Part 3: Technology Optimization

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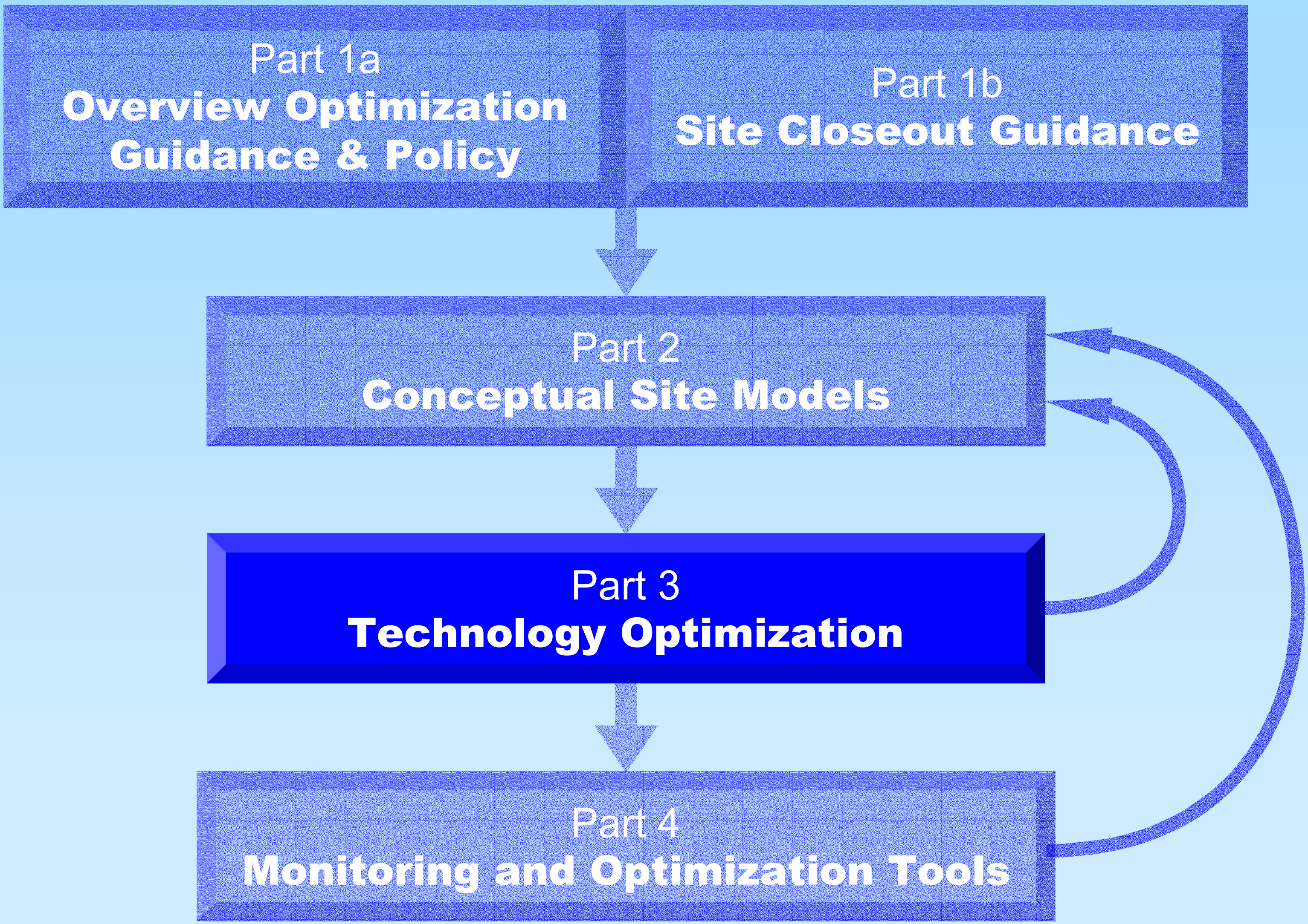
Battelle

RITS Spring 2004: Optimization of Remedial Actions



Presentation Overview

- Introduction
- FS through ROD
  - Identification and evaluation of remedial technologies
  - Performance objectives
  - Exit strategies
- Post-ROD
  - Design/implementation strategies
  - Continuing optimization during remedial action
- Summary

Relevant Guidance for Part 3

- **Guidance for Optimizing Remedy Evaluation, Selection, and Design, Draft 2004**
  - Section 3: During FS (Identification, screening, cost analysis)
  - Section 4: ROD Flexibility
  - Section 5: Remedial Design (Post-ROD)
- **Guidance for Optimizing Remedial Action Operation, Interim-Final, April 2001**
  - Step-wise program for optimization during RA Operation
  - Technology-specific monitoring parameters/troubleshooting

Presentation Focus

1. Use multiple technologies with an exit strategy for each

2. Design with project life-cycle in mind

3. Continual re-evaluation

Objective and Overview: Why, When, and How to Optimize

- Why:
  - Achieve environmentally protective site closeout at least cost
  - Remedial systems selected and developed with sound and creative engineering and implemented with insightful decision-making can still benefit from optimization, because things change (i.e. economics and political/regulatory factors, technology advances, life-cycle factors)
- When (key phases to optimize):
  - Remedial Investigation (RI)
  - Feasibility Study (FS)
  - ROD Development
  - Remedial Design (Value engineering)
  - Remedial Action Optimization/LTMgt (Continually)

Objective and Overview: Why, When and How to Optimize (cont.)

- How:
  - Appropriate use of up-to-date conceptual site model
  - Flexible RAOs considering technology limitations and risk assessments
  - Use of treatment trains for each target zone
  - Develop performance objectives for each element of each treatment train
  - Develop an exit strategy for each remedy component considering life-cycle factors
  - Cost analysis as a decision-making tool
  - Consider life-cycle factors in remedial design
  - Perform design review similar to value engineering
  - Continually evaluate all the above through RA operation

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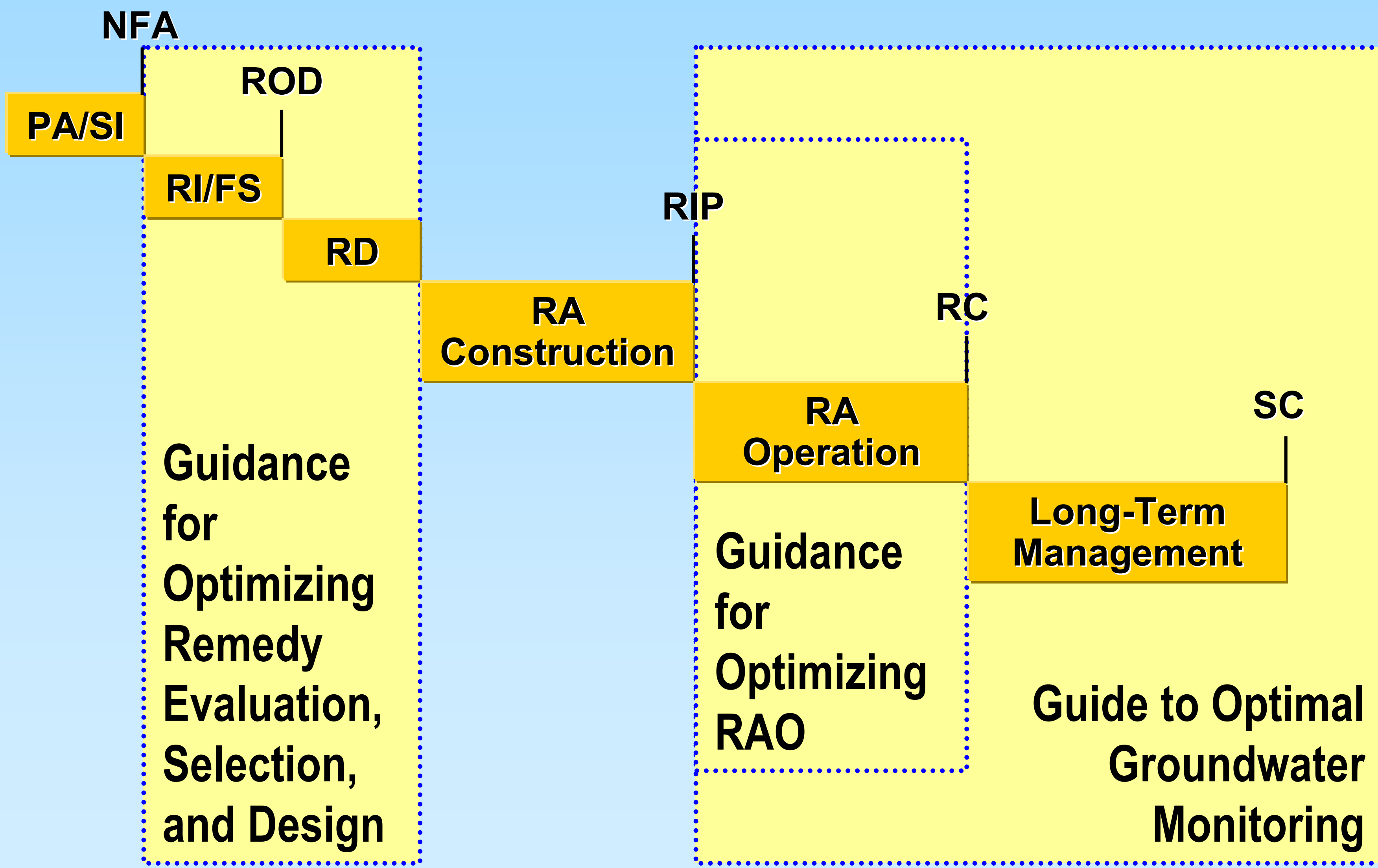
Guidance Documents and IR Program Phases



Identification and Evaluation of Remedial Technologies

- For each target zone evaluate which of the general RA categories meets the threshold criteria (protection of human health and environment and ARAR compliance)
  - No further action
  - Land use controls
  - Containment and engineering controls
  - In situ treatment/mass removal
  - Ex situ treatment/mass removal

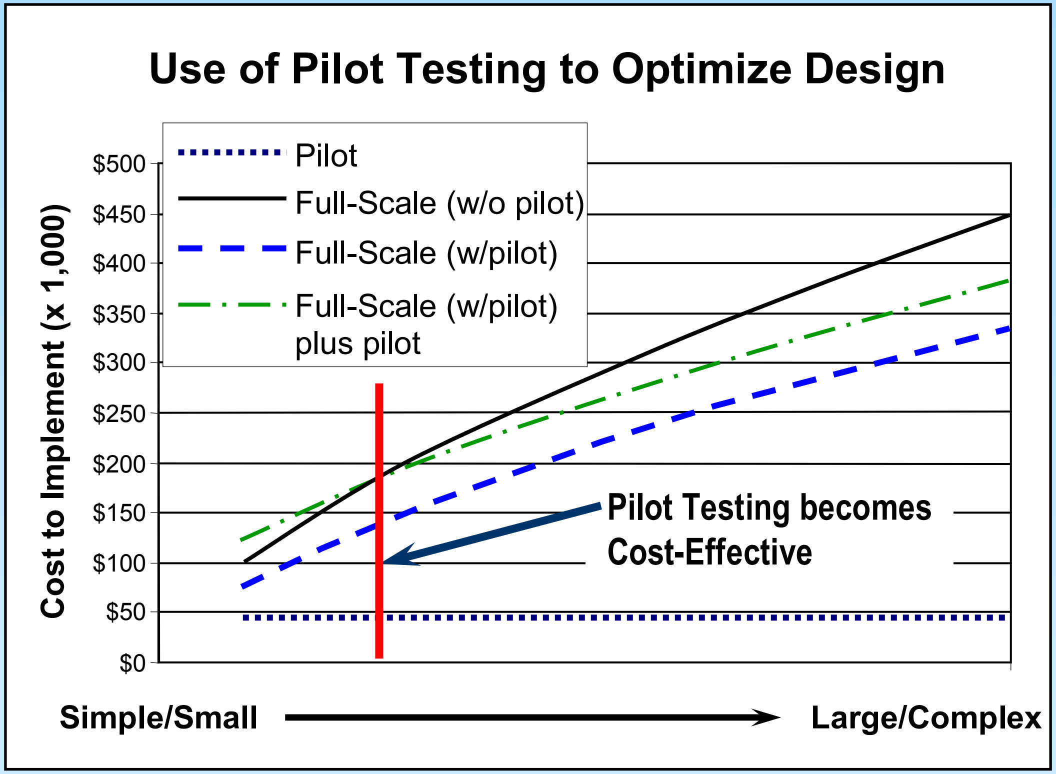
- Review applicability of presumptive remedies for each of the above general categories that meets threshold criteria
- Cautiously evaluate innovative technologies where applicable using reliable sources – not vendor claims

Navy Experience with Mass Removal/Destruction Technologies

- Pump and treat (P&T) is not effective for source removal
  - Should be avoided if possible, costly with long-term operation
  - Useful where hydraulic control is needed, but should be coupled with source removal to limit duration of operation
- Source removal technologies successfully implemented
  - Bioslurping/Multi-phase extraction (MPE)
  - In Situ Air Sparging with Soil Vapor Extraction (IAS/SVE)
  - In Situ Chemical Oxidation (ISCO), most success with permanganate
  - Enhanced biodegradation

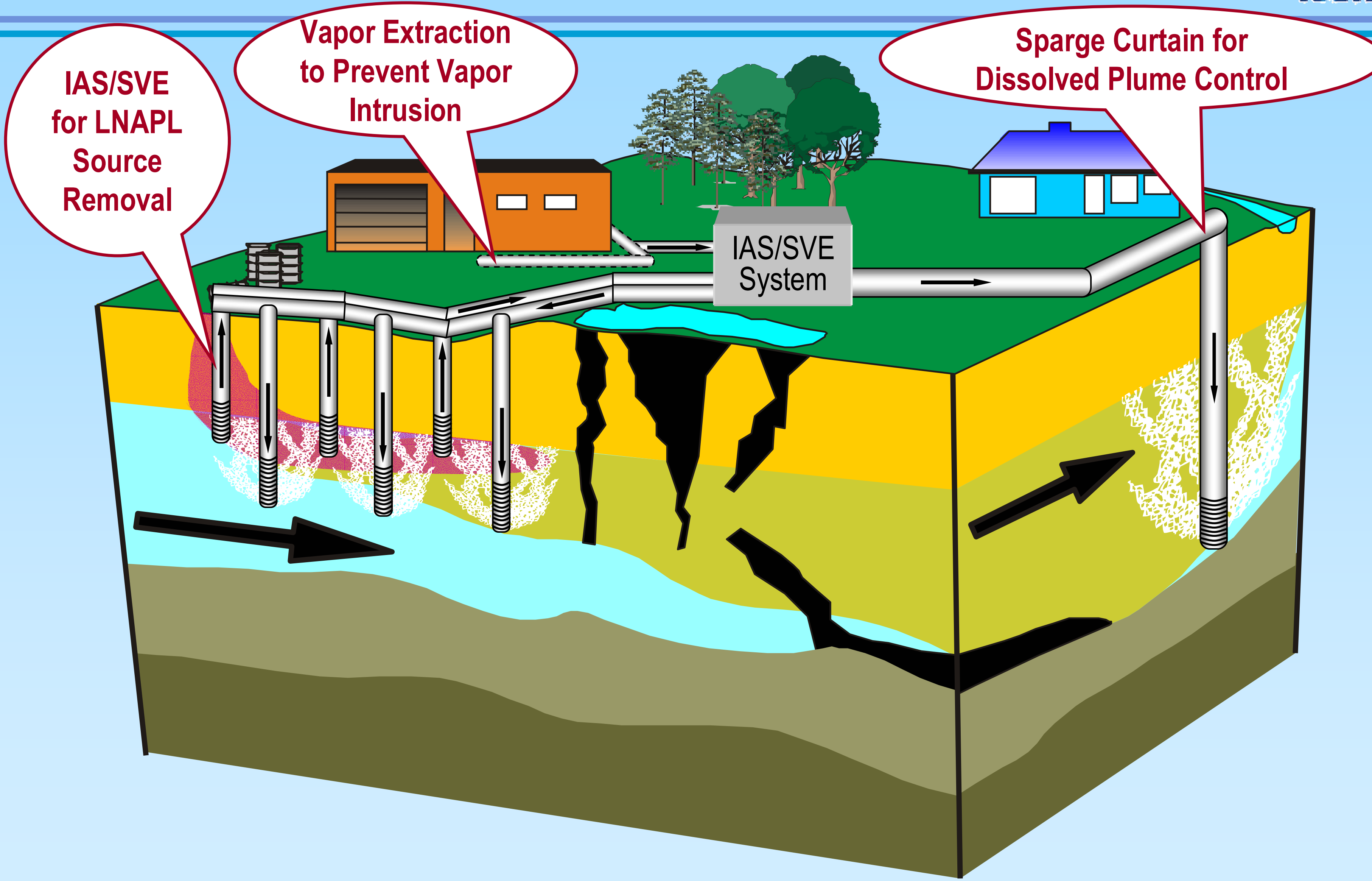
Use Pilot or Bench-Scale Studies

- Demonstrate Effectiveness
  - Testing of innovative technologies
  - Bioremediation: microcosms and/or pilot test
  - Chemical oxidization: soil demand testing and/or pilot test
- Optimize Design
  - Optimize design parameters for any in situ technology, including MPE, IAS, SVE, ISCO, ZVI (zero-valent iron), and bioremediation
  - Greater benefit to larger sites or those with complex geology

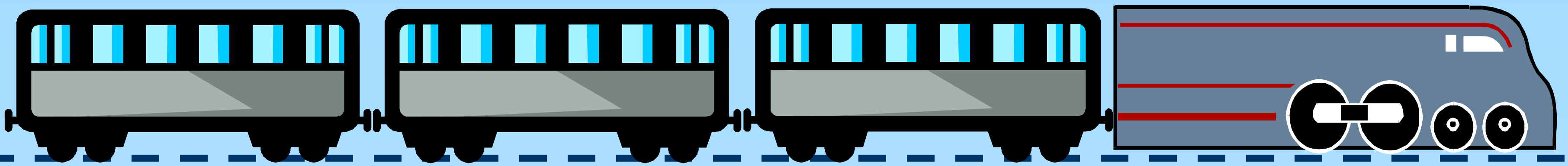


Development of Remedial Approaches

Consider the site holistically (Use of a remedial system in multiple target zones)



Development of Remedial Approaches
Treatment Train Concept



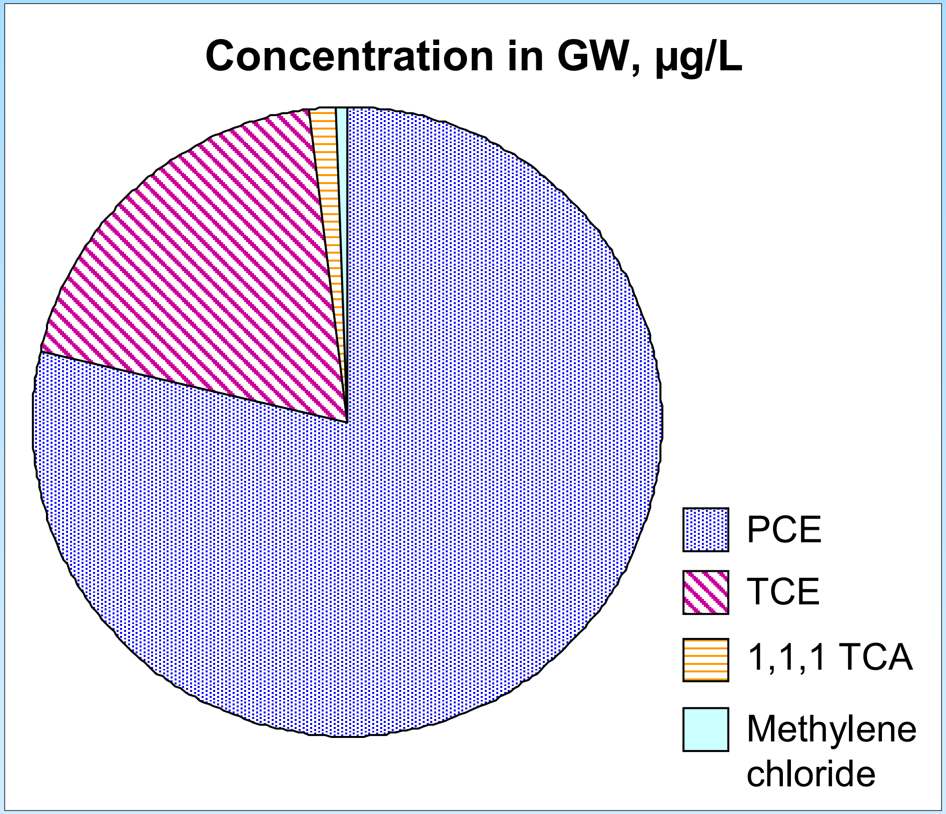
Active	Less Active	Passive
$$$$$$$	$$$$	$

- Develop several remedial strategies from lists of appropriate technologies
  - Sequential operations over time
  - Multiple unit processes in a single treatment system
- A single technology will rarely achieve a protective site closeout at the least cost
- Opens the door for performance-based exit strategy

Treatment Train Example

Ex Situ Technologies Operating Simultaneously

- Large dissolved plume impacted public supply wells
- Groundwater P&T is needed (200 gpm) and is expected to operate for 20 years
- Mixture of chlorinated VOCs



Source: ERM

Treatment Train Example (cont.)

