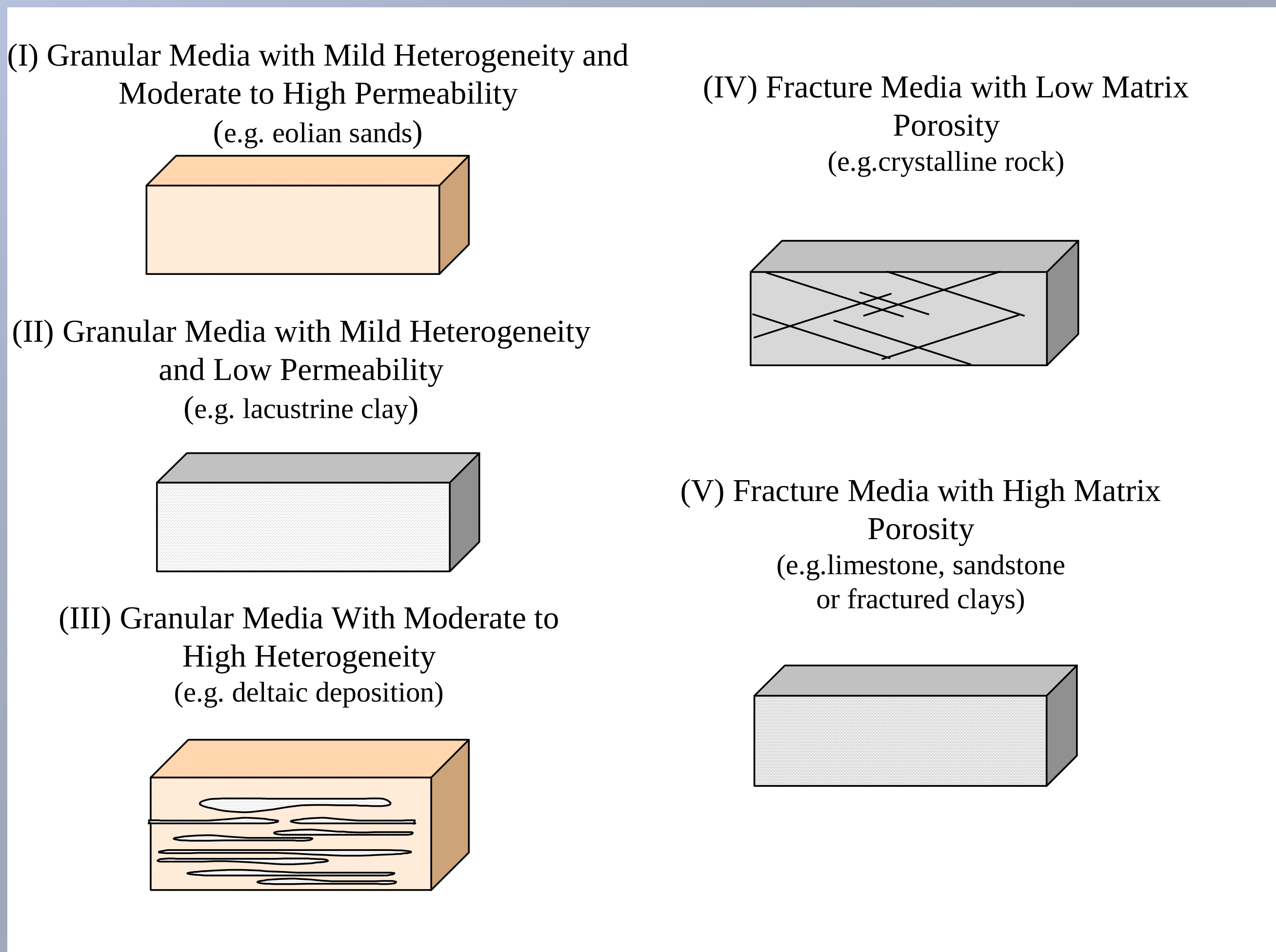


Conceptual Framework for Report





Hydrogeologic Settings



Chapter 3: Characterization

Addresses several aspects of source zone characterization, including:

- Characterization methods and tools
- The importance of source zone characterization to determining cleanup objectives
- Scale issues
- Coping with uncertainties during source characterization
- The potential ramifications of inadequate characterization

Source Characterization

At many DNAPL sites, there was inadequate site characterization to support the remediation strategies and success metrics chosen.

At most sites where source zone remediation was attempted, characterization was insufficient to evaluate performance in terms of remaining mass

Uncertainty

- An evaluation of the uncertainties associated with the source strength and location, with the hydrogeologic characteristics of the subsurface, is essential for determining the likelihood of achieving success.
  - *statistical, inverse, and stochastic inverse methods*

- Obtaining a better handle on uncertainty via increased characterization will facilitate more precise remediation.

Chapter 4: Remediation Objectives

In order to determine if source zone remediation is appropriate at a site, one must be able to determine if the objectives can be accomplished

Remediation Objectives:

In the majority of cases, the objective was not stated in advance, thus this question could not be answered

Remediation Objectives II

- Need to define absolute objectives as part of the decision process
- Absolute objectives are important in and of themselves (e.g.: protect human health), if they are not achieved, project is not a success

Metrics

- Each objective should have a metric, that is, a quantity that can be measured at the particular site in order to evaluate achievement of the objective.

- How can you determine if you have met your objective if you cannot measure it somehow

Functional Objectives

- Some objectives do not have appropriate direct metrics

  Protect human health –cannot directly measure short-term effects on human health

- Derive functional objective with metric

  Concentration in water for example, assumes if water meets specified limits, health will be protected

Absolute vs Functional objectives

- Protect human health
  - A common absolute objective
- Reduce concentration at well to MCL
  - A related functional objective
  - If municipal water was supplied, health could be protected without reducing concentrations in wells- thus it is not an absolute objective
  - If required by regulators, attainment of MCLs may be absolute

Inappropriate Metrics

- Inappropriate metrics common in reported source zone remediation projects.

  -Absolute goal: protect local users health (that is why project was done)

  -Metric: Mass removed (does not measure protection of health)

Chapter 4 Conclusions

- Remedial objectives should be laid out *before* deciding whether to attempt source remediation or selecting a technology.
- A clear distinction between functional and absolute objectives is needed to evaluate options.
- Objectives should strive to encompass the long time frames characteristic of many site cleanups that involve DNAPLs.

Source Remediation Technologies

Chapter 5 evaluates those technologies that have surfaced as leading candidates for source zone remediation

- Excavation, containment, and pump-and-treat
- Multiphase extraction
- Surfactant and cosolvent flushing
- Chemical oxidation
- Chemical reduction
- Steam flooding
- Thermal conduction heating
- Electrical resistance heating
- Air sparging
- Enhanced bioremediation

Comparison Table

			Likely Effectiveness at Appropriate Sites						
Technology	Applicable Contaminant Types	Media Settings	Mass Removal	Local Aqueous Concentration Reduction	Mass Flux Reduction	Reduction of Source Migration Potential	Change in Toxicity	Limitations	Comments
Chemical Oxidation	Halogenated ethenes and ethanes	I	Medium -High	Medium	Medium	Low	Medium -High	May be large heat release, soil fouling (MnO_{2-} ppt from $KMnO_4$), or metals released due to pH changes. Delivery of chemical oxidants will be poor in all but high-permeability media. Significant natural organic matter will limit efficacy.	Only applicable to immobilized sources (low NAPL saturation, or sorbed). Limited experience in fractured media, most failures attributed to channeling in heterogeneous media. May require multiple injections.
		II	Low	Low	Low	Low	Low		
		III	Low-Medium	Low-Medium	Medium-High	Low	Low-Medium		
		IV	Low	Low-Medium	Low-Medium	Low-Medium	Low		
		V	Low	Low	Low	Low	Low		