Ex Situ Technologies Operating Simultaneously

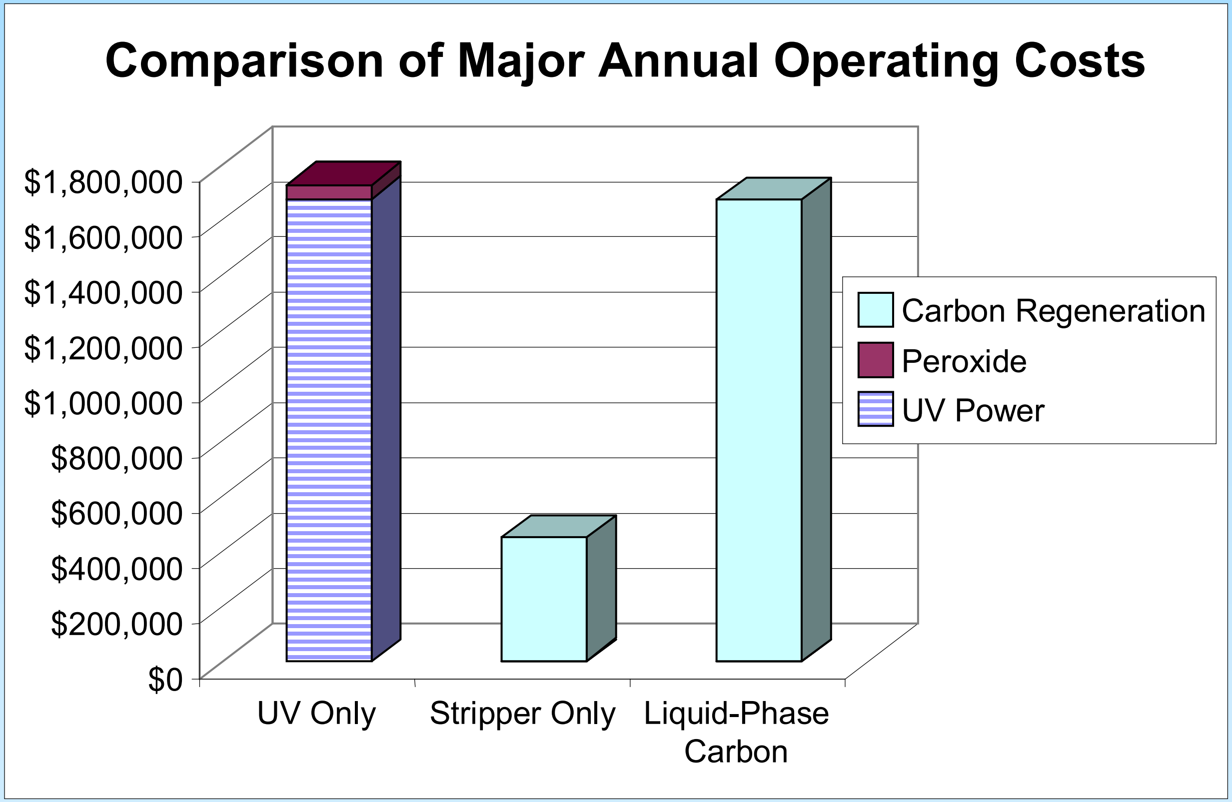
- Technologies Considered
  - Air stripping with emission controls: Effective for all VOCs but air emission controls are costly
  - UV/peroxidation: Effective for all VOCs but energy cost is high, particularly for alkanes (1,1,1 TCA and methylene chloride)
  - Liquid phase carbon: Effective for all VOCs except methylene chloride. Operating cost is high

Source: ERM

Treatment Train Example (cont.)

Ex Situ Technologies Operating Simultaneously

- Cost Evaluation Performed
- Appears that air stripping is the most cost-effective

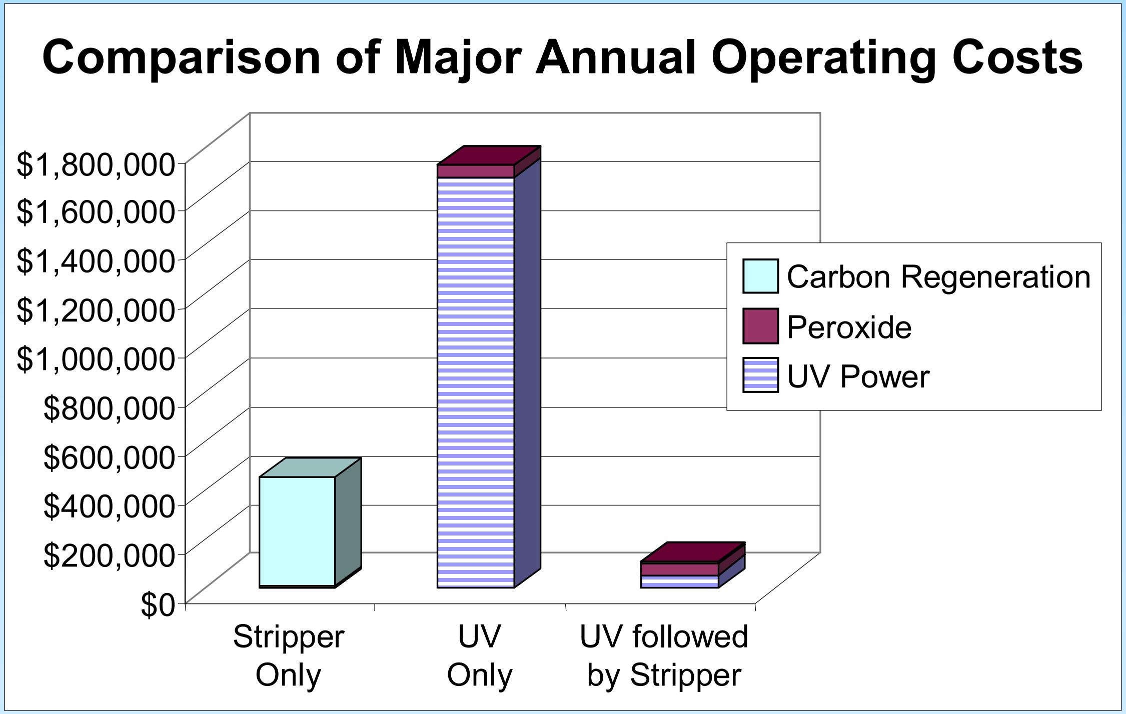


Source: ERM

Development of Remedial Approaches
Treatment Train Example (cont.)

Ex Situ Technologies Operating Simultaneously

- Optimized using Treatment Train Concept
- Evaluated combinations of technologies
- Optimum approach: UV/peroxidation → air stripping
  - UV reactor is used to destroy alkenes with low power requirement
  - Air stripping used to remove low levels of alkanes (1,1,1-TCA and methylene chloride)
  - No emission controls needed for air stripper



Source: ERM

Treatment Train Example (cont.)

Ex Situ Technologies Operating Simultaneously

No Emission Controls

UV/Peroxidation

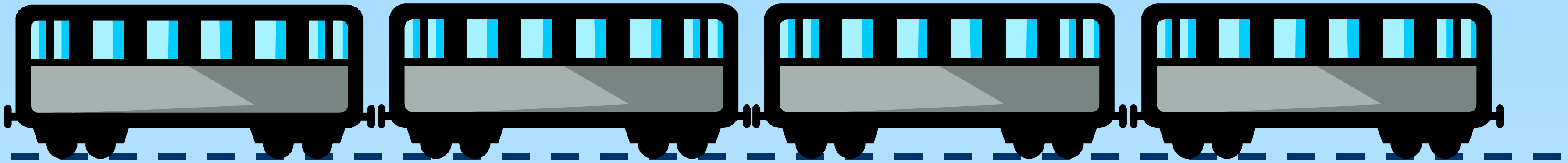
Air Stripping

Source: ERM

Development of Remedial Approaches

Treatment Train Example (cont.)

In Situ Technologies Operating Sequentially



1	2	3	4
MPE	IAS/SVE	Biosparge	MNA

- Use the most appropriate technology considering site conditions
- Allows exit strategy for more costly operating systems without maximum contaminant levels (MCLs) being met
- Provisions should be made in ROD to avoid costly administrative process

Optimization Example: In Situ Treatment Train
Remediation of Large-Scale Gasoline Spill via IAS/SVE

- 700,000 gallons released: 14-acre free product plume
- Large dissolved benzene plume
- Public supply wells at risk

Source: ERM

Optimization Example: In Situ Treatment Train
Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

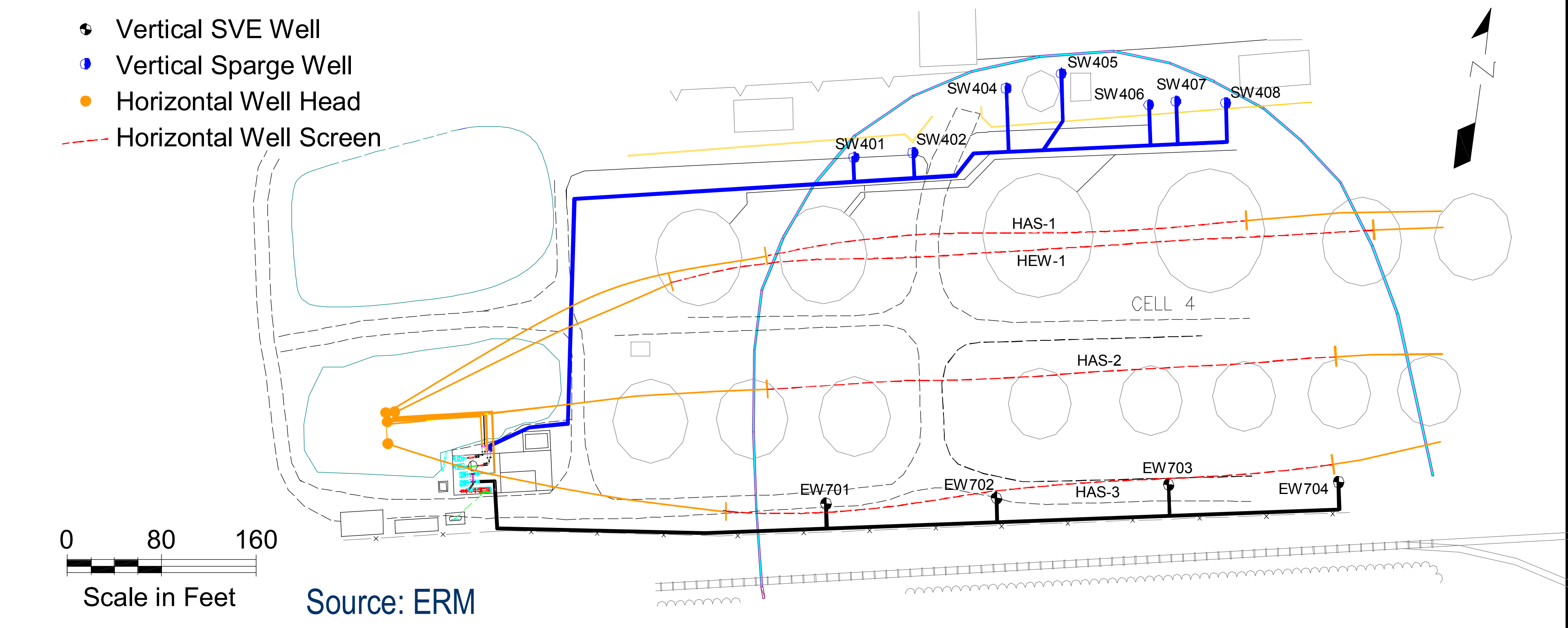
- RAO: Free product removal and protection of public supply wells
- Emergency dual-phase product recovery used for bulk of free-phase LNAPL
- Large change in water table elevation resulted in 10-foot-thick smear zone
- RA selected is IAS/SVE to remove source of benzene-laden NAPL spread out in smear zone in order to allow for monitored natural attenuation (MNA) of dissolved benzene

Source: ERM

Optimization Example: In Situ Treatment Train
Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

North Sector

- Horizontal sparge and SVE wells used for tank farm

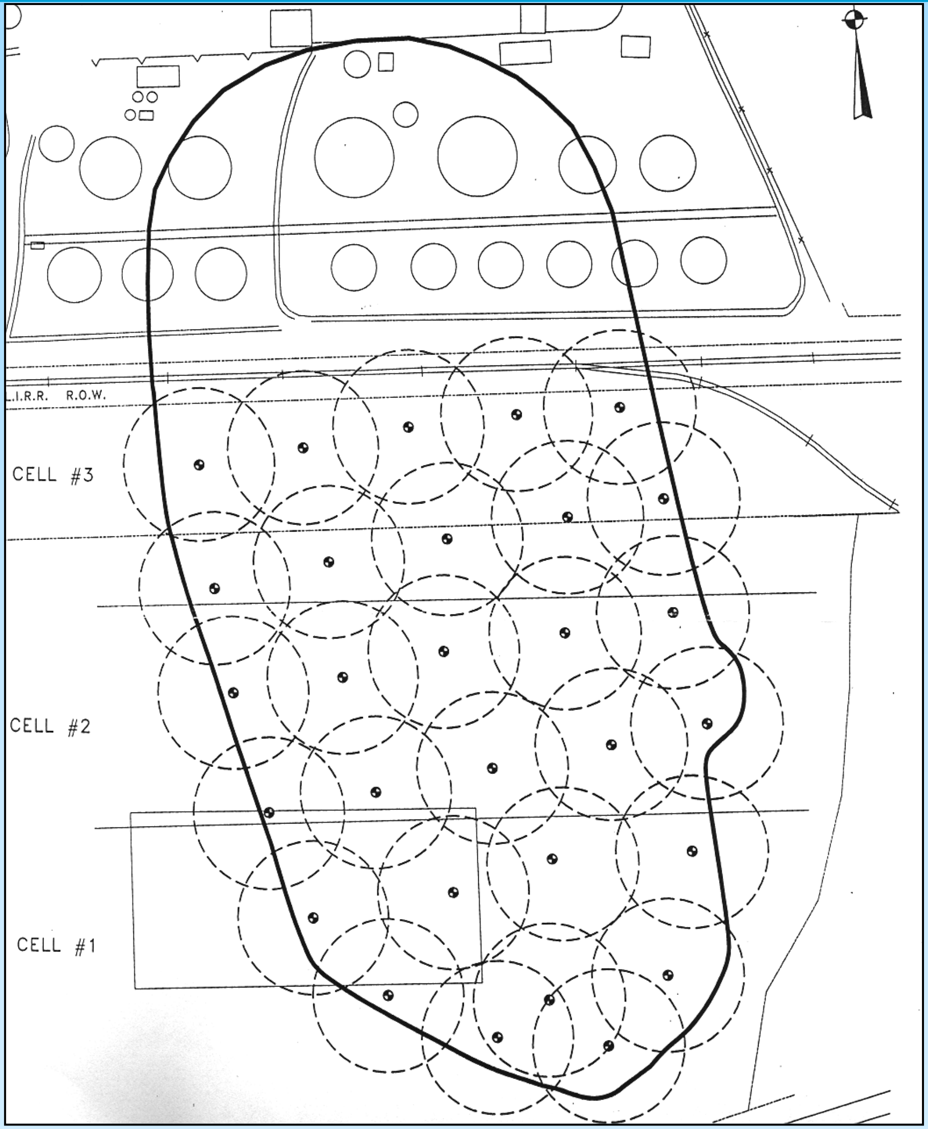


Source: ERM

Optimization Example: In Situ Treatment Train
Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

South Sector

- Vertical sparge and SVE wells used in downgradient open area



Source: ERM

Optimization Example: In Situ Treatment Train
Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

- **In Situ Treatment Train**
  - Phase I: SVE-only until VOC concentrations decrease
  - Phase II: pulsed IAS/AS for aggressive removal of smear zone
  - Phase III: biosparge designed to maintain elevated dissolved oxygen (DO) levels with no SVE
  - Phase IV: MNA
- **Concurrent sparge curtain to prevent dissolved benzene from migrating off-site allowing P&T shutdown**

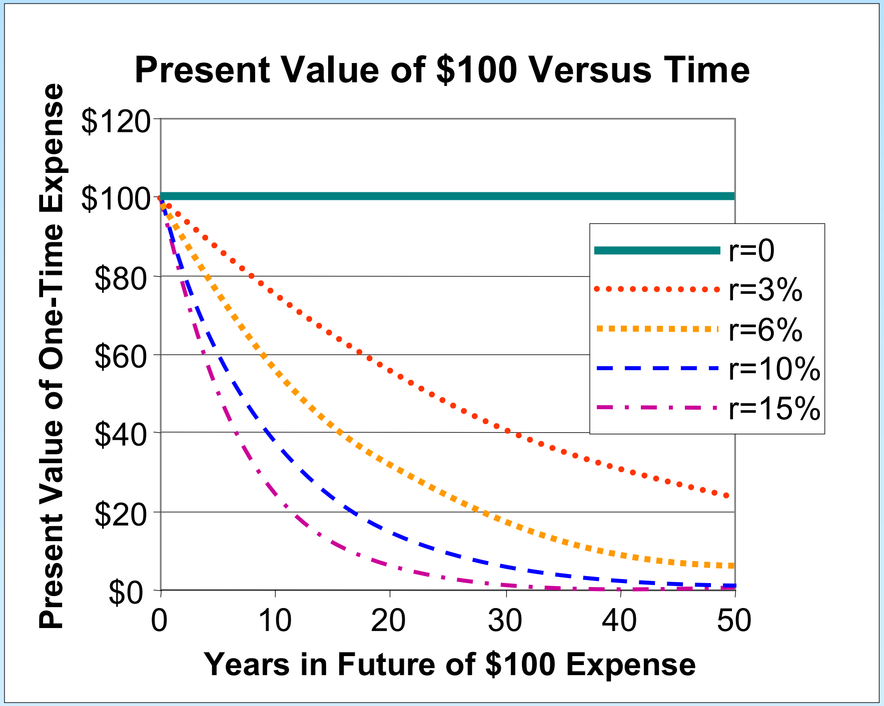
Source: ERM

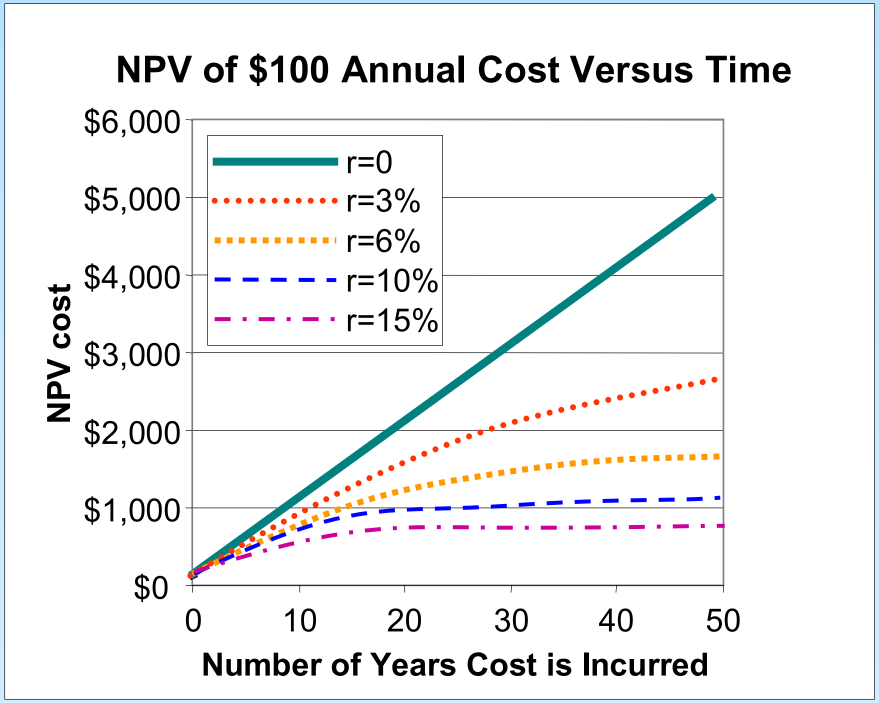
Perform Life-Cycle Analysis

- **Determine the overall net present value cost of each remedial strategy**
  - **NPV = C + (A)*(CRF) + (Fi)*(PVFi), where**
    - NPV = net present value
    - C = capital cost
    - A = reoccurring annual cost
    - CRF = capital recovery factor at rate of return (r) and number of years incurred (n)
      - $CRF = ((1+r)^n-1)/(r*(1+r)^n)$
    - Fi = future cost at some years in the future
    - PVFi = present value factor at a rate of return (r) and years into the future (ni)
      - $PVFi = 1/(1+r)^{(ni)}$
- **Although DON does not invest money there is still a time-value of money factor: CERCLA policy for FS requires 7% for nonfederal sites, and Office of Budget Management (OBM) for federal sites.**
  - **http://www.whitehouse.gov/omb/circulars/a094/a94_appx-c.html**
- **Perform sensitivity/uncertainty analysis to identify potential high cost elements**

Perform Life-Cycle Analysis (cont.)

- Determine net present value cost
- Perform sensitivity/uncertainty analysis to identify potential high cost elements