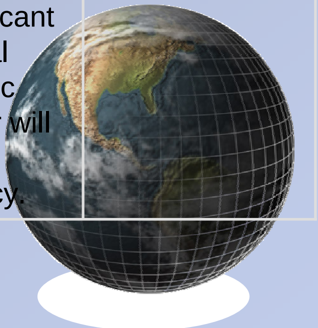
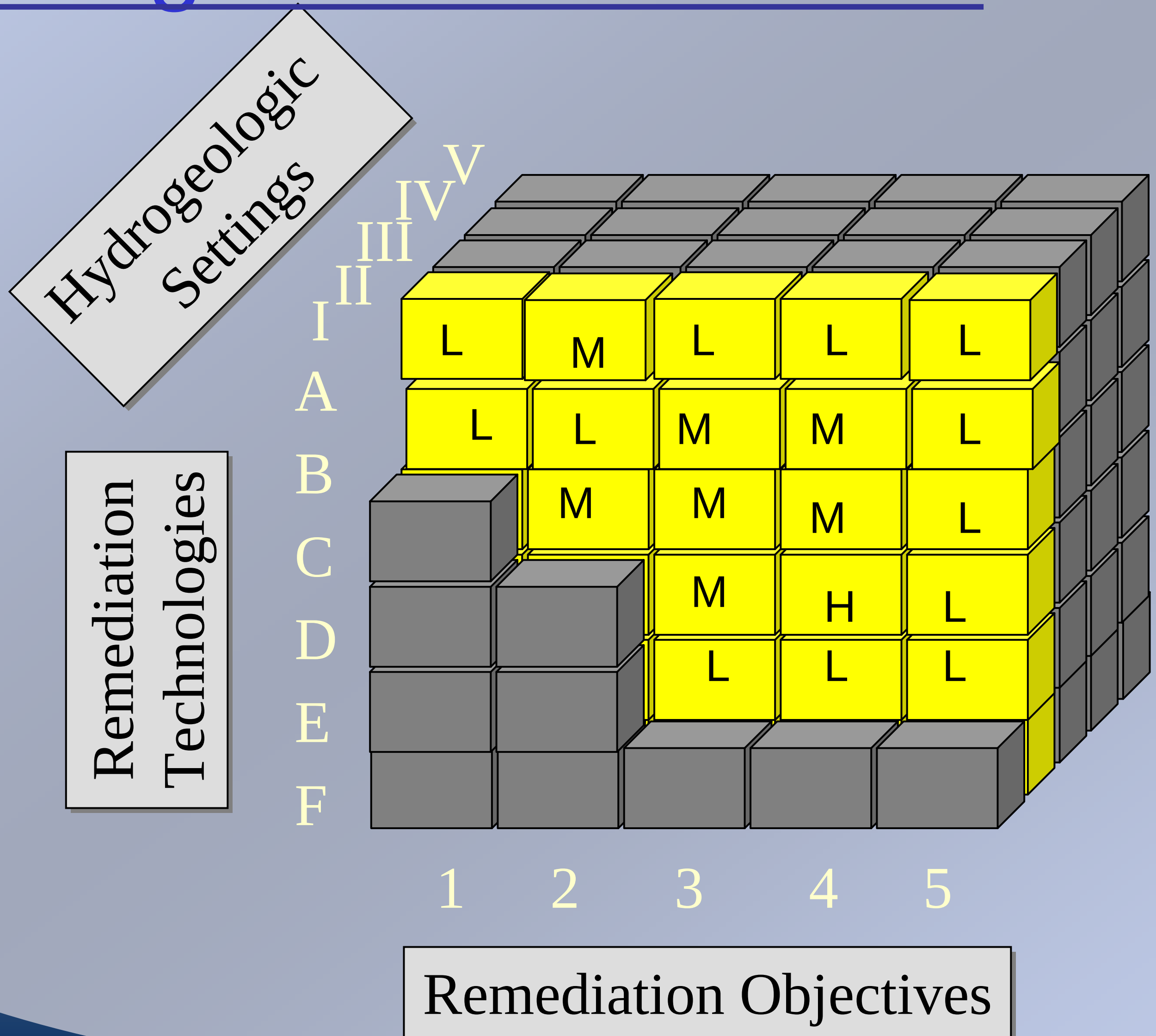
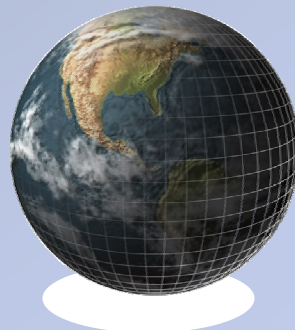
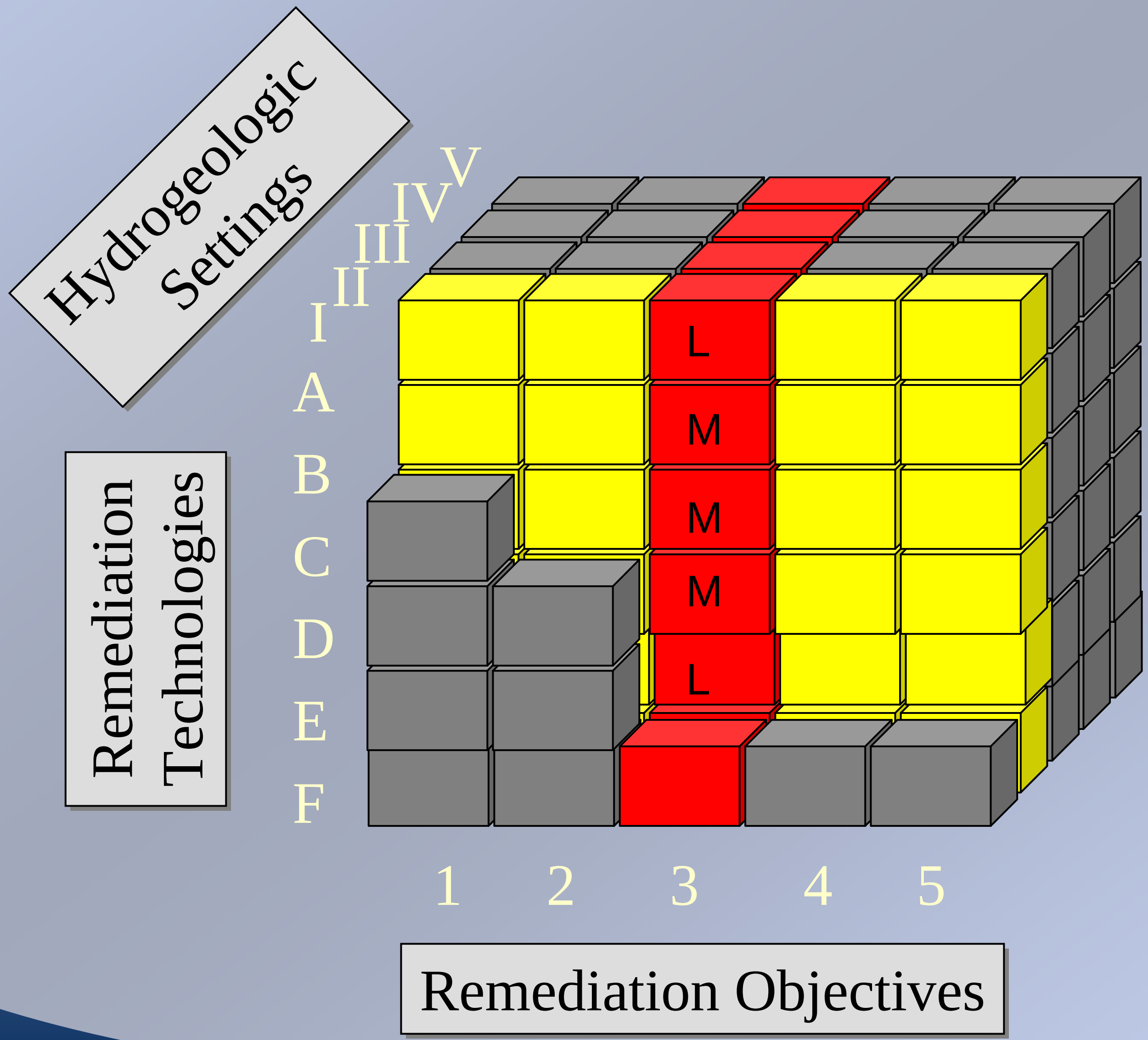