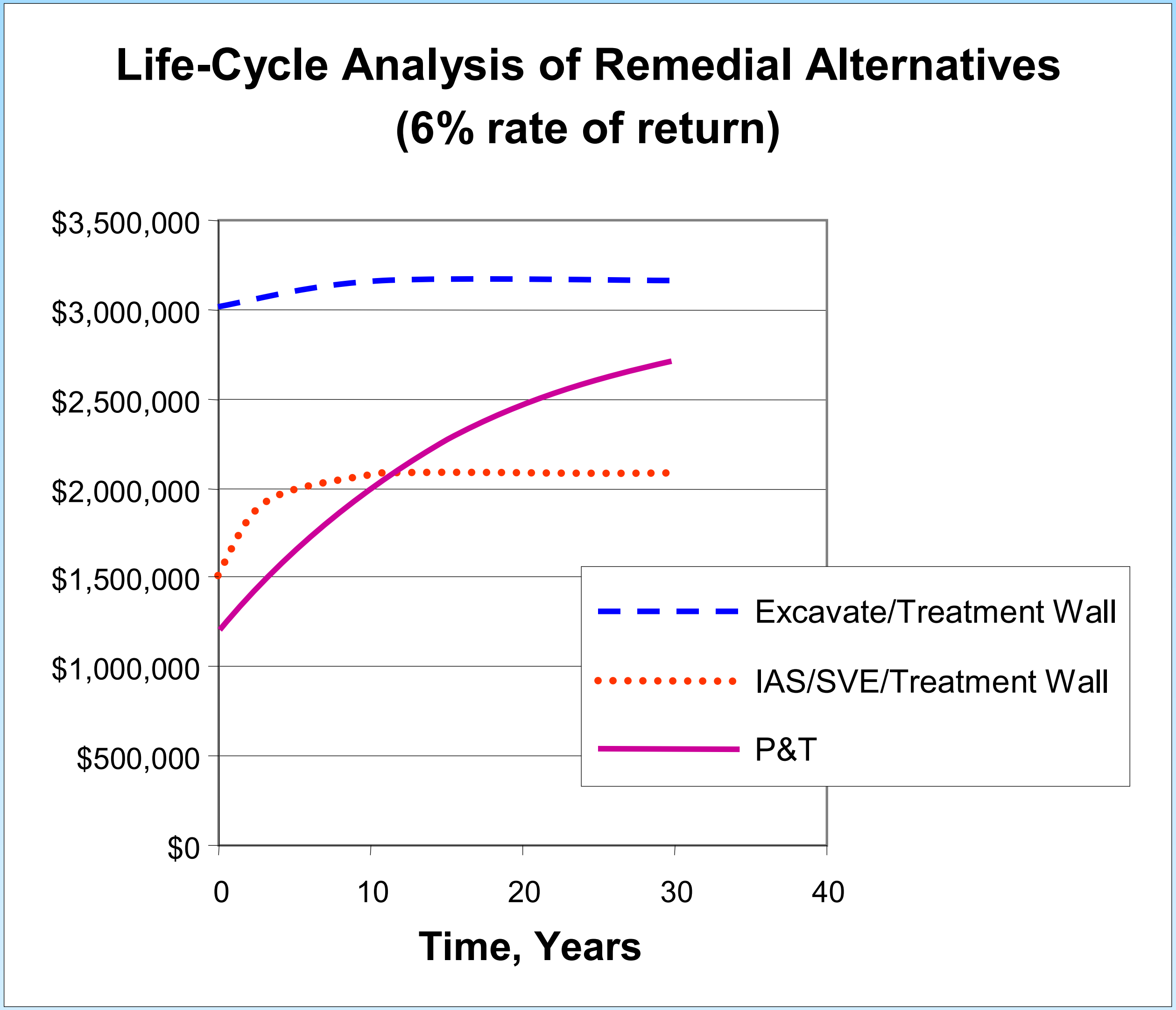




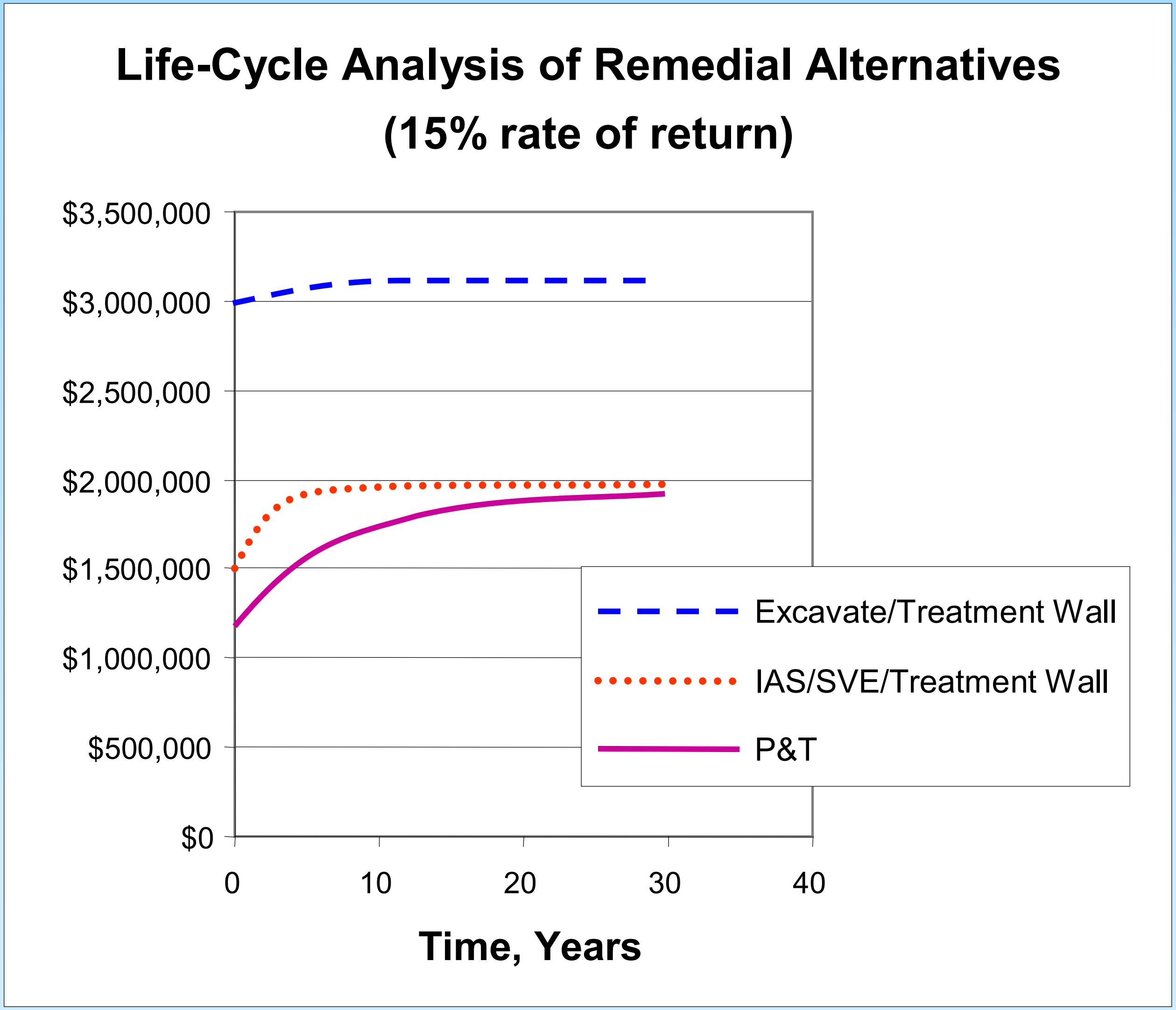
Example of Life-Cycle Analysis

- Excavate hot spot with treatment wall for dissolved plume
  - Highest capital cost to excavate and install barrier ($3 million)
  - Annual cost of $20,000 for LTM for 10 years
- Pump and Treat
  - Lower capital cost ($1.2 million)
  - Without source removal annual cost is $110,000 for 30 years
- IAS/SVE in hot spot with treatment wall for dissolved plume
  - Moderate capital cost ($1.5 Million)
  - Annual cost of IAS/SVE operation of $150,000 for 3 years
  - Annual cost of $20,000 for LTM for 13 years

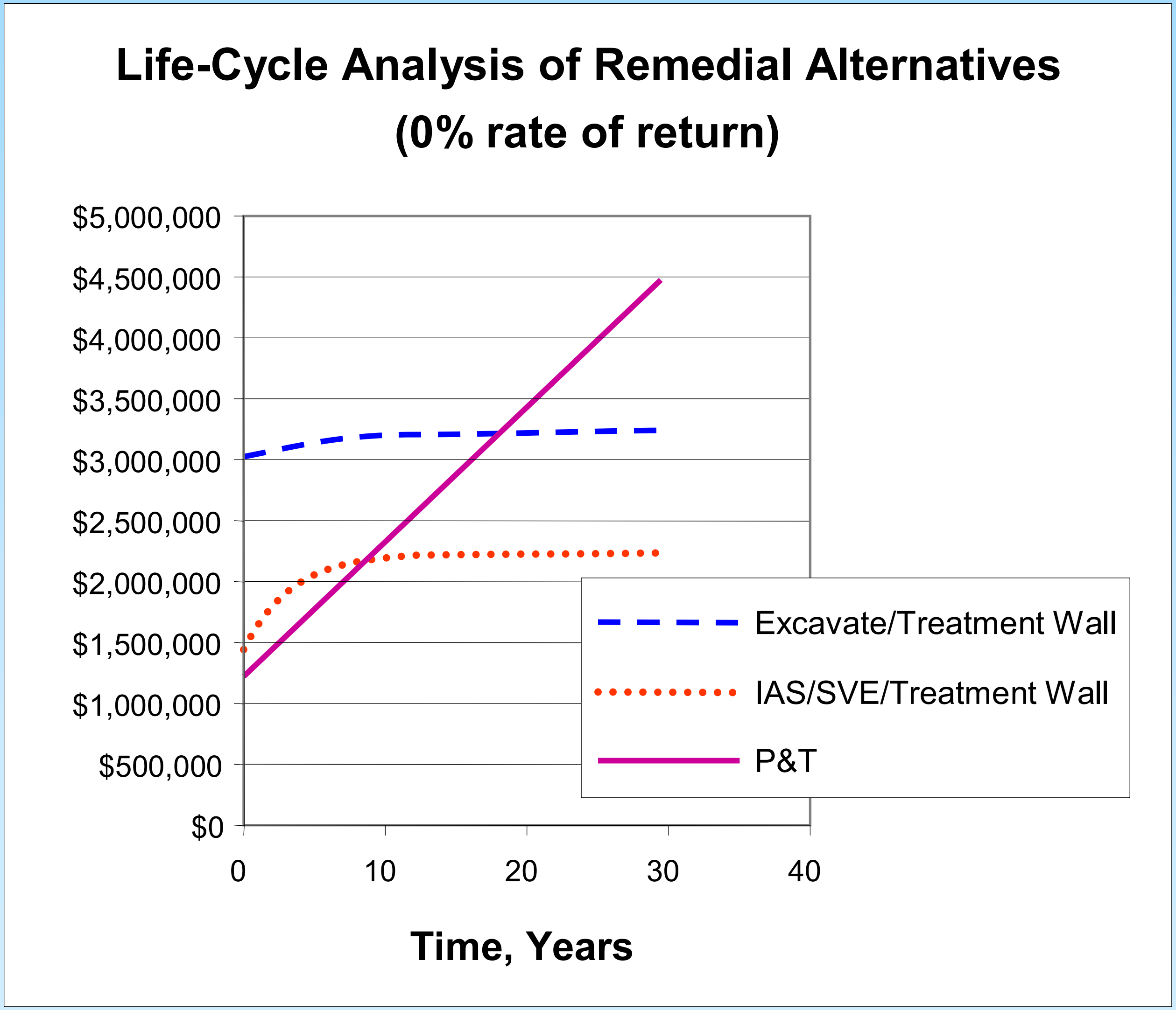
Example of Life-Cycle Analysis (cont.)



Example of Life-Cycle Analysis (cont.)



Example of Life-Cycle Analysis (cont.)



Evaluation of Remedial Approaches

- Nine FS Criteria
  - Threshold criteria
    - Protection of human health and the environment **(Remedy must be cost-effective)**
    - Compliance with ARARs **(cost can be considered as factor to waive ARAR)**
  - Primary balancing criteria
    - Long-term effectiveness
    - Reduction in toxicity, mobility, or volume through treatment
    - Short-term effectiveness
    - Implementability
    - **Cost**
  - Modifying criteria
    - State acceptance
    - Community acceptance
- Cost is a critical criterion
  - Comprehensive NPV cost estimate accounts for parts of other criteria
  - **Cost drives the optimization program although other criteria must be considered**

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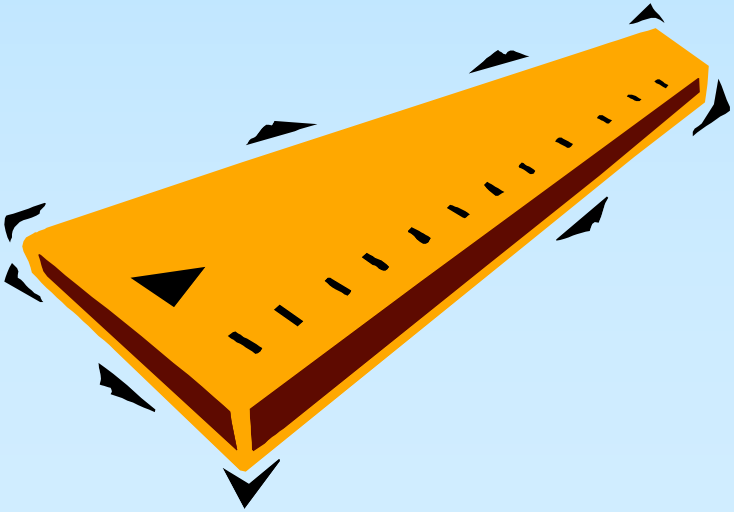
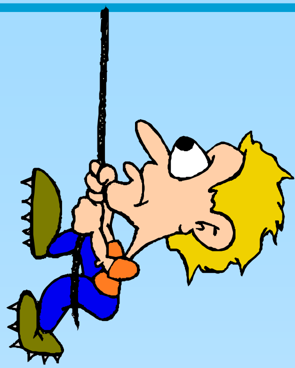
Performance Objectives

- Is it working?
  - Establish criteria to measure operational efficiency of each technology
- Should it be adjusted/modified?
  - Used to optimize Remedial Action Operations
  - May trigger operational adjustments or design modifications
- Should it be stopped?
  - Used to demonstrate that system operated efficiently which is a necessary element of many exit strategies
- Examples of Operational Efficiency Criteria
  - Extraction flowrate
  - Vacuum level
  - DO level
  - Distribution of chemical oxidant
  - Redox potential



Practical Goals as Element of Exit Strategy



Poor

Meet MCL

Better

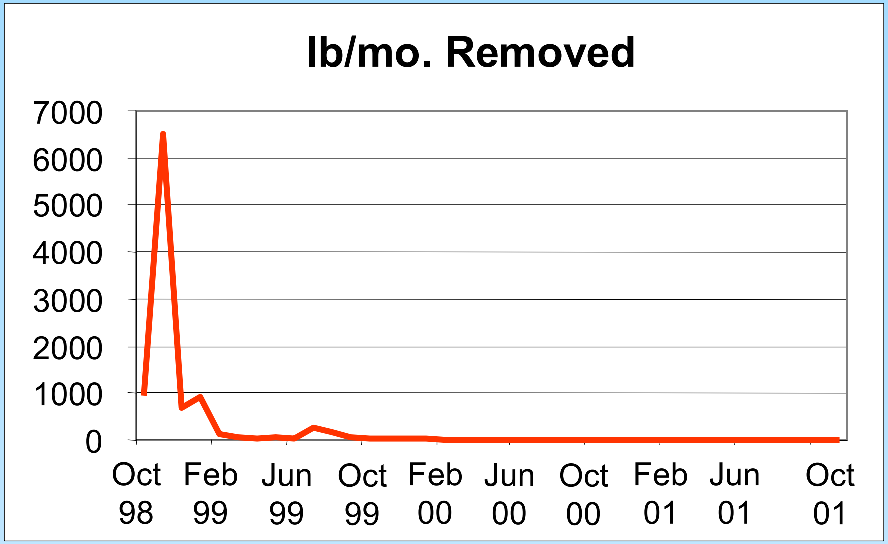
90% VOC removal or 90% reduction in concentration

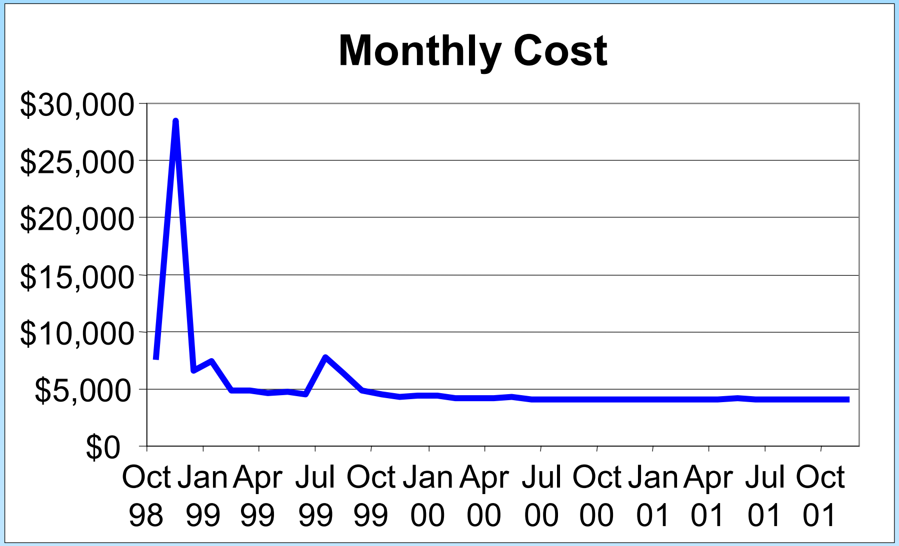
Best

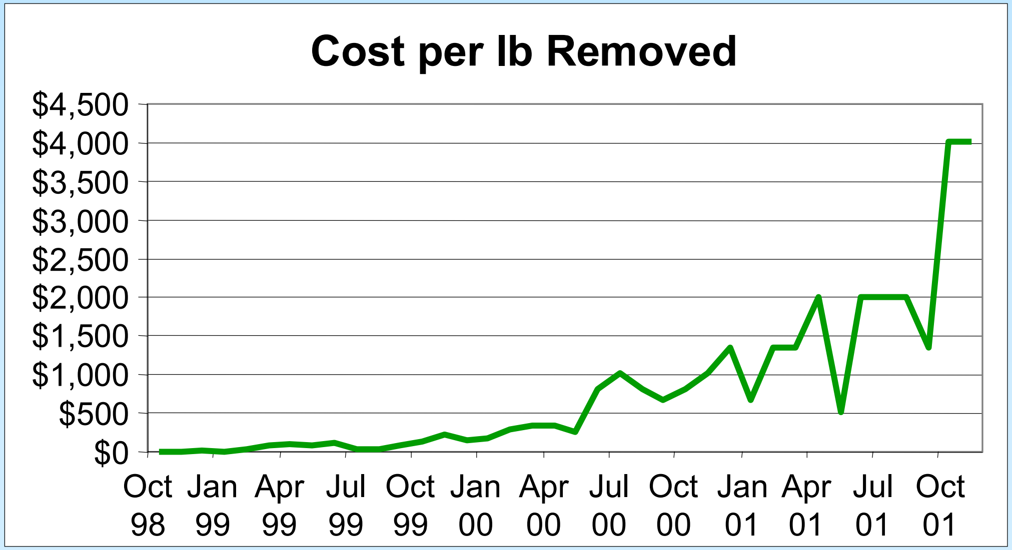
Asymptotic condition is reached with respect to mass removal and/or concentration remaining

A particular cost-per-pound removed is exceeded

Mass Removal and Cost Per Unit Mass Removed During Project Life-Cycle







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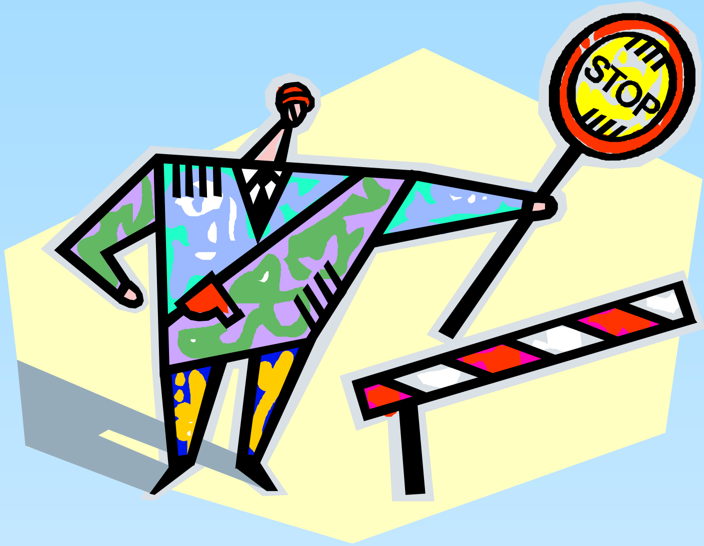
Exit Strategy
Be Prepared to Stop Before Starting

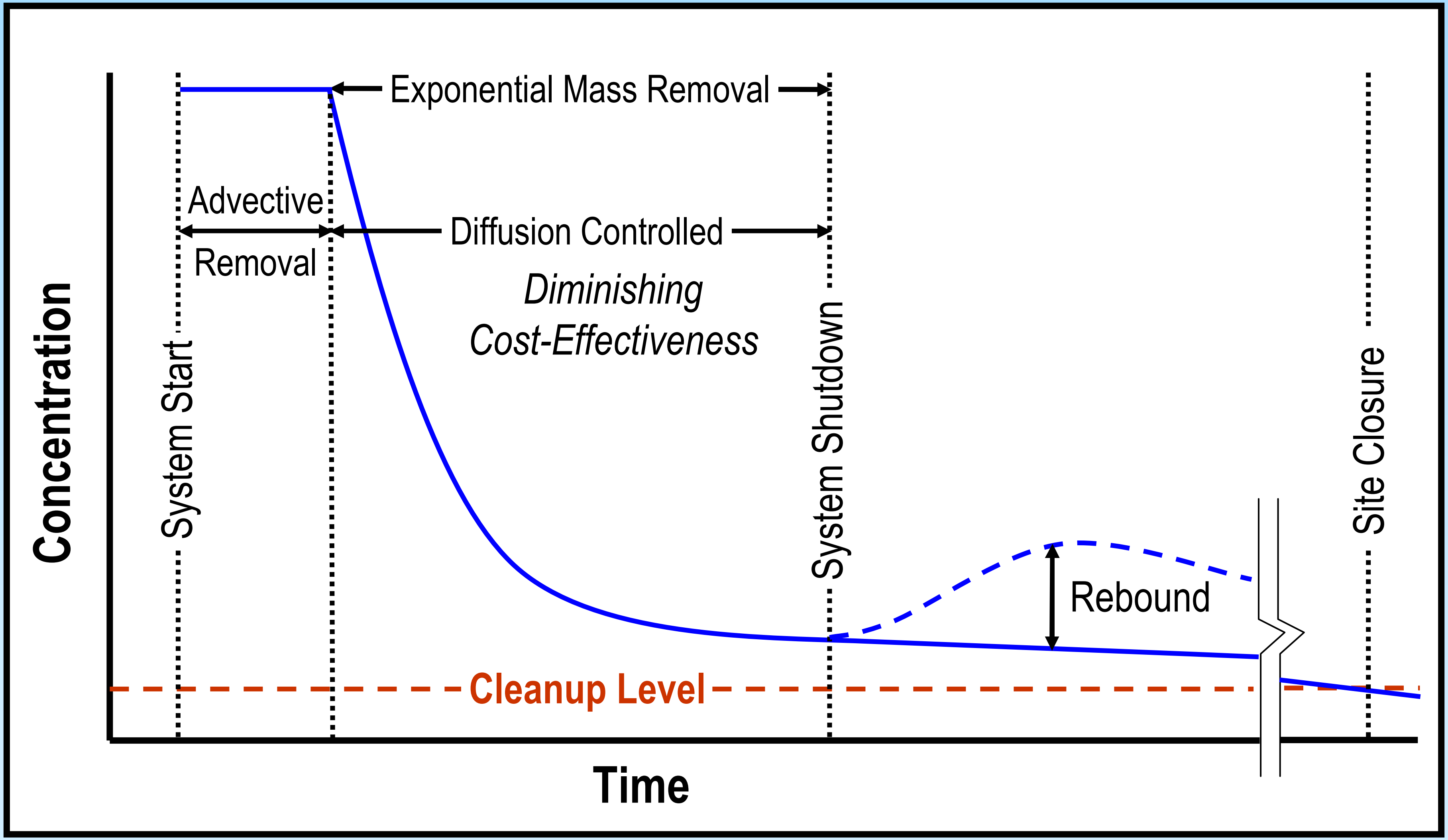
- **Exit strategy: accepted by regulators documented (FS, ROD and RD)**
  - **Establish *before* system installation**
  - **Flexibility in ROD to allow transitioning or exit without Explanation of Significant Differences (ESD) or amendment**
  - **Use Operations, Maintenance, Monitoring and Optimization (OMMO) (part of RD submittal) to specify criteria to determine if performance objectives are met**
    - Monitoring plan
    - Method to evaluate results
- **Make transitioning part of RA operation**
  - **Transition to less active or passive phases**
  - **Performance objectives as basis**



Use Flexible Performance-Based ROD

Inflexible	Flexible
Maintain hydraulic control	Prevent contaminant migration
Use MPE to remove LNAPL to less than 0.1 ft in all Monitoring Wells	Remove LNAPL to maximum extent practicable using MPE or alternate methods
Use SVE to achieve 100% control of injected sparge air	Prevent migration of VOC vapors using SVE or alternate methods as required to meet ARARs
Treat off-gas using a thermal oxidizer and achieve a minimum of 98% VOC destruction	Treat off-gas using a thermal oxidizer or alternate methods as required to meet ARARs

Exit Strategy
Rebound Evaluation



Rebound Evaluation (cont.)

- Include rebound evaluation and contingency should rebounding occur
  - One sample round should not be considered rebounding
  - Use statistical approach to evaluate rebounding
  - Contingency should not be an overreaction
    - Reevaluate risk caused by rebound levels
    - Consider the demonstrated limitations of the applied technology
    - Don’t get caught in a loop

Rebound Evaluation (cont.)

- Example Definition

$$\text{Rebound} = \frac{\log\left(C_r / C_f\right)}{\log\left(C_o / C_f\right)}$$

Where:

C_o = Initial COC concentration

C_f = Concentration at last periodic sampling event prior to system shutdown

C_r = Concentration after extended system shutdown

Typical Values at Air Sparging Sites (Bass et al.)

- Rebound < 0.2 Permanent Reduction
- Rebound > 0.5 Substantial Rebound

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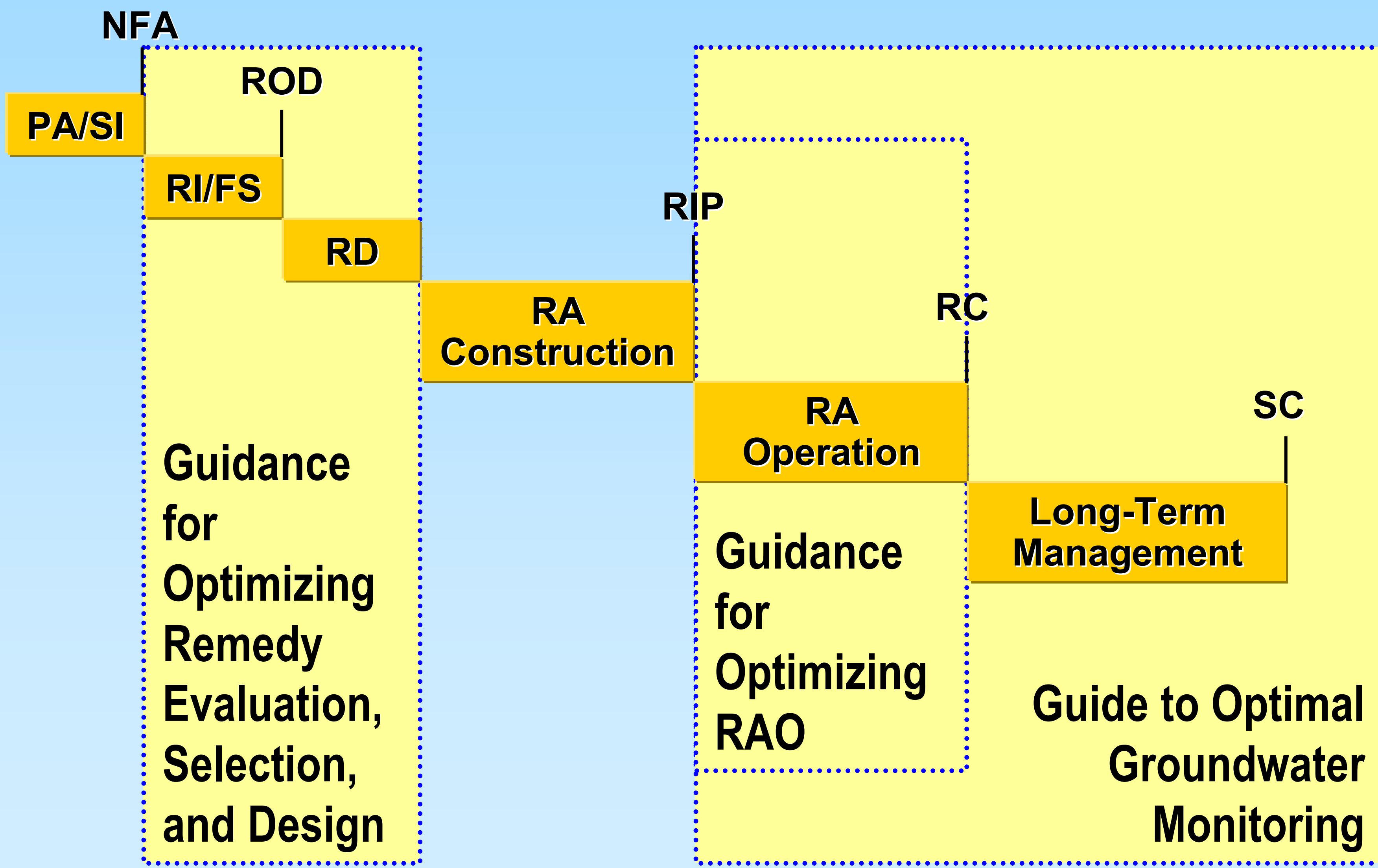
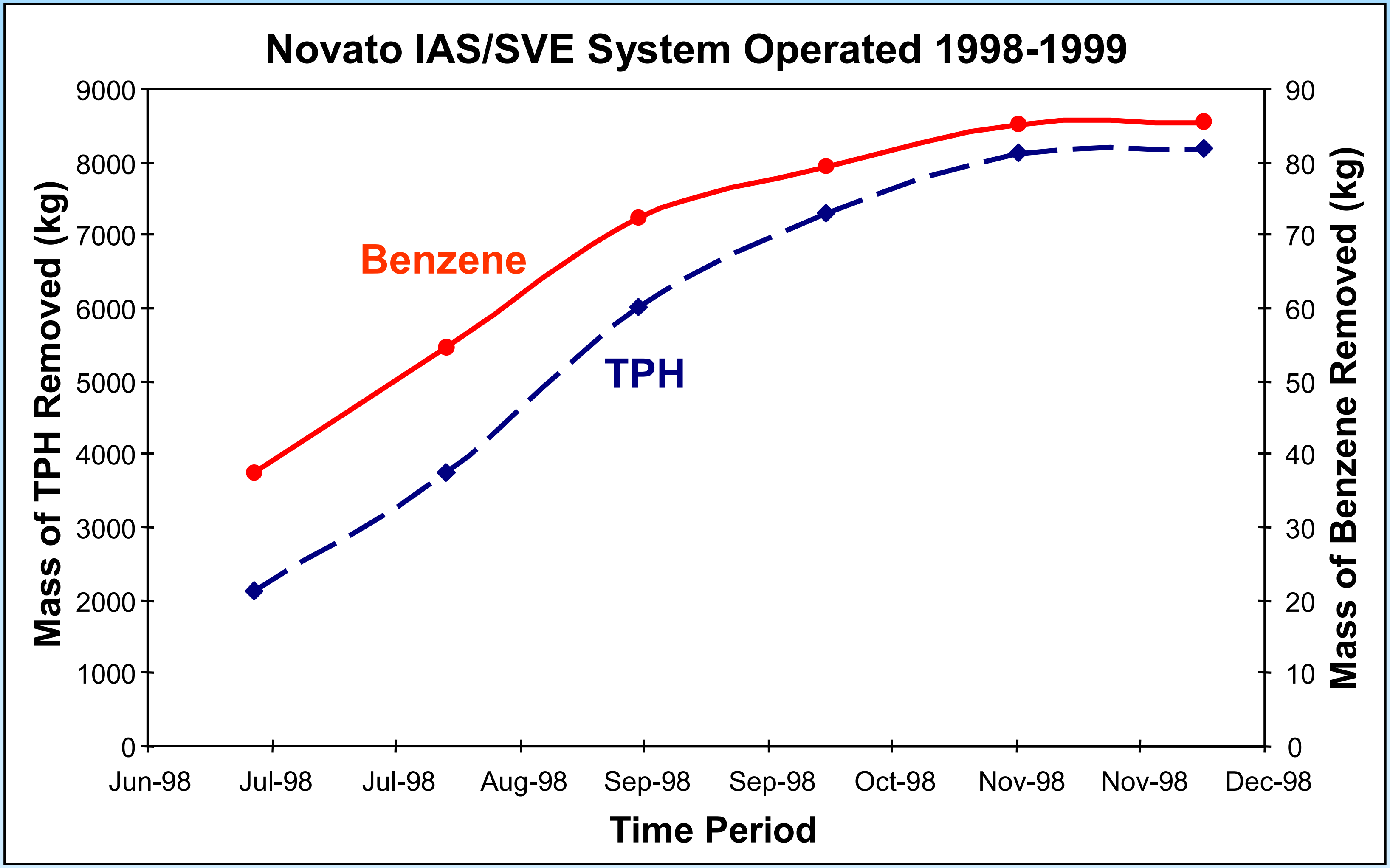


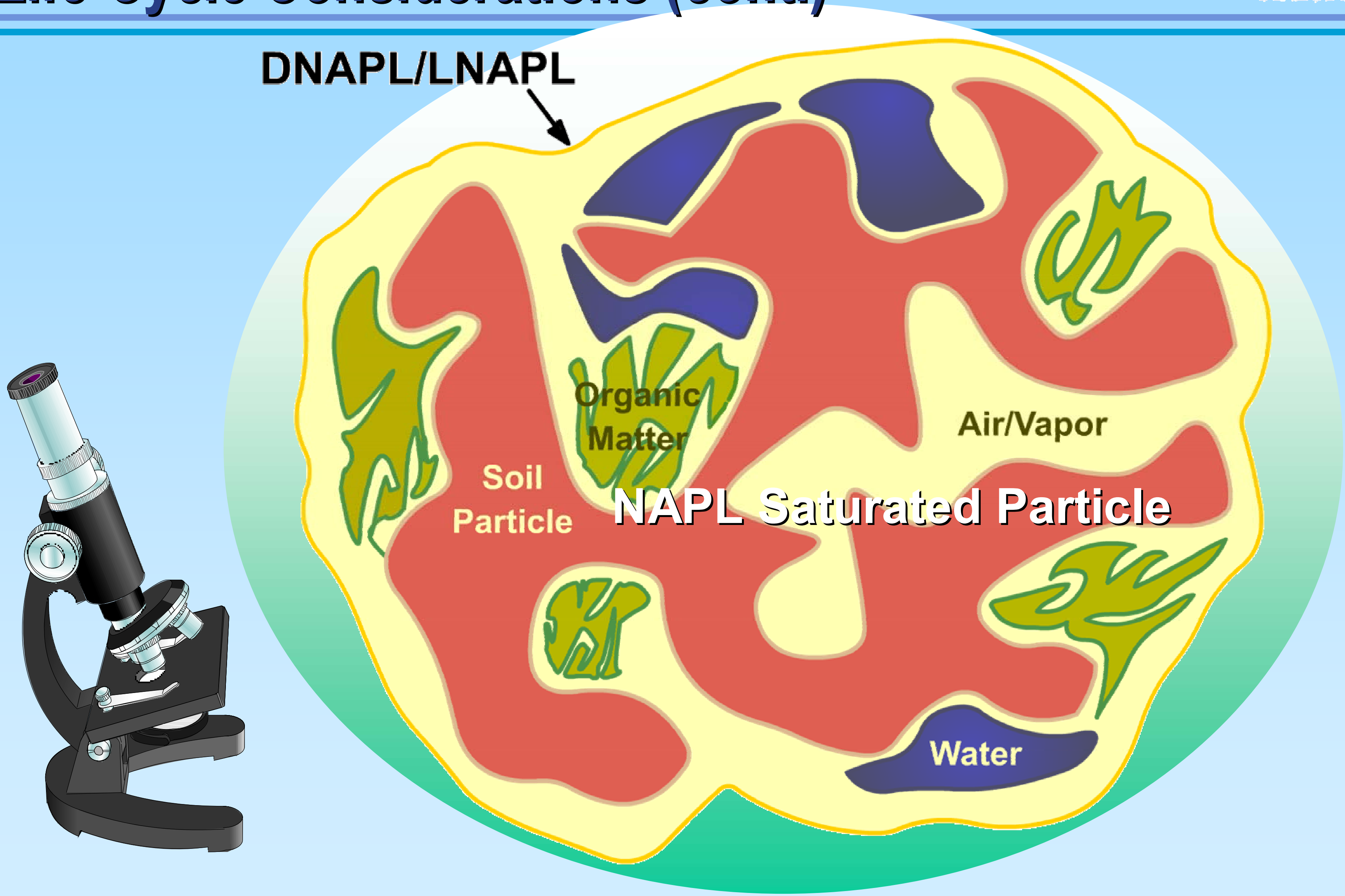
Implementation Strategies

- During RD revisit CSM and selected remedies
  - Years can pass from FS to RD
  - Site conditions can change
  - Technological advances are made
  - New performance data for selected remedial technologies may become available
  - Changes in regulatory/public policy
  - Economics can change (i.e., price of disposal)

Implementation Strategies: Life-Cycle Considerations

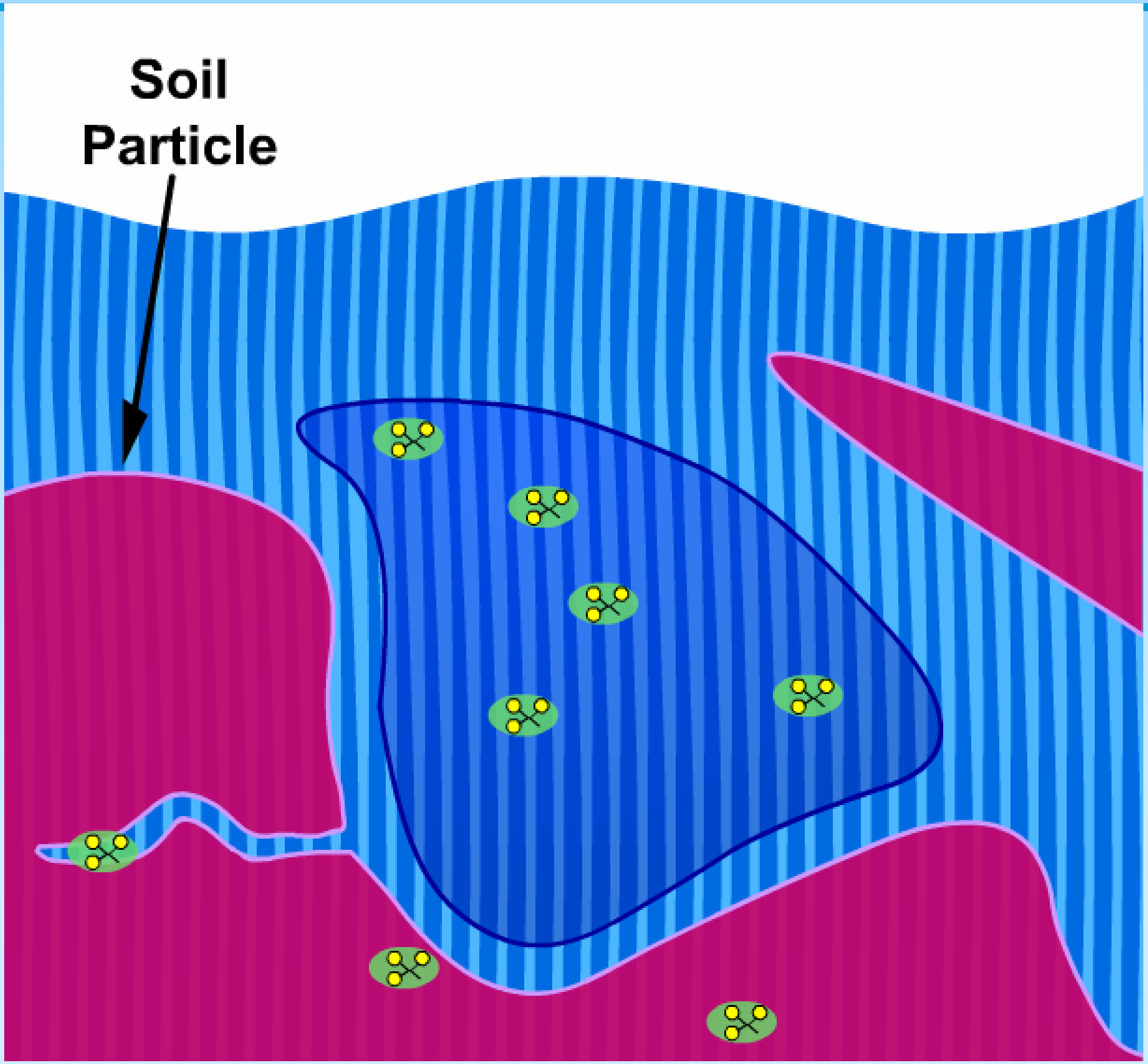


Implementation Strategies: Life-Cycle Considerations (cont.)

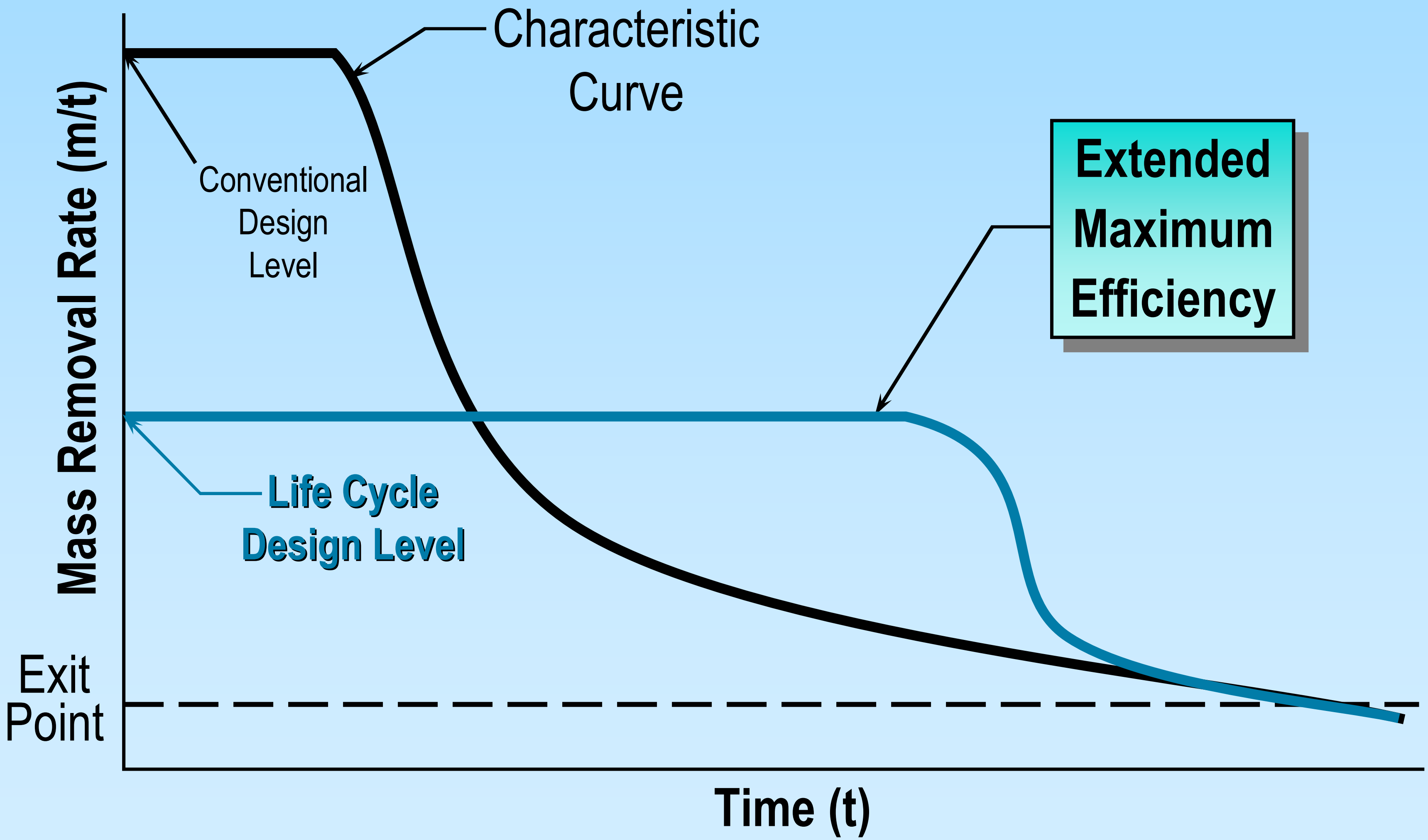


Implementation Strategies: Life-Cycle Considerations (cont.)