Table Designed for High Order Screening





Select potential technologies



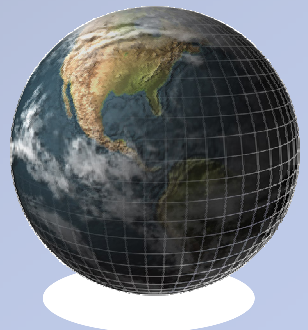
Chapter 5 Conclusions

- Several source remediation technologies have been demonstrated to achieve substantial mass removal
- A number have demonstrated concentration reductions.
- Although theoretical, modeling and laboratory data suggest that partial mass removal can affect local concentration and down gradient mass flux, this has also not been documented in field tests

Thus, available data from field studies do not demonstrate what effect source remediation is likely to have on water quality

Chapter 5 Conclusions

- Performance of *most* technologies is highly affected by site heterogeneities
- Most of the technologies are not applicable in, are negatively impacted by, or have not been adequately demonstrated in low-permeability or fractured materials.
- Existing data inadequate to predict effect on water quality



General Conclusions I

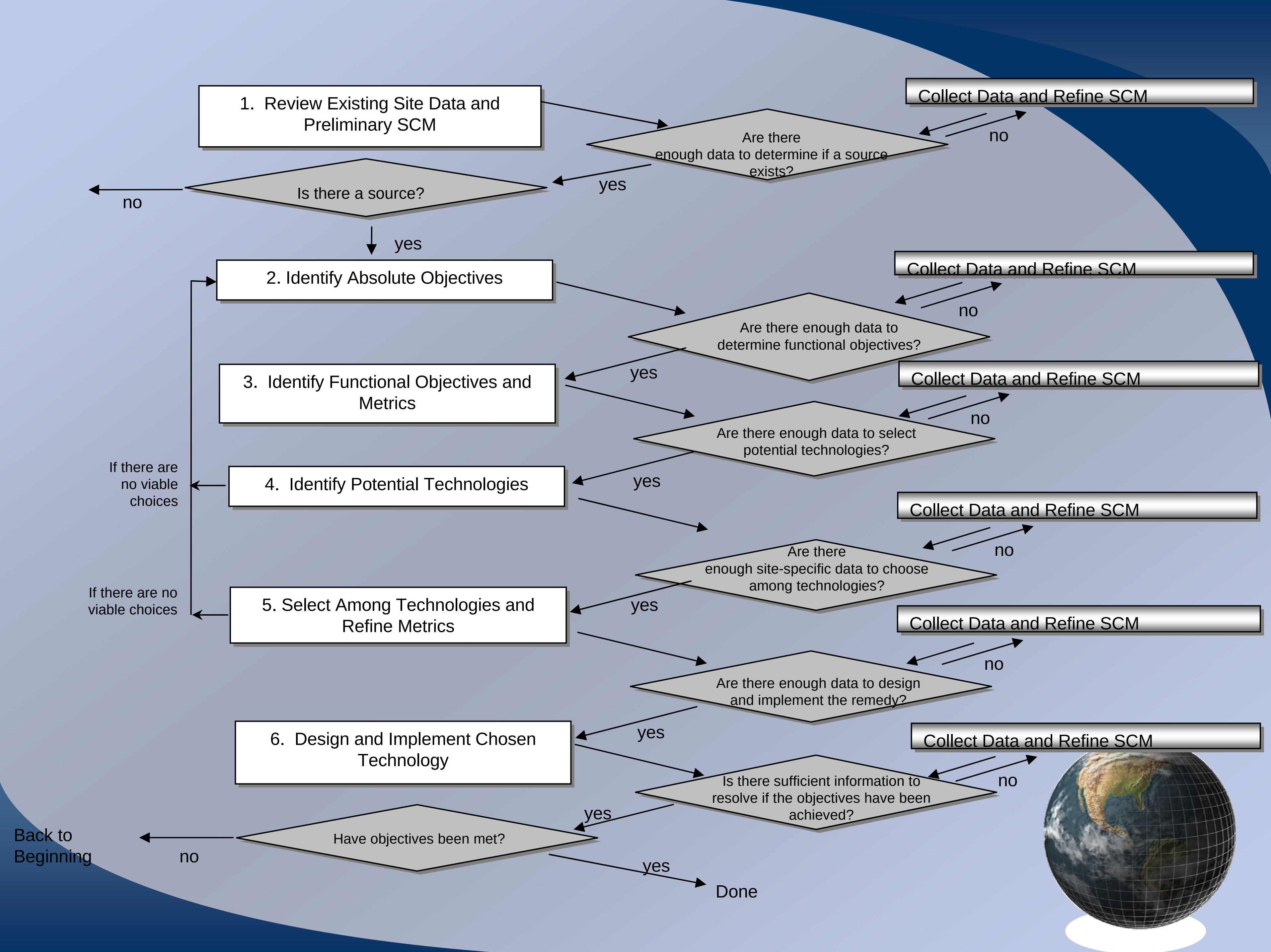
- The data are inadequate to determine how effective most technologies will be in anything except the simpler hydrogeologic settings.