- Removal via Dissolution and Advection is a Slow Process where NAPL is Present

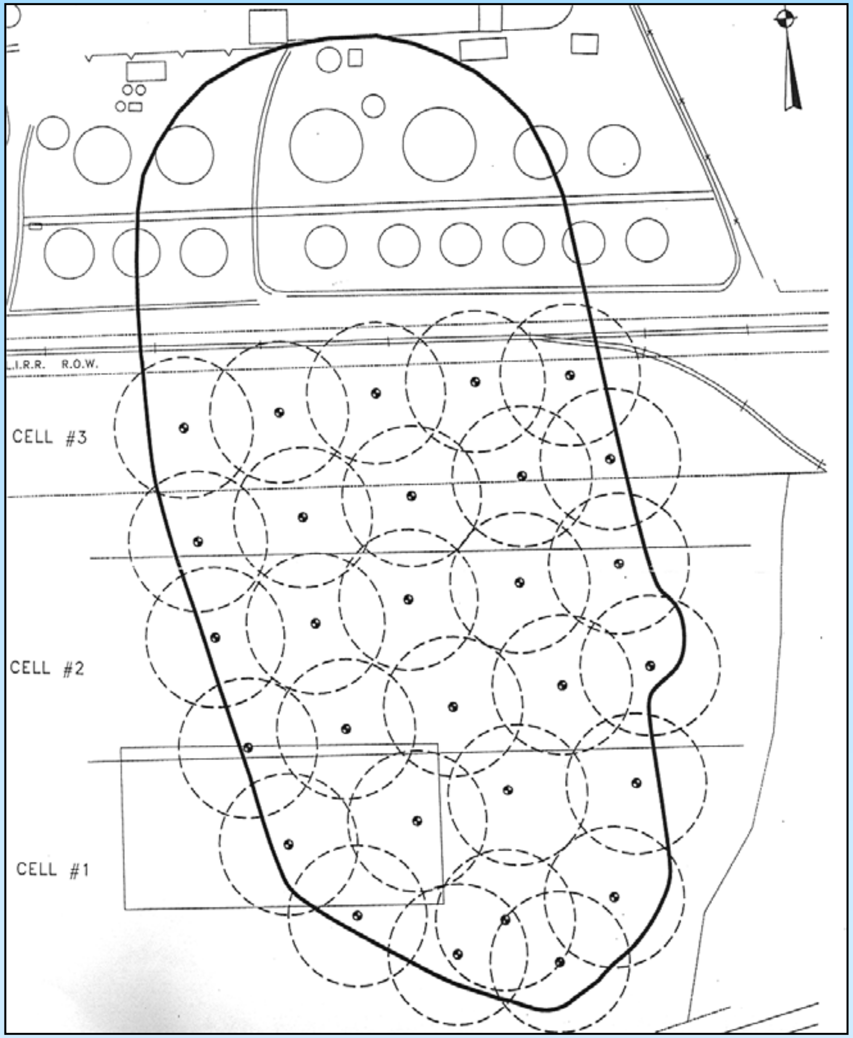


Life-Cycle Considerations: Designing for Typical Mass Removal Trend



Optimization Example: Life-Cycle Considerations
Remediation of Large-Scale Gasoline Spill via IAS/SVE

- Site was broken down into cells to maximize efficiency
  - Reduced equipment size
  - Accounted for diffusion-limiting conditions
  - Pulsing of a sparge air has been found to redirect airflow paths and increase mass removal rate
  - Reduced the cost per mass of contaminant removed
- Programmable Logic Controller (PLC) and automatic valves used to allow pulsing of cells so equipment is in use 100% of time but focused on different areas



Source: ERM

Optimization Example: Life-Cycle Considerations
Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

- Catalytic oxidizer was initially the limiting factor when concentrations were very high
- After less than two months, oxidizer was no longer limiting factor

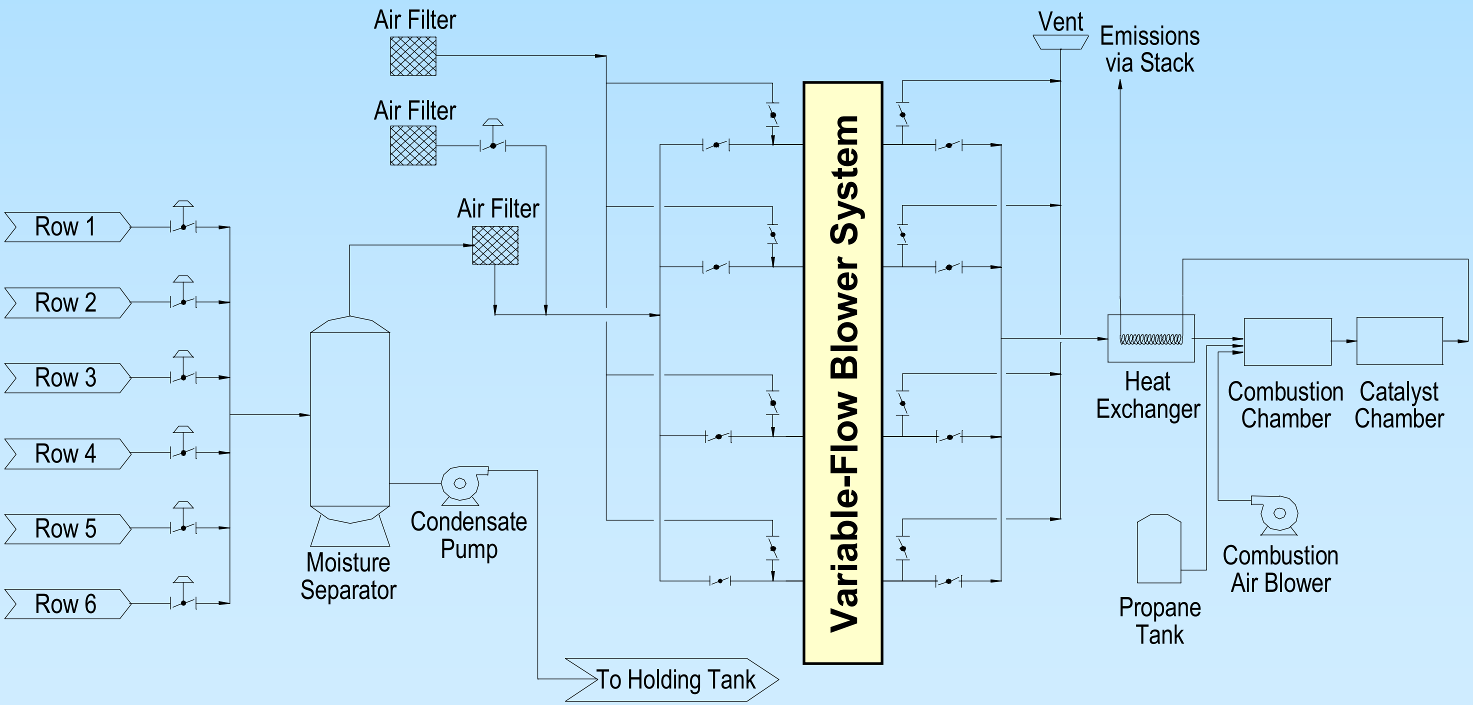
North Sector Oxidizer

South Sector Oxidizer

Source: ERM

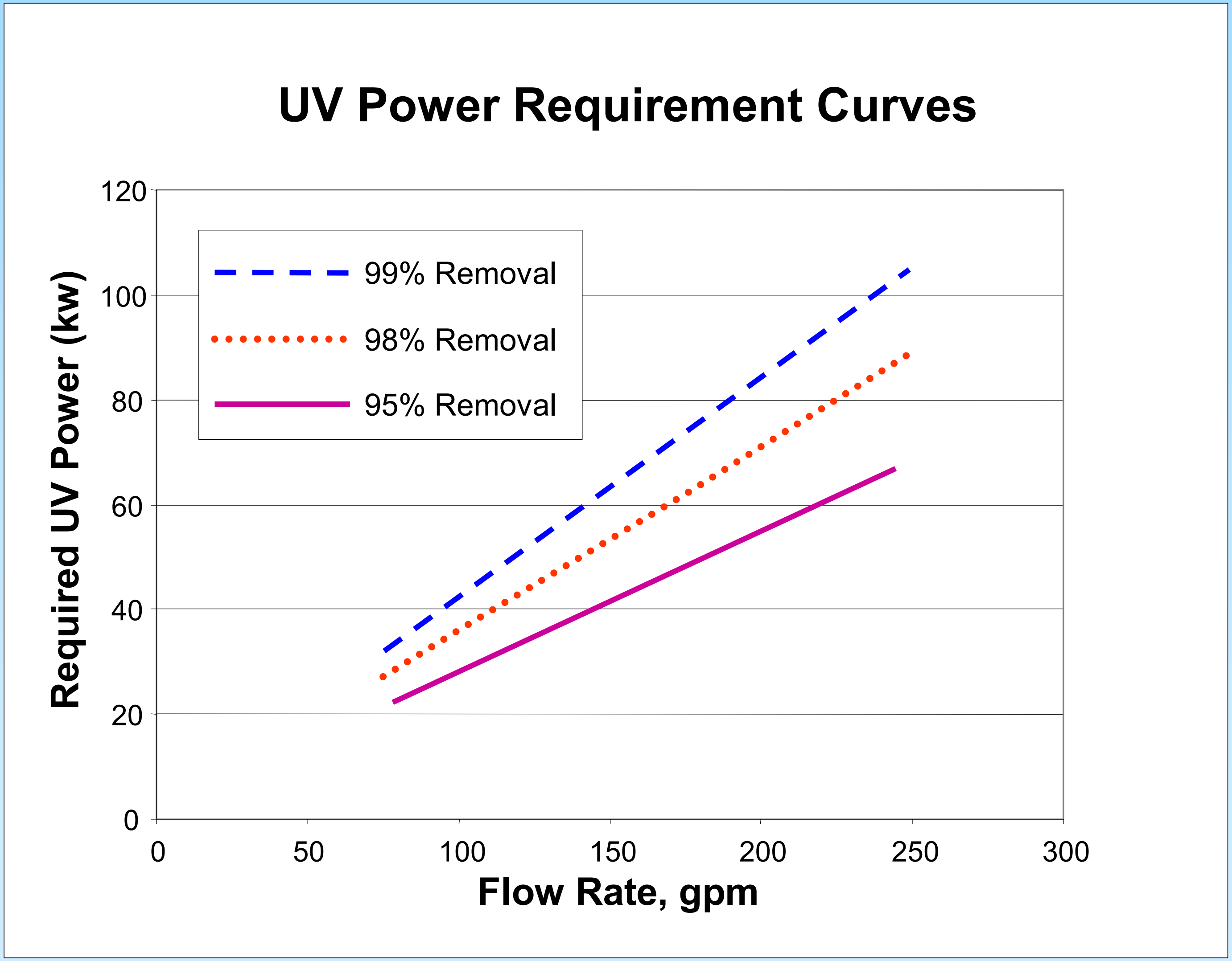
Optimization Example: Life-Cycle Considerations Remediation of Large-Scale Gasoline Spill via IAS/SVE (cont.)

- Programmable logic controller (PLC)
- 70% efficient heat exchanger with automatic bypass control valves
- Automatic control of dilution air flow, SVE flow and sparge flow



Source: ERM

Life-Cycle Approach to Groundwater Treatment: UV/Peroxidation Example

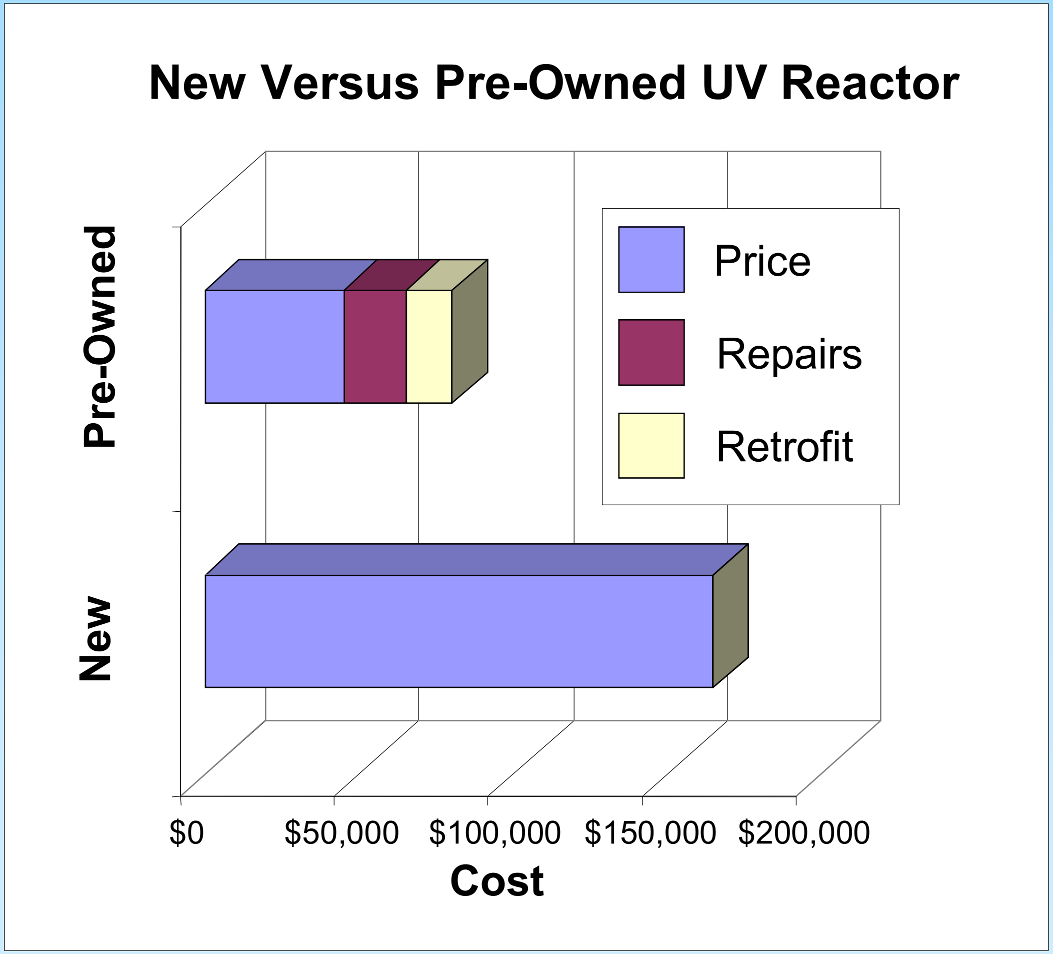


Life-Cycle Approach to Groundwater Treatment: Air Stripping

- Blower requires significant energy for large systems
- Blower power is essentially constant at any flowrate or VOC concentration
- To reduce power:
  - Remove trays (if tray stripper) to reduce pressure
  - Change gear ratio to reduce speed

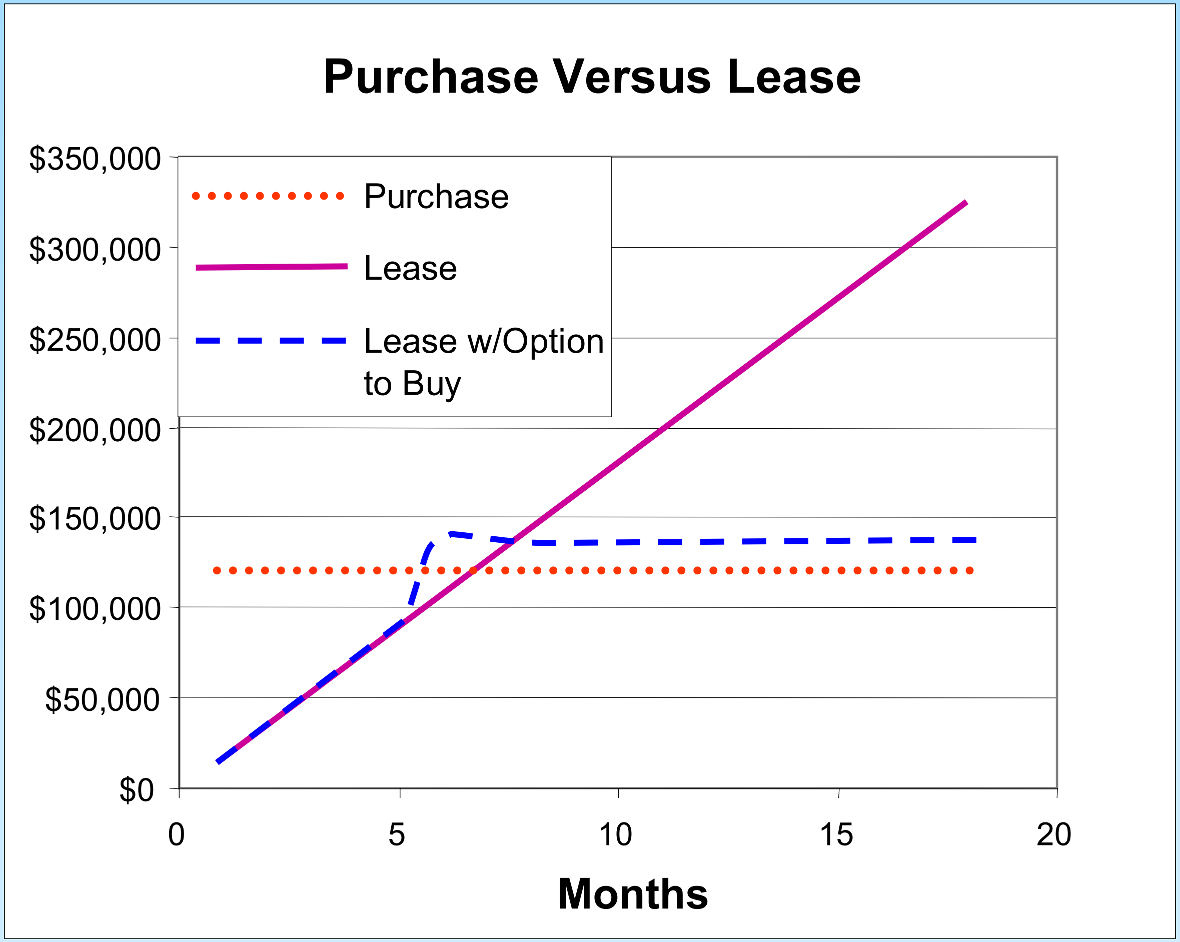
Implementation Strategies

- Purchase pre-owned equipment
  - Other sites that no longer need certain equipment
  - Evaluate condition and refurbishment/retrofit needs
  - Could purchase from brokers



Implementation Strategies (cont.)

- Lease equipment
  - Good for short-term needs (less than six months)
  - Lease with option to buy in the event system must continue to operate for a prolonged period



Implementation Strategies (cont.)

- Design mobile system
- Can be used at different units of same site or across sites/bases
  - When no longer needed, a mobile unit is more attractive for resale by Navy or Navy's contractor

Optimization Example: During RD and RAO Superfund Site in Long Island, New York

- Original IAS/SVE design required new equipment installed inside a new building to be located adjacent to contaminated area
  - Both the contaminated area and equipment compound were to be fenced off
  - Greatly reduced available space for parking outside active building
  - New equipment in new building greatly increased capital cost
- Operating plan was to perform IAS/SVE until cleanup standards were met with no provisions for performance-based shutdown
- PRP took over project and performed design review to optimize the system design and operating plan

Source: ERM

Optimization Example: During RD and RAO (cont.) Superfund Site in Long Island, New York

- Changed to leased trailer-mounted equipment installed over contaminated area
- Use of mobile equipment allowed subsurface soil sampling to be done by moving equipment
  - Reduced space needed by approximately 50% allowing more parking available in a congested area.
  - Capital cost and installation time was greatly reduced
  - Also included a multilevel exit strategy allowing performance-based exit should soil MCL-based remedial objective not be met

Source: ERM

Photo Source: ERM

Implementation Strategies (cont.)

- Use standard equipment where possible
  - Allows for competitive bidding for each piece of equipment
  - Reduces cost during operation
  - Replacement parts are more readily available
- Be consistent in equipment selection where possible
  - Operators become familiar with equipment O&M
  - Parts can be interchangeable
  - Cost of maintenance visits from vendors is reduced by allowing one vendor to service multiple pieces of equipment

Implementation Strategies: Process Controls Considerations

- Highly automated: higher capital cost, reduces O&M cost
- Telemetry is more advantageous for remote sites
- Supervisory Control and Data Acquisition (SCADA)
  – Expensive
  – Reduces reporting time
  – Reports are more consistent
  – Better database for process optimization
- Evaluation of control system
  – Use NPV analysis
  – Develop preliminary process and instrumentation diagram (P&ID) and meet with process engineer, control system specialist and system operator

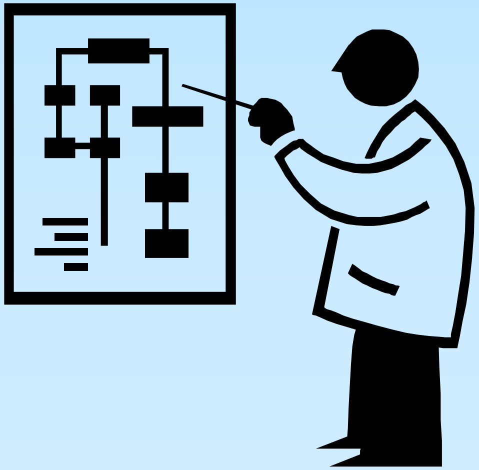
Implementation Strategies: Value Engineering to Optimize RD

- Why ?
  - Reduce cost while still meeting remedial objectives
  - Revisit design feature objectives
  - During RD process, the design tends to become more complicated

Implementation Strategies: Value Engineering to Optimize RD (cont.)

- Second law of thermodynamics: The universe becomes more chaotic unless energy is added to restore order

- First law (not quite a law) of engineering design: As more engineers spend more time on a design, it tends to become more complicated unless energy is added to simplify: Value Engineering

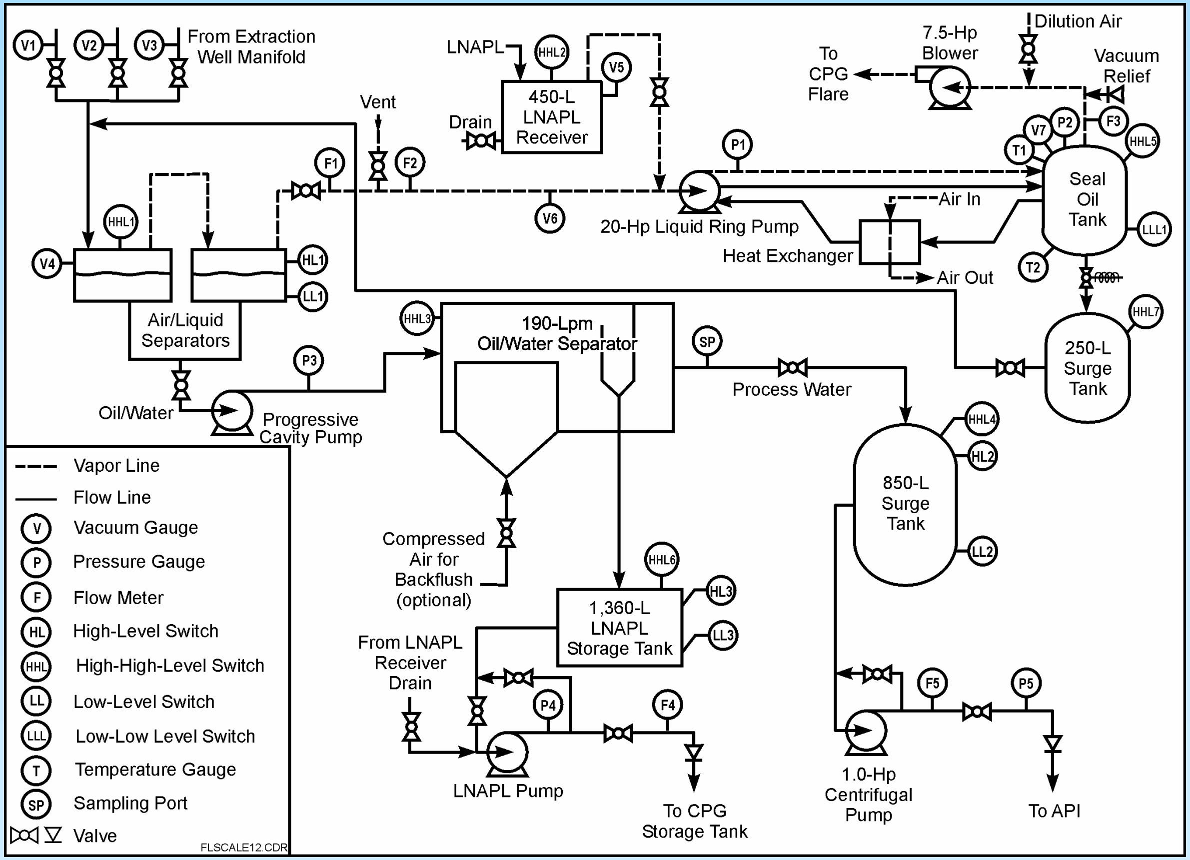


Implementation Strategies: Value Engineering to Optimize RD (cont.)

- Who ?
  - Broad participation of project team
  - One individual cannot make unilateral decisions to eliminate design elements

Implementation Strategies: Value Engineering to Optimize RD (cont.)

- When ?
  - Need sufficient level of design but not 100% complete
  - Should have a 90% P&ID and preliminary equipment sizing and layout drawings and an engineering cost estimate

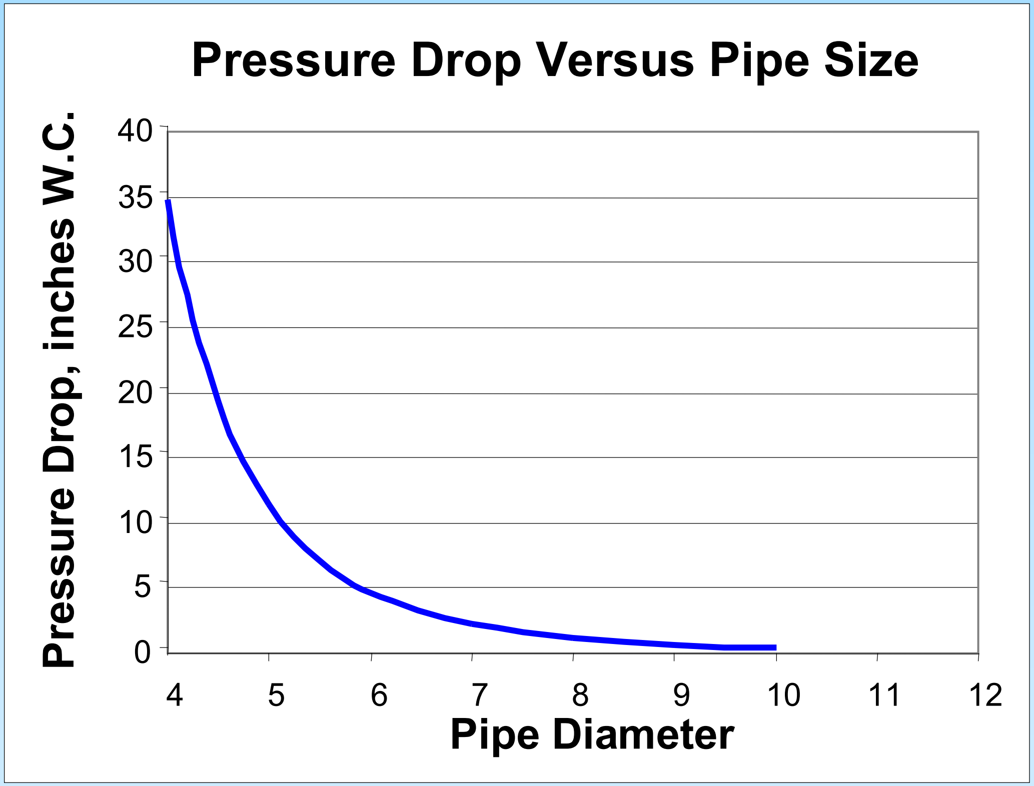


Implementation Strategies
Value Engineering: What is Really Needed

- Equipment redundancy (duplex versus simplex)
  - Objective is not to minimize downtime
  - To maximize cost-effectiveness some unplanned downtime is acceptable
- Material selection
  - Compatibility with worst-case short-term conditions may not be optimum design
  - Evaluate less expensive materials considering the expected project duration
- Instrumentation and control objectives
  - Analog versus digital signals
  - SCADA versus PLC versus relays
  - Telemetry
  - Automated data collection and reporting

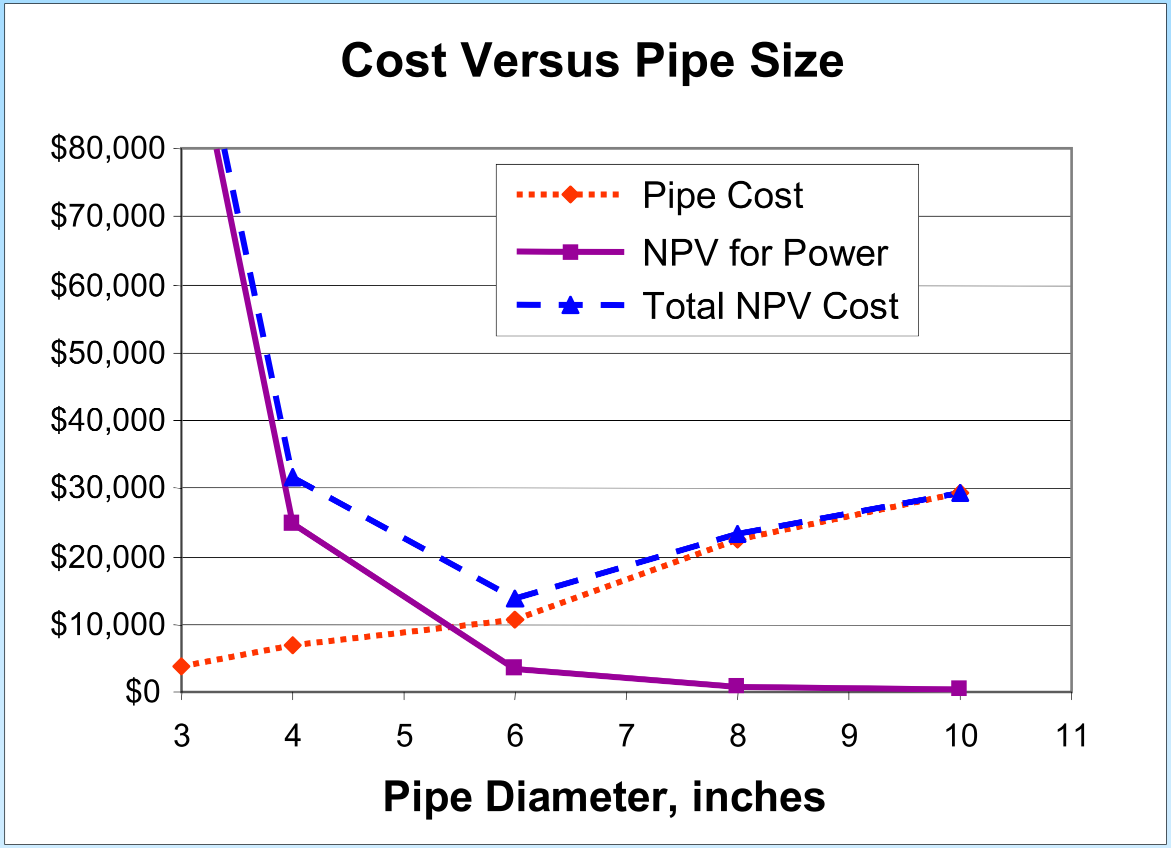
Implementation Strategies
Value Engineering: Capital versus Annual Cost

- Common power savings options:
  - Pipe sizing, capital cost versus pumping power
  - Pumping versus gravity flow
  - Flow control valves versus variable frequency drives (VFDs)
  - High efficiency motors



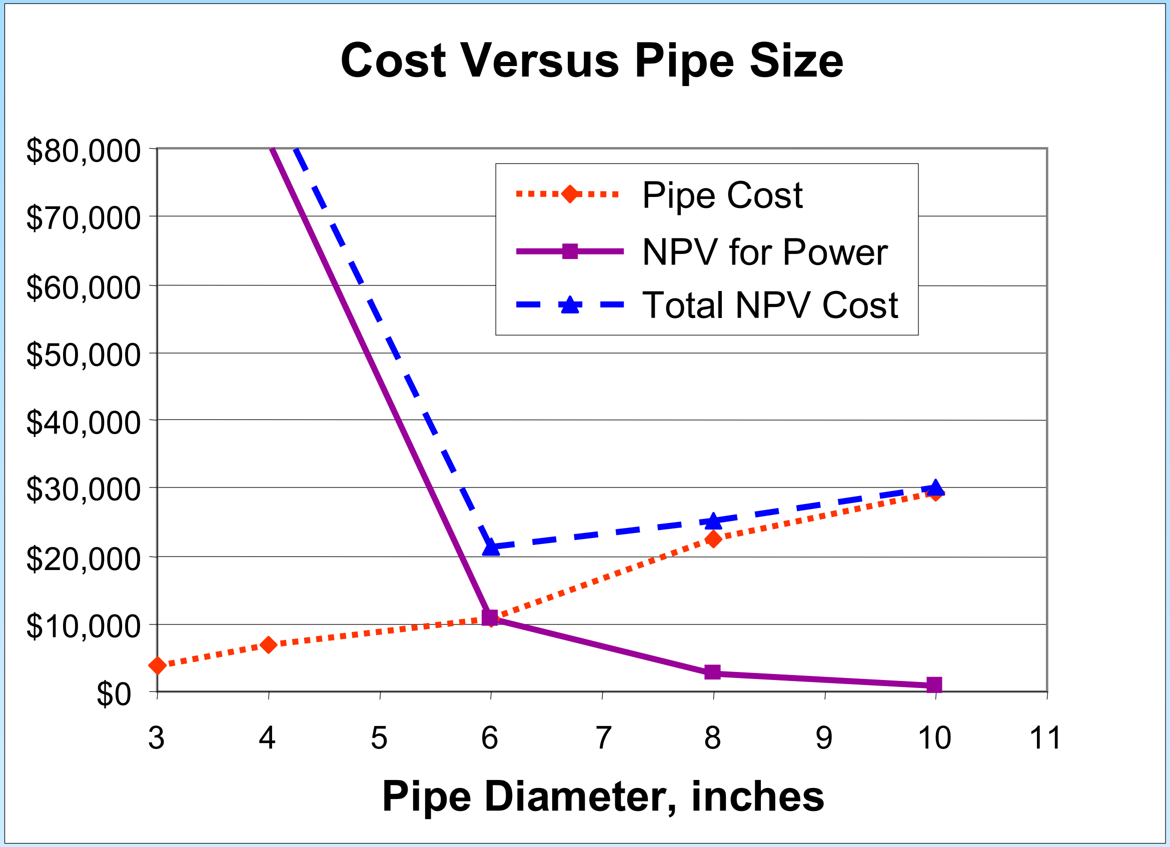
Implementation Strategies
Value Engineering: Capital versus Annual Cost (cont.)

- Example:
  - 500-cfm sparge air through 500-ft piping
  - Power cost: $0.12/kw-hr
  - R=6%
  - n=5 years
- Optimum size is 6 inches to minimize life-cycle cost



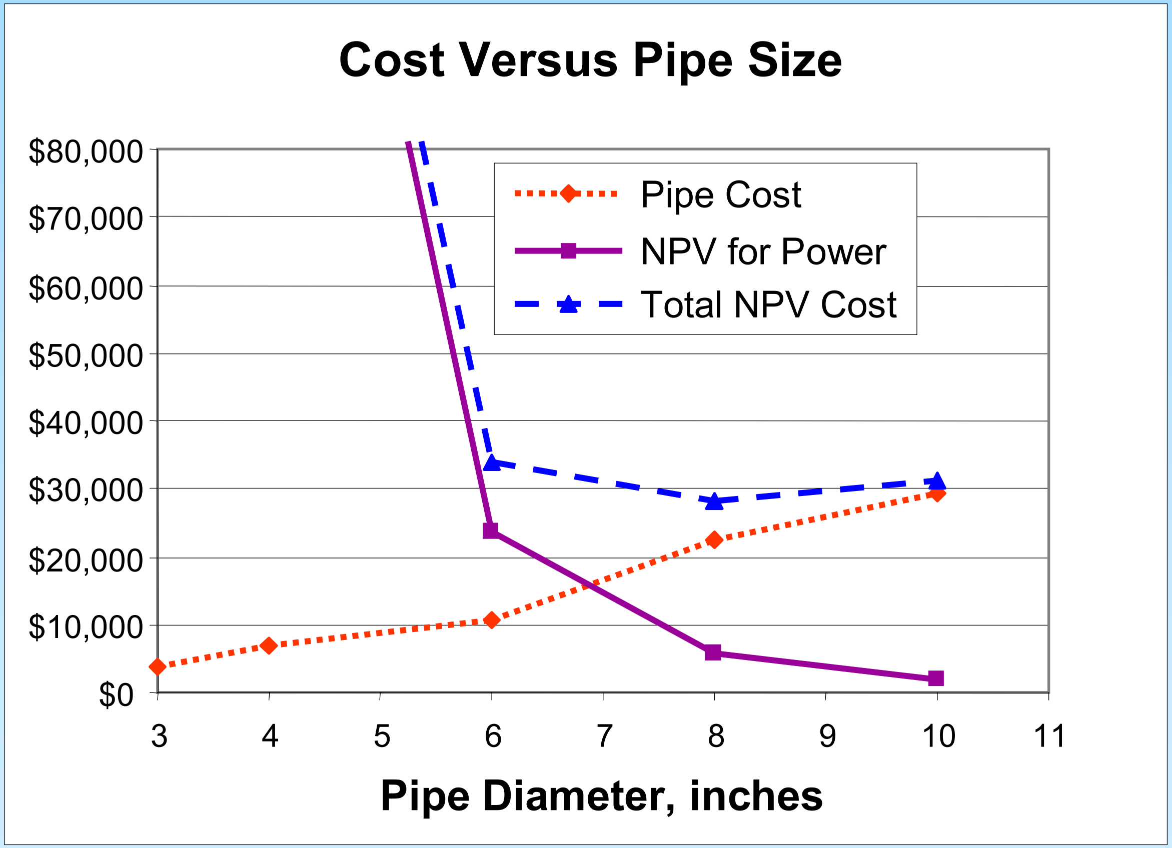
Implementation Strategies
Value Engineering: Capital versus Annual Cost (cont.)

- Example:
  - 500-cfm sparge air through 500-ft piping
  - Power cost: $0.12/kw-hr
  - R=6%
  - Increase n to 30 years
- Optimum size is still 6 inches to minimize life-cycle cost



Implementation Strategies
Value Engineering: Capital versus Annual Cost (cont.)

- Example:
  - 500 cfm sparge air through 500 feet piping
  - Power cost: $0.12/kw-hr
  - Not accounting for time value of money, R=0%
  - n=30 years
- Impact of R=0%
  - 8-inch size appears to be optimum
  - Capital cost more than doubles
  - Little benefit of larger pipe
  - Illustrates the importance of considering time value of money



Implementation Strategies
Value Engineering: Capital versus Annual Cost (cont.)

- Other common options
  - Carbon versus oxidizer
  - Use of catalyst and heat exchanger
  - On-site regeneration
  - Sludge dewatering
  - Chemical selection/bulk storage
  - Building versus equipment enclosures

Blower Package Inside Weather/Acoustical Enclosure

Source: ERM

Implementation Strategies (cont.)

- Develop OMMO Manual
  - Ensures operator collects proper data for optimization during RAO
  - Documentation of transition/exit strategy
- Permitting
  - Be consistent with treatment train concept
  - Use discharge limits rather than specific technologies for treatment
  - Avoid overcommitting to data collection

Presentation Overview

- Introduction
- FS through ROD
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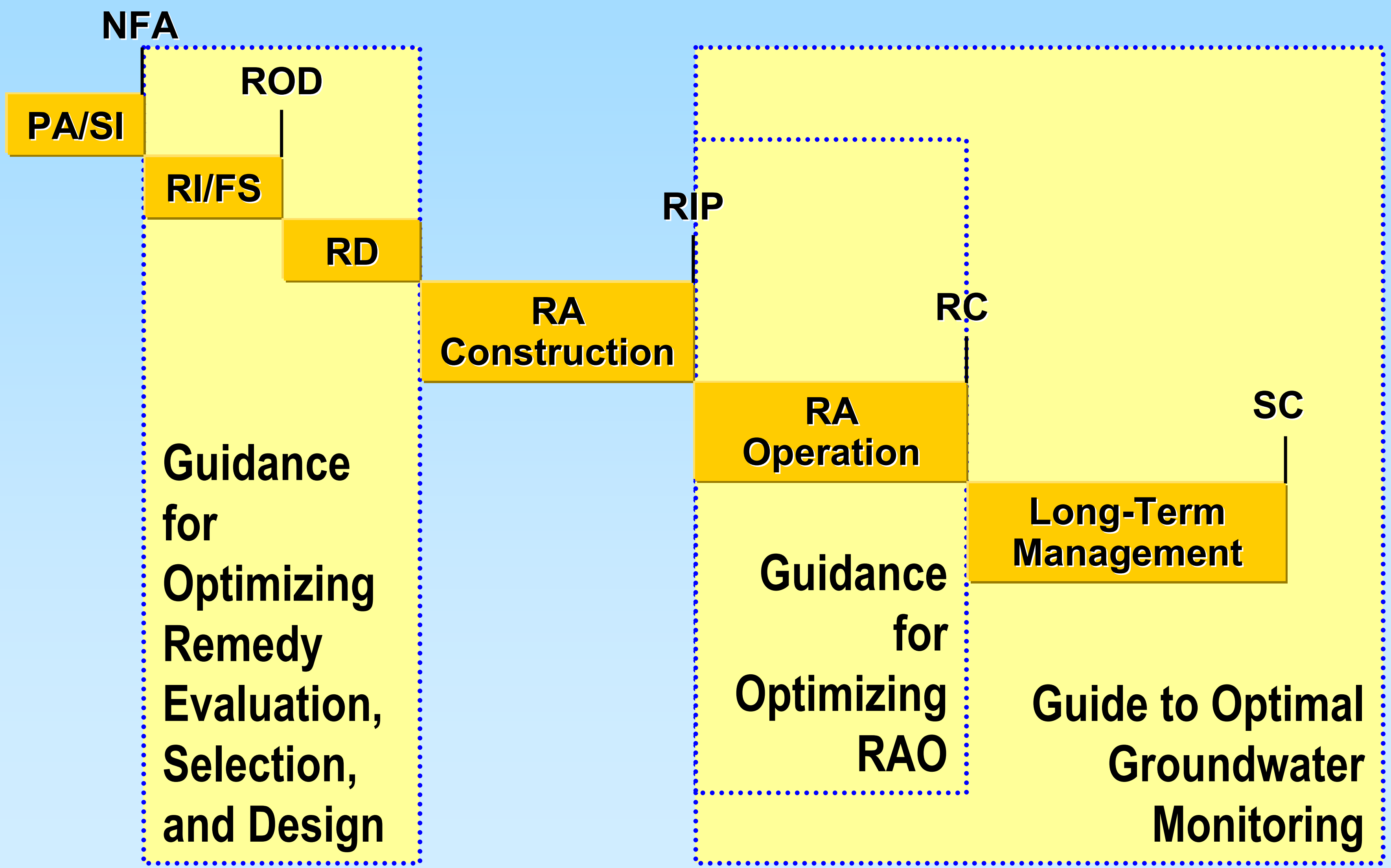
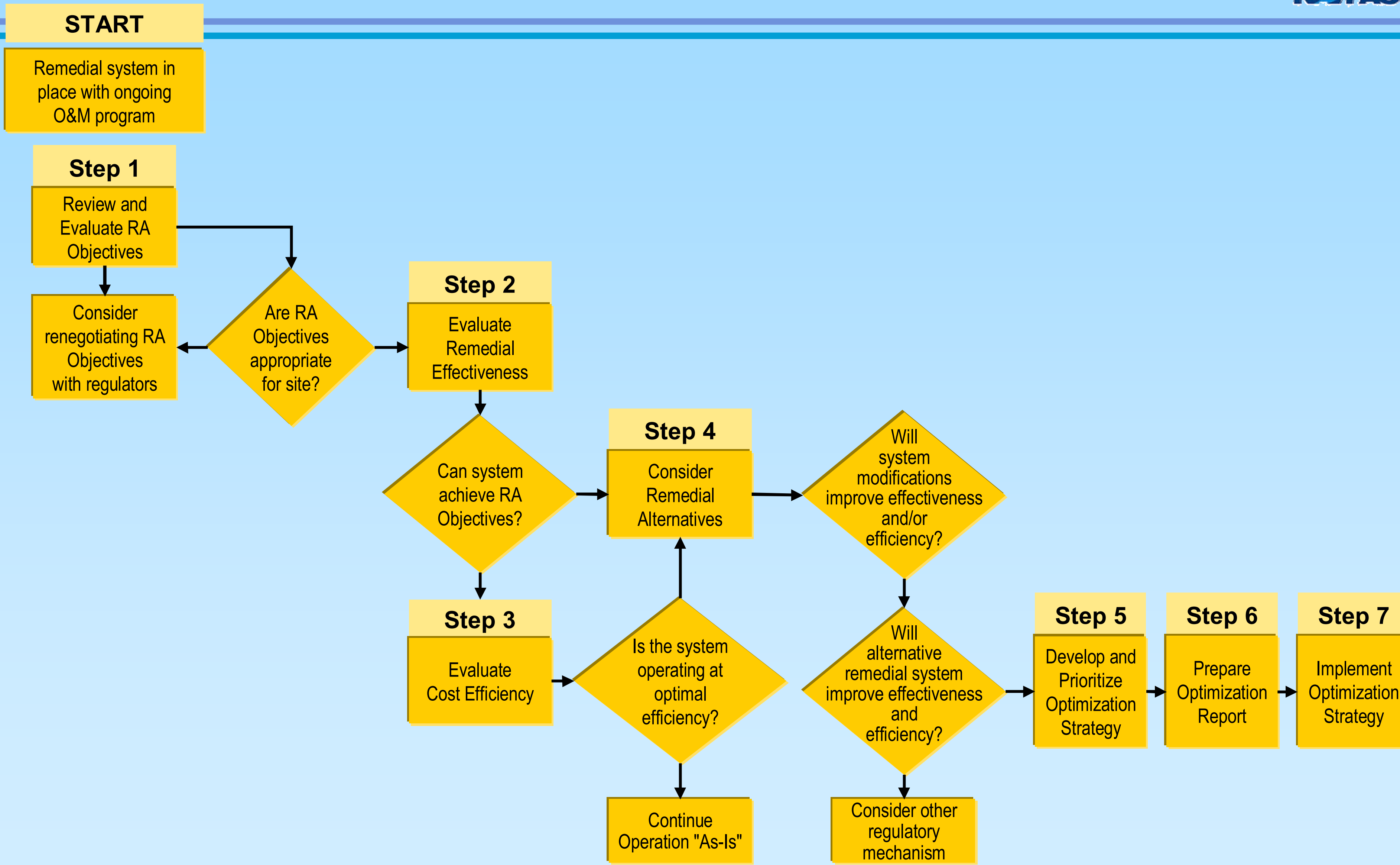
  - Exit strategies
- Post-ROD
  - Design/implementation strategies
  - Continuing optimization during remedial action
- Summary