- Almost all of the source remediation technologies evaluated require more systematic field-scale testing to better understand their technical and economic performance.

- It is unlikely that available source remediation technologies will work in the most hydrogeologically complex settings such as karst.

Protocol for Source Remediation

Source remediation is sufficiently complex to warrant a formal protocol.


1. Review Existing Site Data and Preliminary SCM
Are there enough data to determine if a source exists?
Collect Data and Refine SCM
no
yes
Is there a source?
no
yes
2. Identify Absolute Objectives
Are there enough data to determine functional objectives?
Collect Data and Refine SCM
no
yes
3. Identify Functional Objectives and Metrics
Are there enough data to select potential technologies?
Collect Data and Refine SCM
no
yes
4. Identify Potential Technologies
If there are no viable choices
Are there enough site-specific data to choose among technologies?
Collect Data and Refine SCM
no
yes
5. Select Among Technologies and Refine Metrics
If there are no viable choices
Are there enough data to design and implement the remedy?
Collect Data and Refine SCM
no
yes
6. Design and Implement Chosen Technology
Is there sufficient information to resolve if the objectives have been achieved?
Collect Data and Refine SCM
no
yes
Have objectives been met?
no
Back to Beginning
yes
Done

Seldom Applied

- The steps described in the protocol—especially developing absolute and functional objectives and their metrics—have seldom been conducted in the manner described .

Future of Source Remediation?

- **Several technologies show enough promise to warrant further investigation**

- **Future work should attempt to determine the full range of conditions under which these technologies can be successfully applied**

- **And to better understand how mass removal via these technologies affects water quality**

In My Opinion

- There are some good reasons for source zone remediation
  - Reduce mass flux
    - Maximize likelihood Natural attenuation will work
  - Remove as much contamination as practical
    - Reduce time to restoration
    - Do all that is possible to restore damage to environment

- In order to determine when it is worthwhile we need to know three things: what is the objective, what can really be accomplished and how much will it cost.