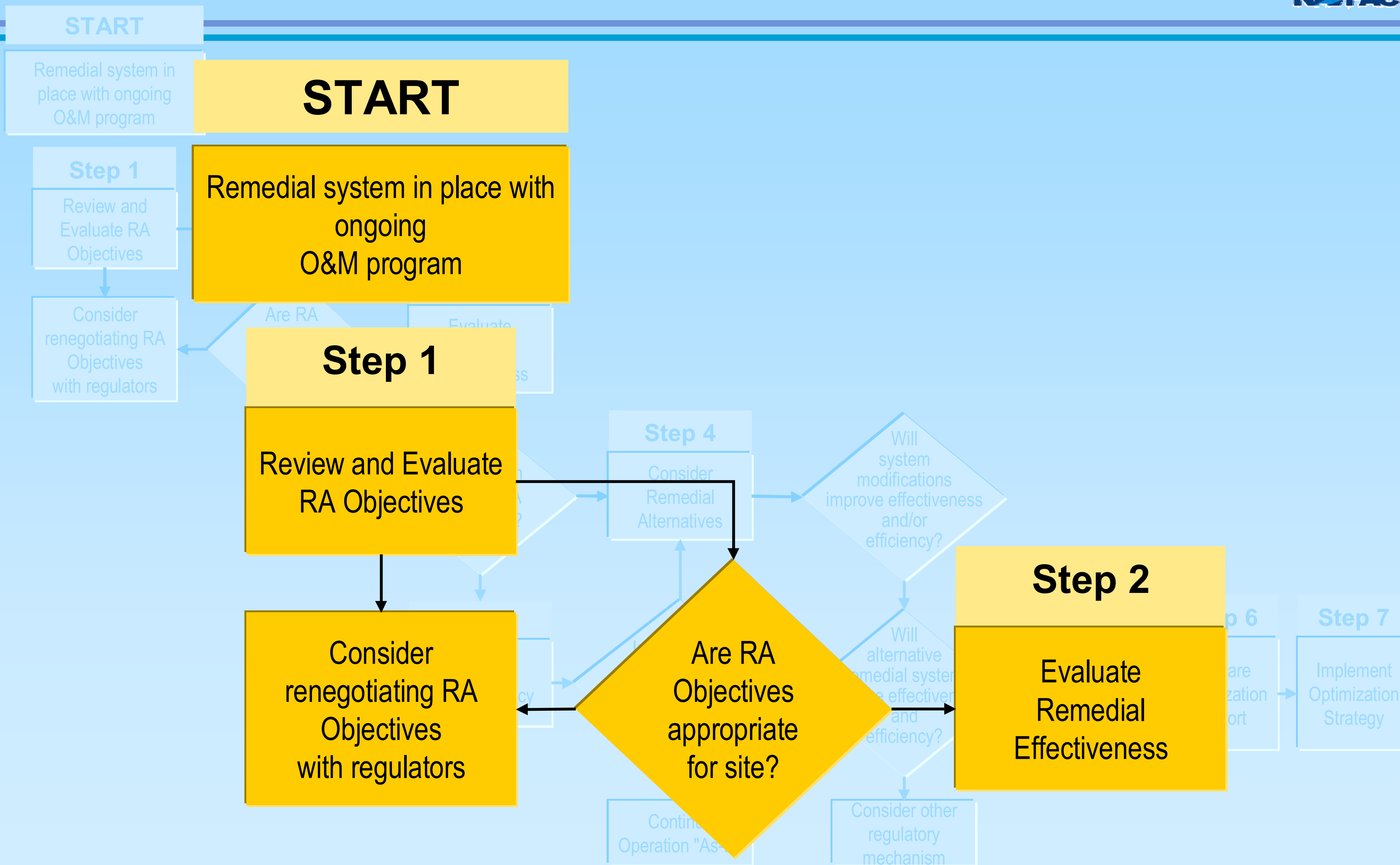
Guidance Documents and IR Program Phases



Optimization During RAO

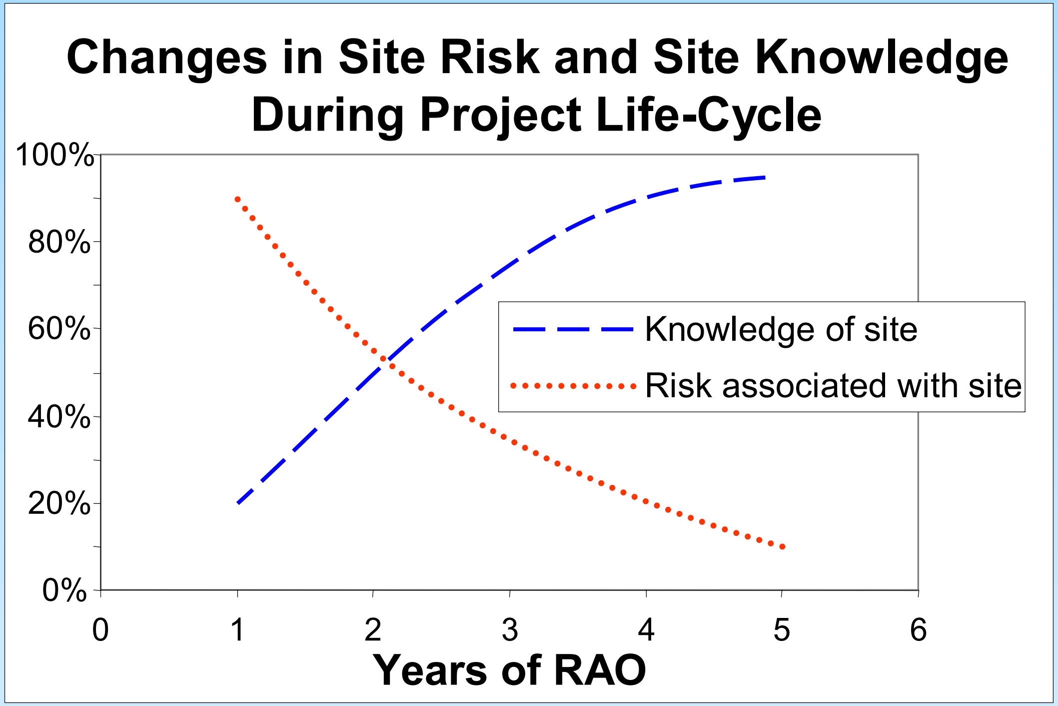


Step 1: Review and Evaluate RA Objectives

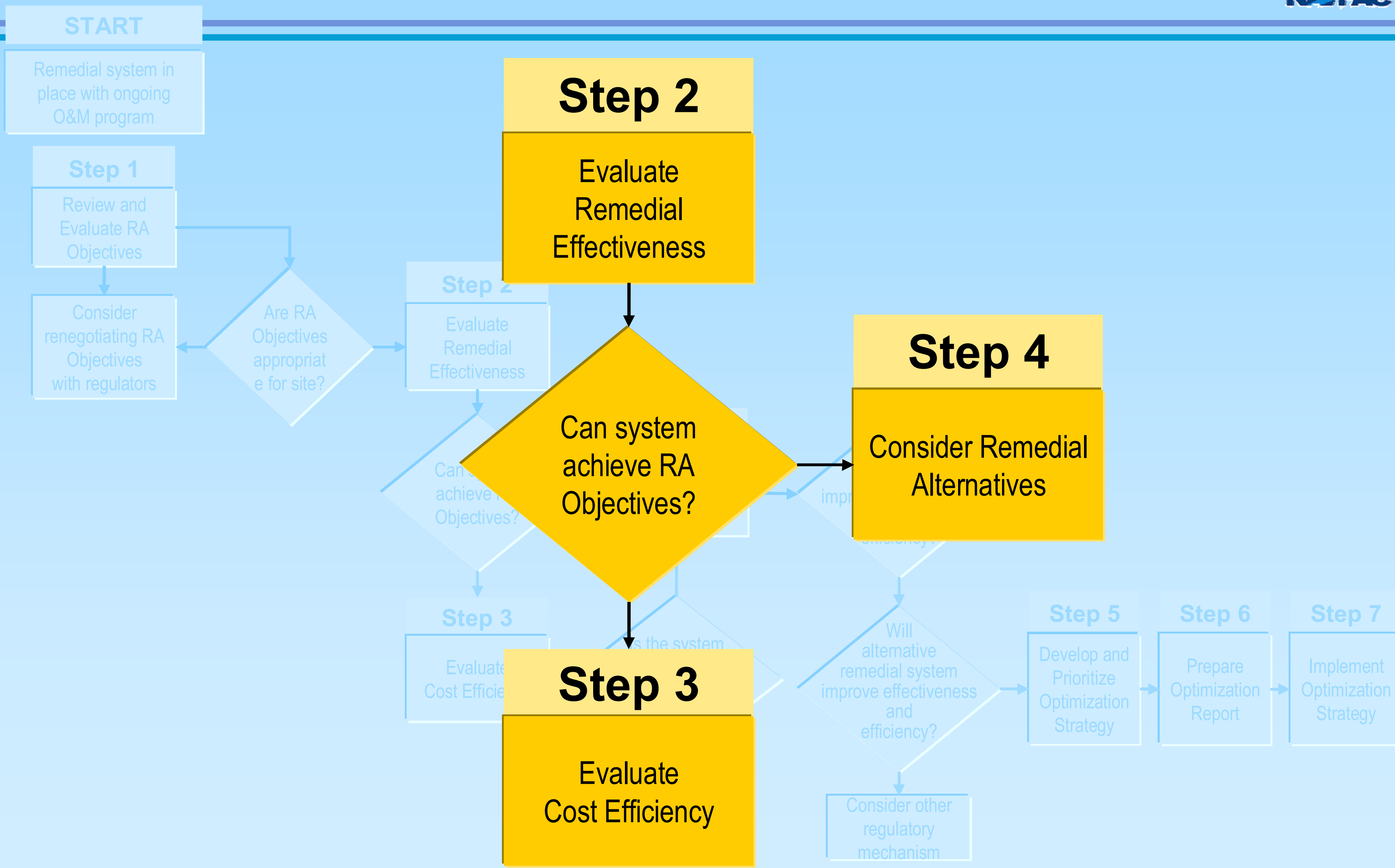


Optimization During Remedial Action Operation
Step 1: Review and Evaluate RAO

- First Update CSM
  - Significant data is obtained during RA
  - Site conditions change during RA life-cycle
  - Knowledge of site increases
  - Risk decreases
- Review and Evaluate RAO
  - Have they been met?
  - Are they still appropriate based on updated CSM?
  - Consider renegotiating
    - Can they be met with available technology?
    - What is the cost savings for an alternate set of objectives?
    - What are the risks with an alternate set of objectives?

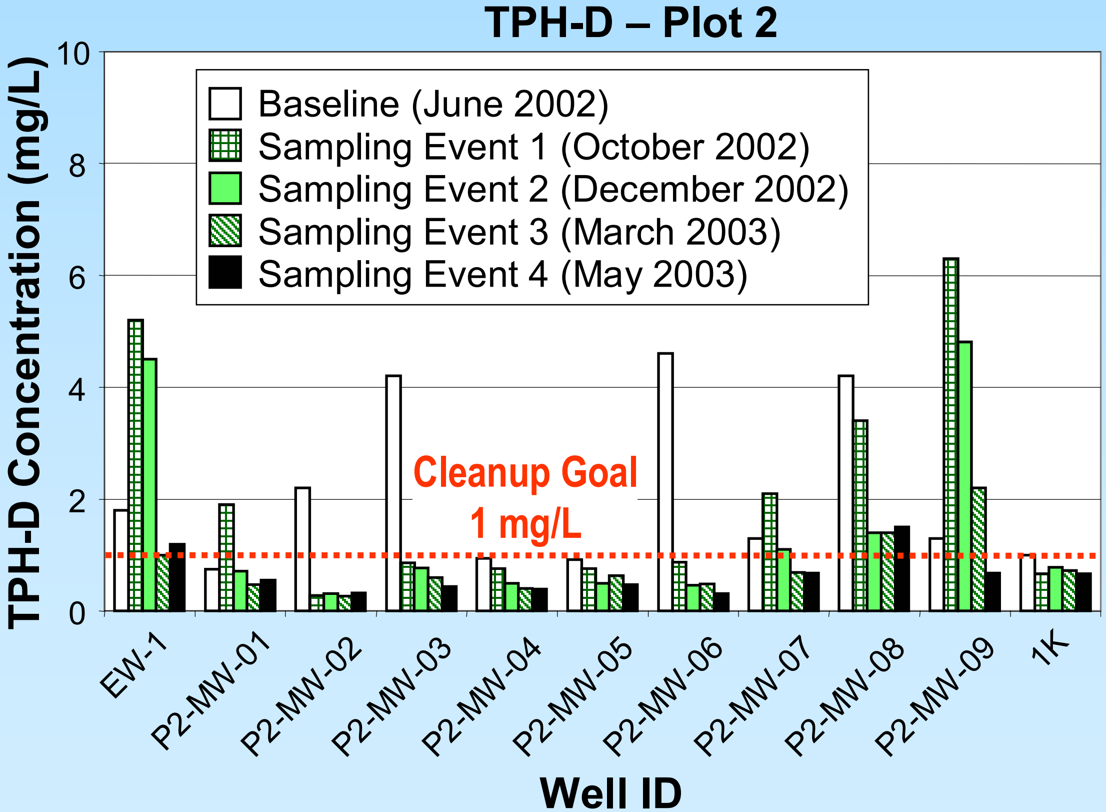


Step 2: Evaluate Remedial Effectiveness



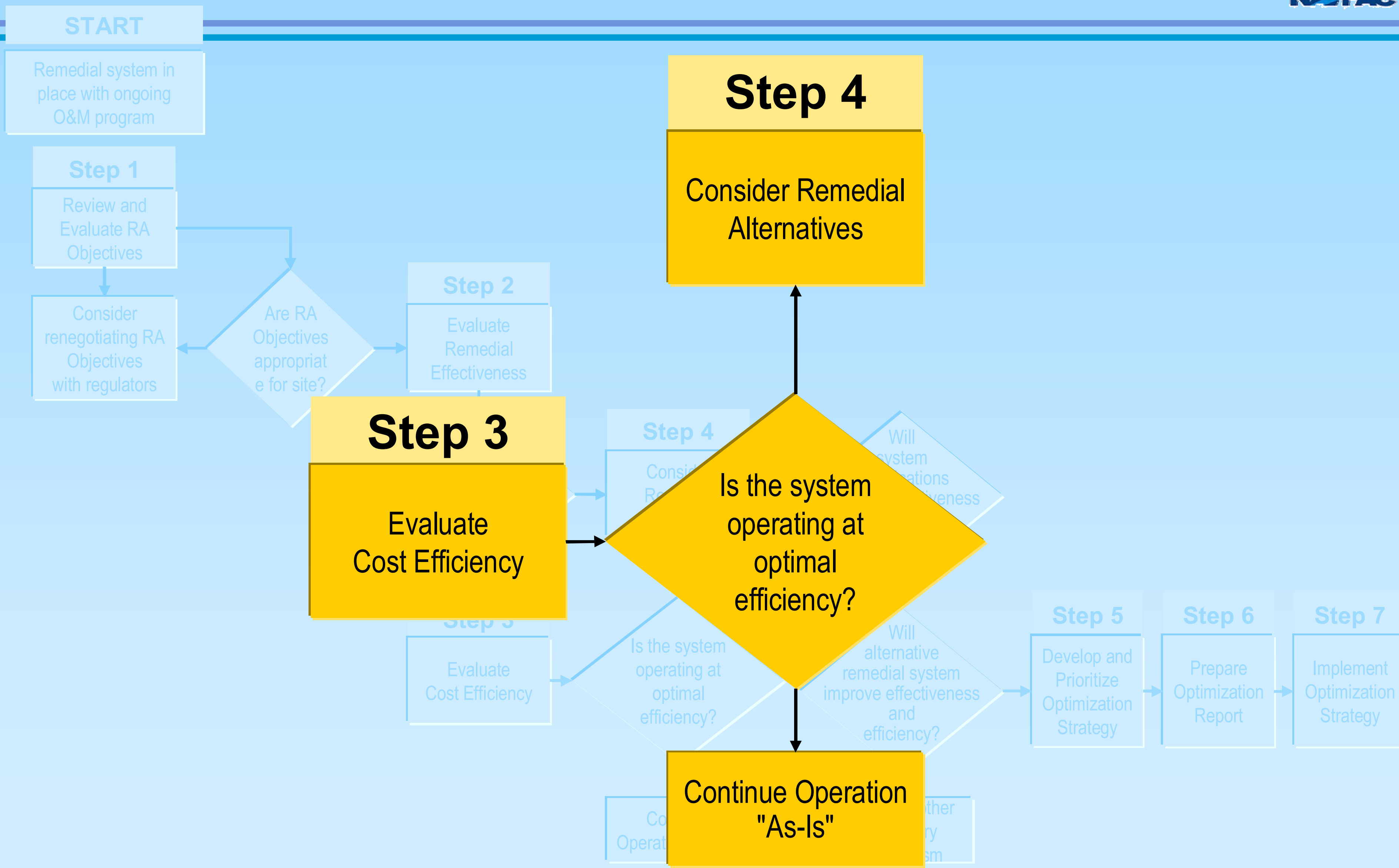
Optimization During Remedial Action Operation
Step 2: Evaluate Remedial Effectiveness

- Reduction in contaminant concentration
- Reduction in free product thickness and area
- Containment achieved
- Can Remedial Action Optimization be met by continued Remedial Action Operation?



Note: System Shut Down on February 12, 2003

Step 3: Evaluate Cost Efficiency



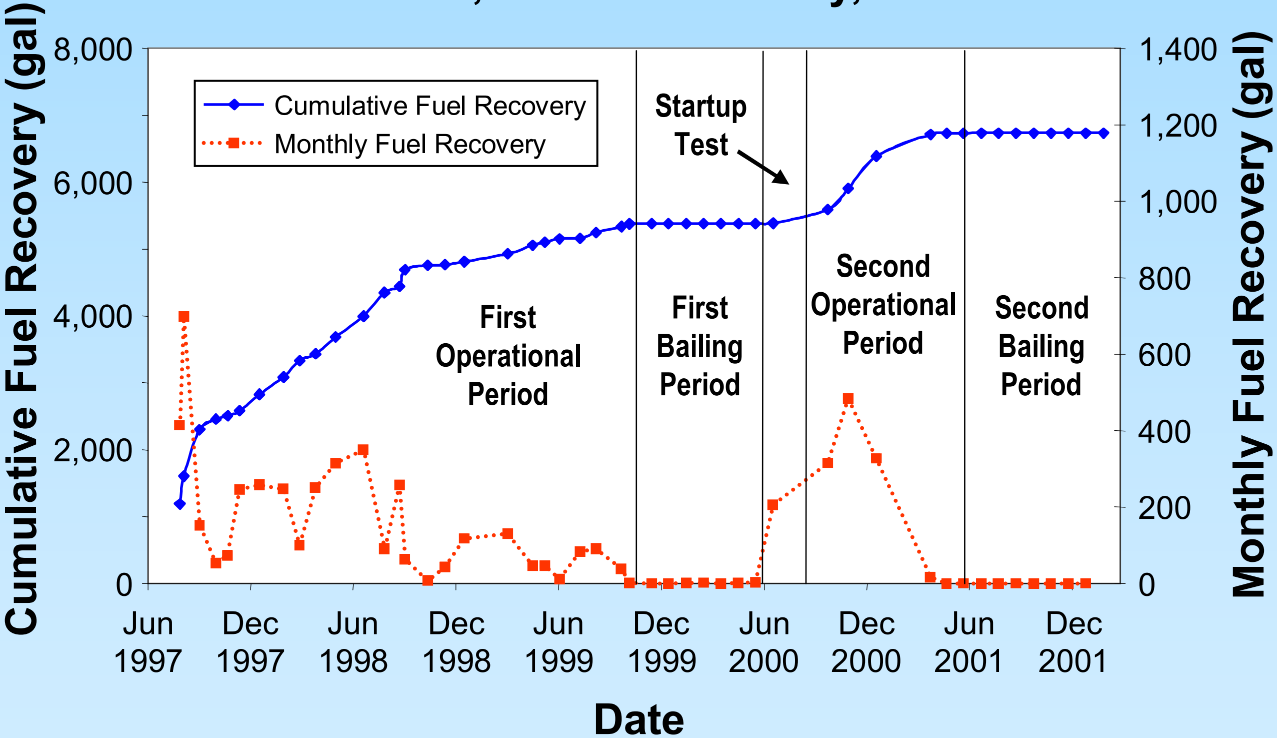
Optimization During Remedial Action Operation
Step 3: Evaluate Cost Efficiency (1 of 2)

- Operational Efficiency
  - Rate of mass removal/degradation
  - Extraction/injection flowrates
  - System reliability
  - Treatment efficiencies
  - Distribution of injected substances

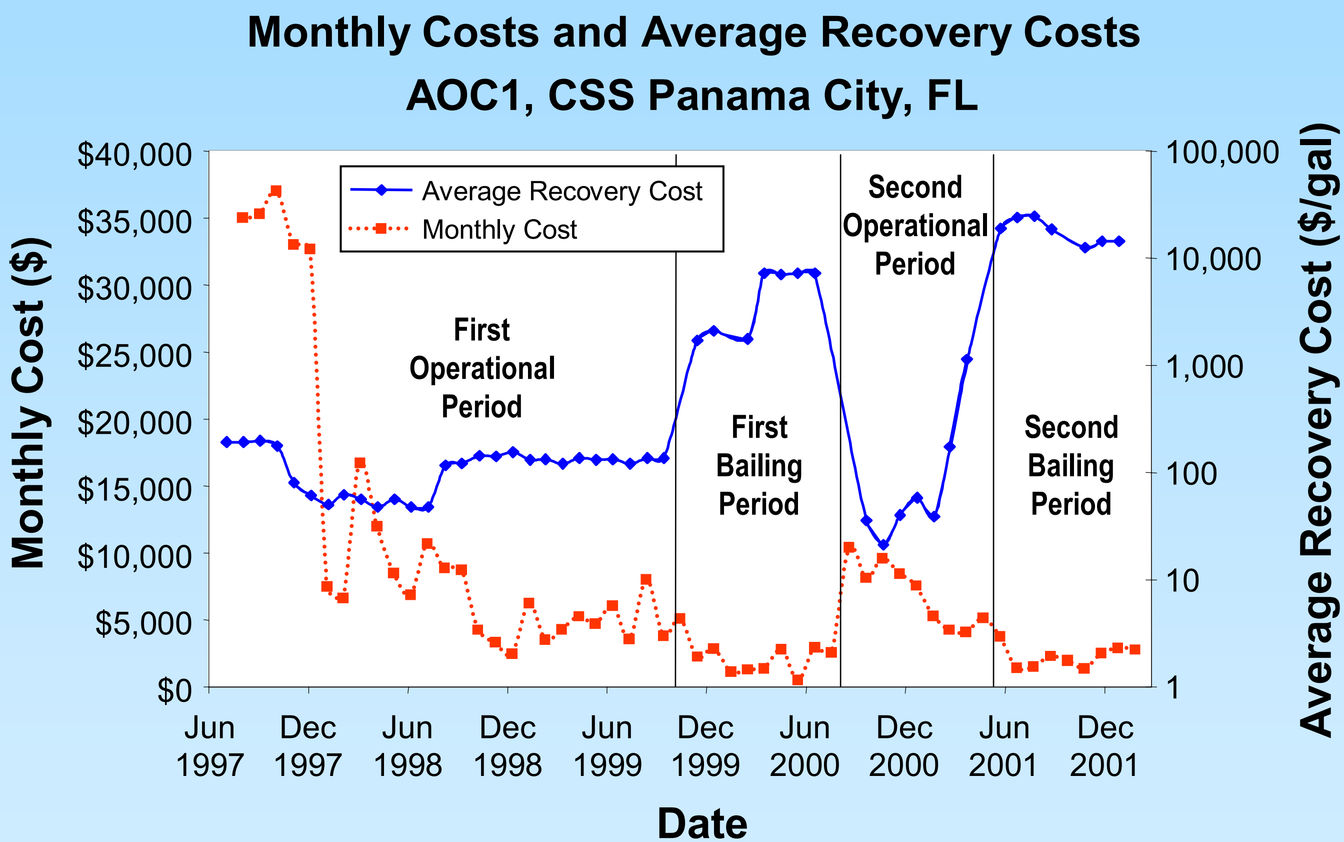
Fuel Recovery

(Free-Phase LNAPL, Aqueous Phase, Off-Gas Combined)

AOC1, CSS Panama City, FL

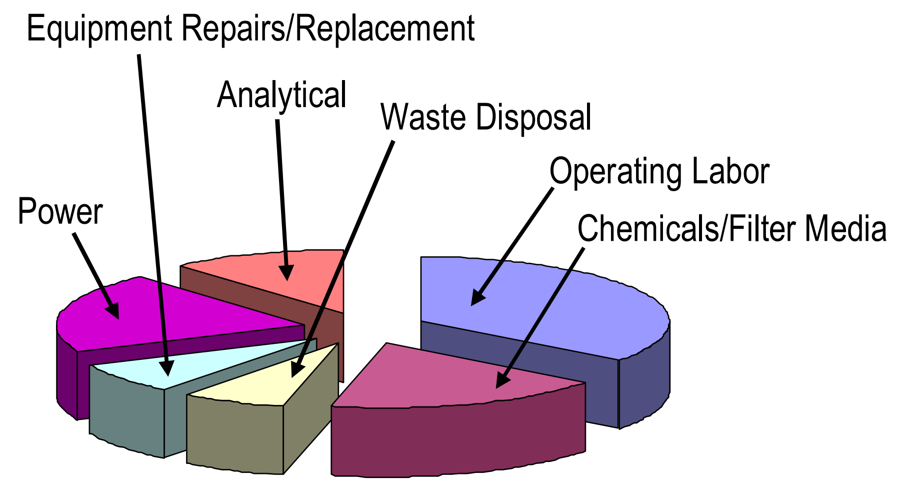


- Costs Evaluation
  - Annual cost
  - Cost per unit progress
  - Estimated cost to completion



Optimization During Remedial Action Operation
Step 3: Focus Cost Evaluation on Major Annual Costs

- Labor
  - Improved automation
  - Bidding strategy
  - Replace troublesome units
- Power
  - Equipment turndown (remove stripper tray and reduce blower speed)
  - High efficiency motors, variable speed drives
- Analytical
  - Reduce sampling frequency
  - Negotiate permits
- General
  - Shutdown wells to reduce flow
  - Bypass unnecessary unit operations
- Treatment Chemicals
  - Purchasing strategy
  - Bulk storage options
- Waste Disposal
  - Re-evaluate options
  - Reduce volume (dewatering)

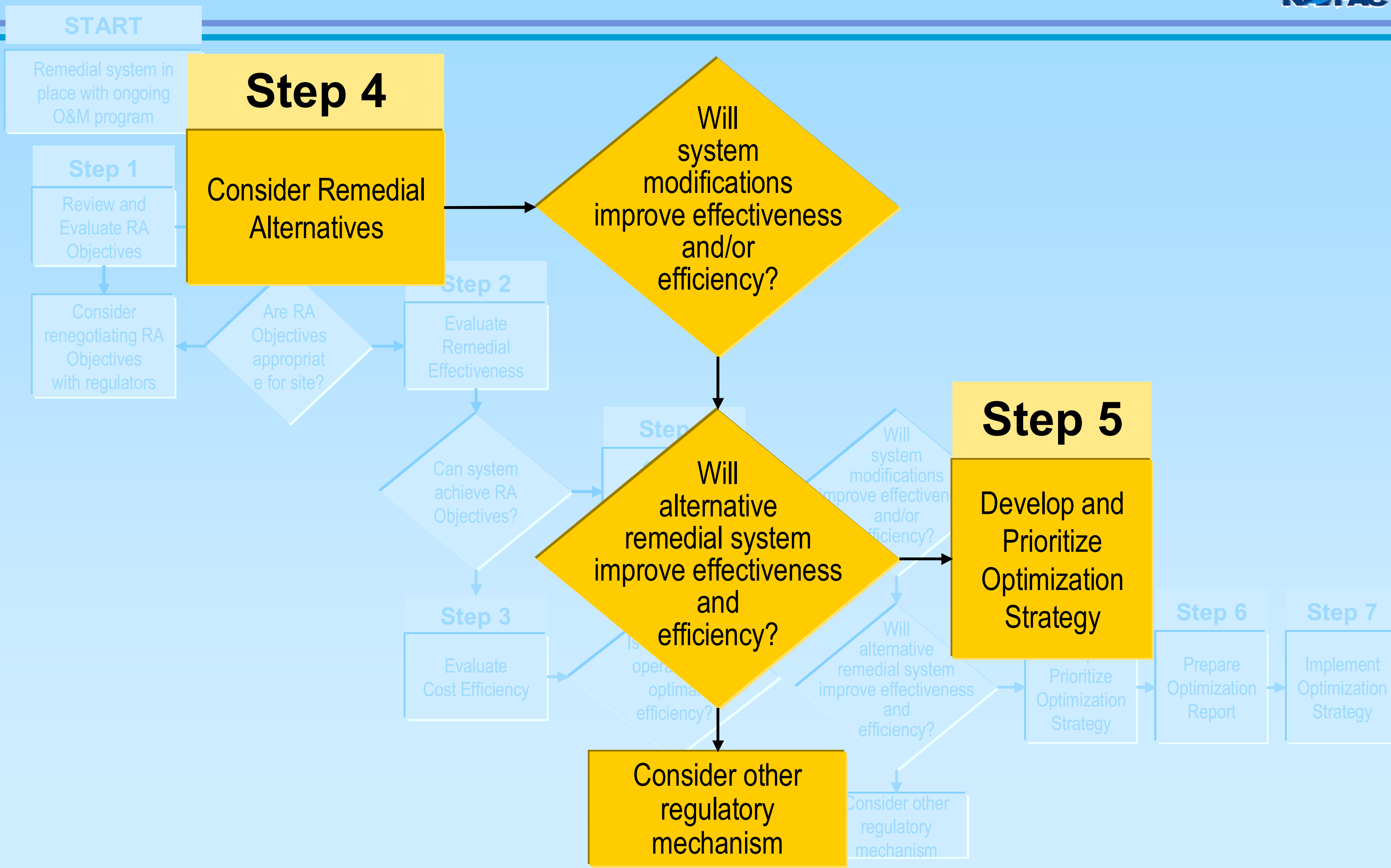


Example O&M Breakdown

Initial Steps to Scope-Out Optimization Analysis Needs

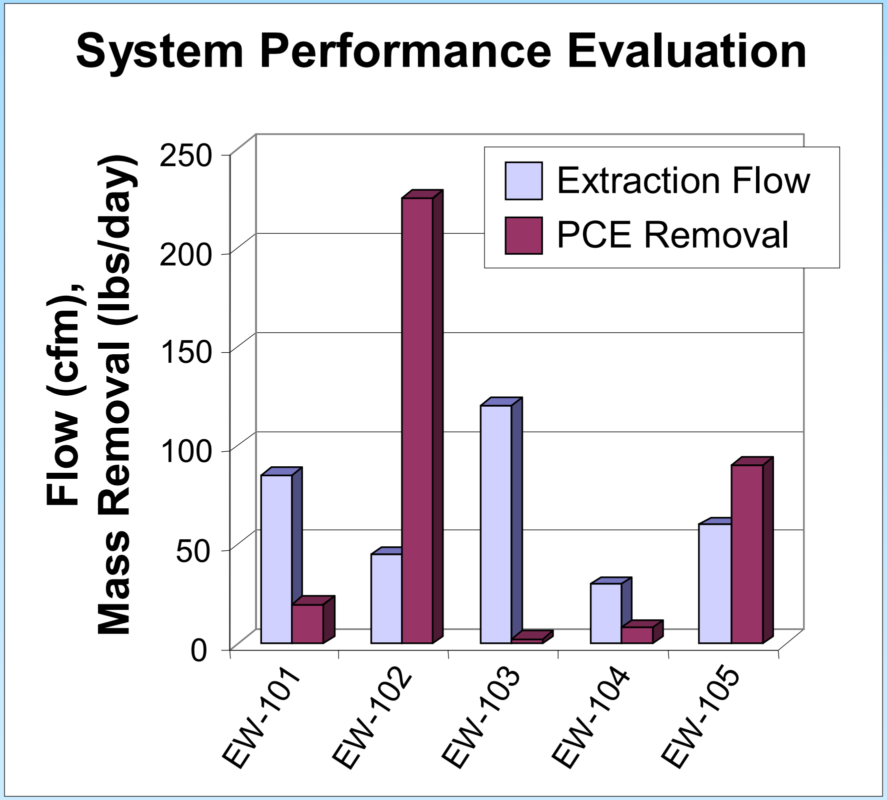
- Sites that are not effective in achieving Remedial Action objectives, focus on:
  - Revisiting RA objectives
  - Modification needed or alternate approaches
- Sites that will operate for long-term (e.g., P&T), focus on:
  - Reducing annual cost
- Sites that are effective and heading to closure, focus on:
  - Operational adjustments/modifications to expedite closure
  - Secondary focus on reducing annual cost

Step 4: Consider Remedial Alternatives



Optimization During Remedial Action Operation Step 4A: Operational Adjustments/Design Modifications

- Simple example of optimizing SVE operation
  - Monitor flowrates and contaminant concentration per well
  - Estimate mass removal per well
  - Make changes in flow scheme
  - Consider additional wells in hottest area
- Technology-specific guidance is available for performance evaluation and troubleshooting and optimizing



Optimization During Remedial Action Operation

Multiphase Extraction (MPE)

- Monitor:
  - NAPL extraction rate
  - Vapor flow and concentration extracted→ Mass removal
  - Groundwater flow and concentration extracted→ Mass removal
  - Vacuum level in EWs and MWs→ Vapor radius of influence (ROI)
  - Liquid level in EWs and MWs→ Liquid ROI
  - MW NAPL thickness, concentration in vapor and groundwater→ Effectiveness
  - Monthly cost and cost per unit mass removed→ Cost-effectiveness

See Guidance for Optimizing Remedial Action Operation, Interim-Final, April 2001, Appendix A

- Potential Adjustments
  - Repair wells to decrease short-circuiting if vacuum level dropped off
  - Redevelop wells if extraction rate dropped off
  - Install new wells to address dead zones or tighten well spacing
  - Vary flowrates from EWs to eliminate stagnation zones
  - Adjust vapor or GW flowrates (or shut down wells) based on well-by-well analysis
  - Operate in "Pulsed" mode in response to diffusion-limiting conditions to increase cost effectiveness
  - Adjust drop-tube in response to changes in product/water interface

Optimization During Remedial Action Operation
Injection Air Sparging/Soil Vapor Extraction

- Monitor:
  - Sparge injection rate and pressure
  - Vapor flow and concentration extracted→ Mass removal
  - Pressure, DO levels, tracer levels, VOC levels in MWs→ Sparge ROI
  - Vacuum level in EWs and MWs→ Vacuum ROI
  - Concentration in vapor and groundwater at MWs→ Effectiveness
  - Concentration in subsurface soil→ Effectiveness
  - Monthly cost and cost per unit mass removed→ Cost-effectiveness

See Guidance for Optimizing Remedial Action Operation, Interim-Final, April 2001, Appendix A

- Potential Adjustments
  - Repair wells to decrease short-circuiting if vacuum level or pressure dropped off
  - Install new wells to address dead zones or tighten well spacing
  - Operate in "Pulsed" mode in response to diffusion-limiting conditions and create new flowpaths to increase cost-effectiveness
  - Vary flowrates from EWs to eliminate stagnation zones
  - Adjust SVE or sparge flowrates (or shut down wells) based on well- by-well analysis

In Situ Chemical Oxidation (ISCO)

- **Monitor:**
  - Mass injection rate of oxidant
  - ORP, pH, alkalinity levels in MWs→ Distribution
  - Concentrations of various chemical species in groundwater at MWs→ Effectiveness
  - Monthly cost and cost per unit mass degraded→ Cost-effectiveness

- **Potential Adjustments**
  - Install new injection wells to improve distribution
  - Use alternate injection methods such as pneumatic or hydraulic fracturing
  - Add more oxidants
  - Alternate technology for hot spots

See Guidance for Optimizing Remedial Action Operation, Interim-Final, April 2001, Appendix A

Optimization During Remedial Action Operation
Bioremediation of Chlorinated Compounds

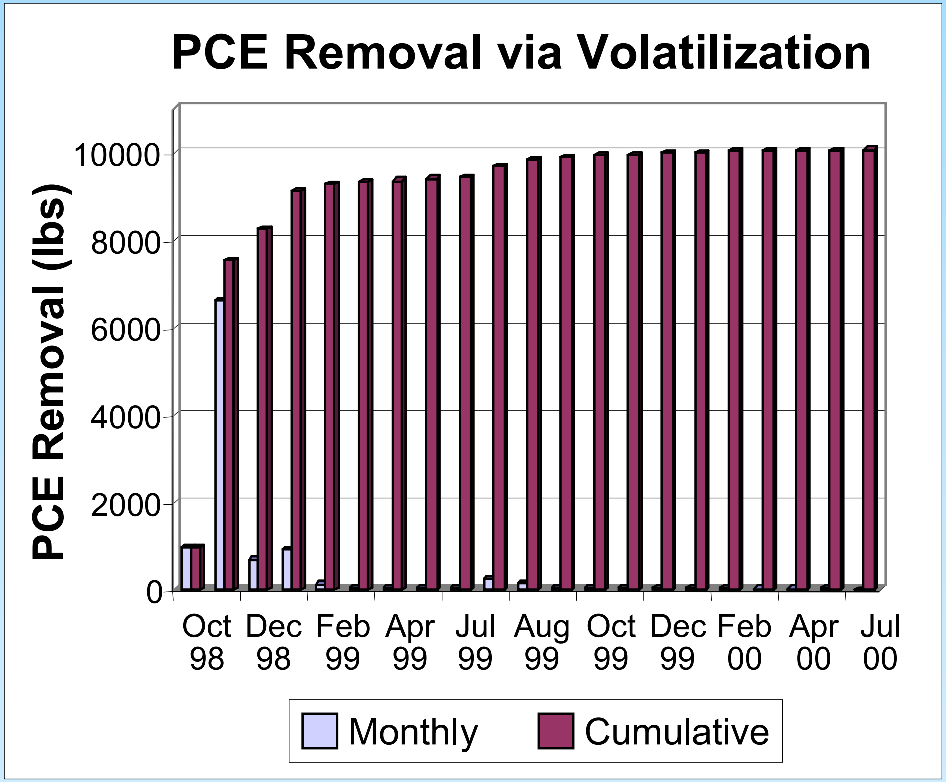
- Monitor:
  - Mass injection rate of bio-stimulants
  - ORP and nutrient levels in MWs→ Distribution
  - Concentrations of various chemical species in groundwater at MWs→ Effectiveness
  - Monthly cost and cost per unit mass degraded→ Cost-effectiveness

- Potential Adjustments
  - Install new injection wells to improve distribution
  - Use alternate injection methods such as pneumatic or hydraulic fracturing
  - Add more biostimulants
  - Bioaugmentation
  - Alternate technology for hot spots

See Guidance for Optimizing Remedial Action Operation, Interim-Final, April 2001, Appendix A

Optimization Example: During RD and RA Operation Superfund Site in Long Island, New York

- During remedial action noted performance decline
  - Initial PCE removal of approximately 9,000 pounds in four months
  - Initial period was followed by very low mass removals
  - Implemented sparge pulsing to and flow variation with limited success
  - Removal less than 20 pounds in November of 1999 at which time total chlorinated VOCs (CVOCs) in groundwater was approximately 10,000 µg/L

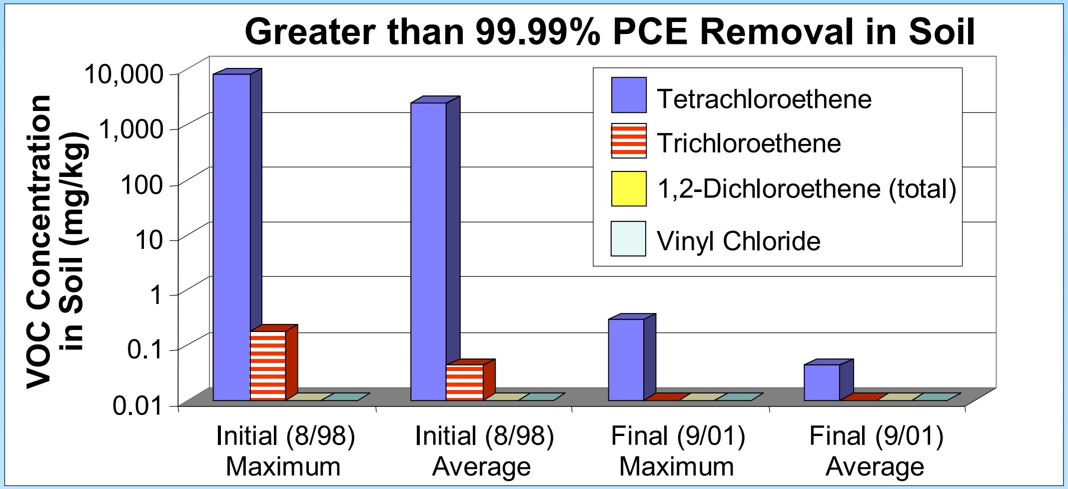


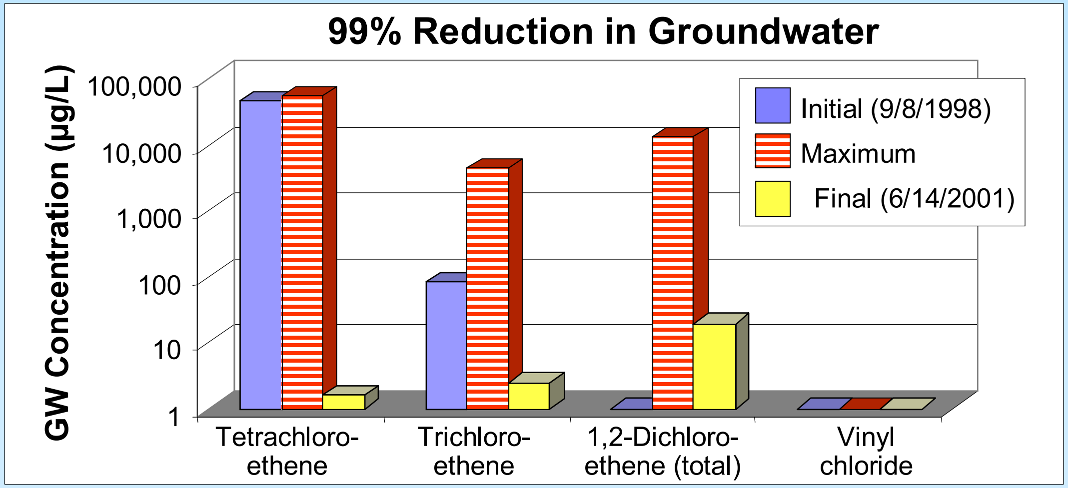
Optimization Example: During RD and RA Operation Superfund Site in Long Island, New York (cont.)

- Optimization needed during RA Operation
  - Did not pursue performance-based exit due to high levels of CVOCs
  - Performance monitoring indicated poor distribution of sparge air in hotspot
    - Low DO in VOW-4D, which had highest VOCs in GW
    - Low VOC levels in vapor phase in VOW-4 well cluster
  - Added six more sparge wells to improve distribution installed with low-cost geoprobe method in December 1999

Optimization Example: During RD and RA Operation Superfund Site in Long Island, New York (cont.)

- Results of Design Modification: improved distribution
  - DO level increased in VOW-4D
  - Vapor concentrations and mass removal rate increased
  - By June 2001, total VOCs were down to 25 µg/L
  - Confirmatory soil sampling indicated MCLs were met and system was shut down
- Lessons Learned
  - Collect sufficient data to allow for troubleshooting
  - Be flexible and recognize when being more aggressive will be beneficial

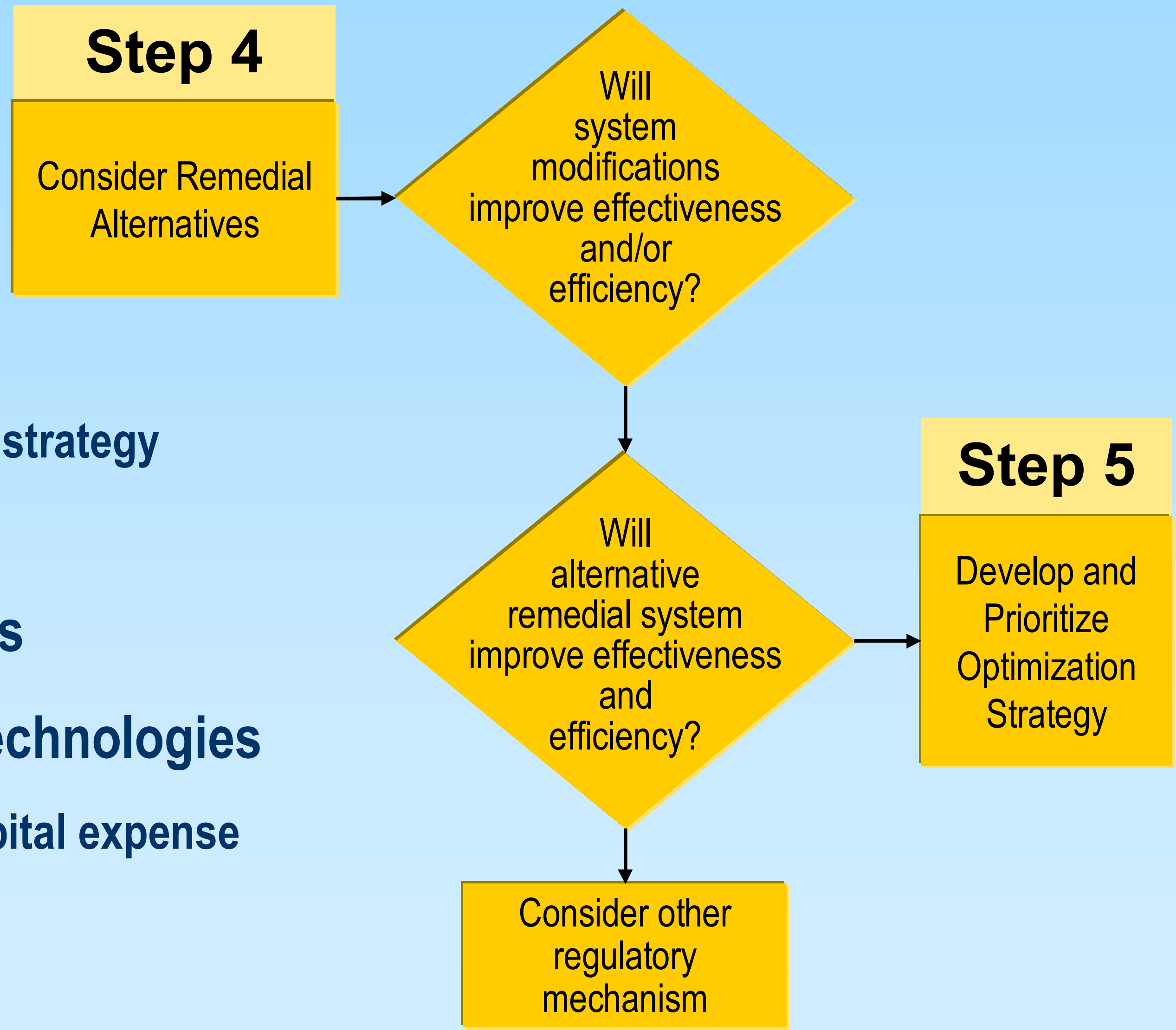




Source: Sirabian, R.

Optimization During Remedial Action Operation
Step 4B: Consider Remedial Alternatives

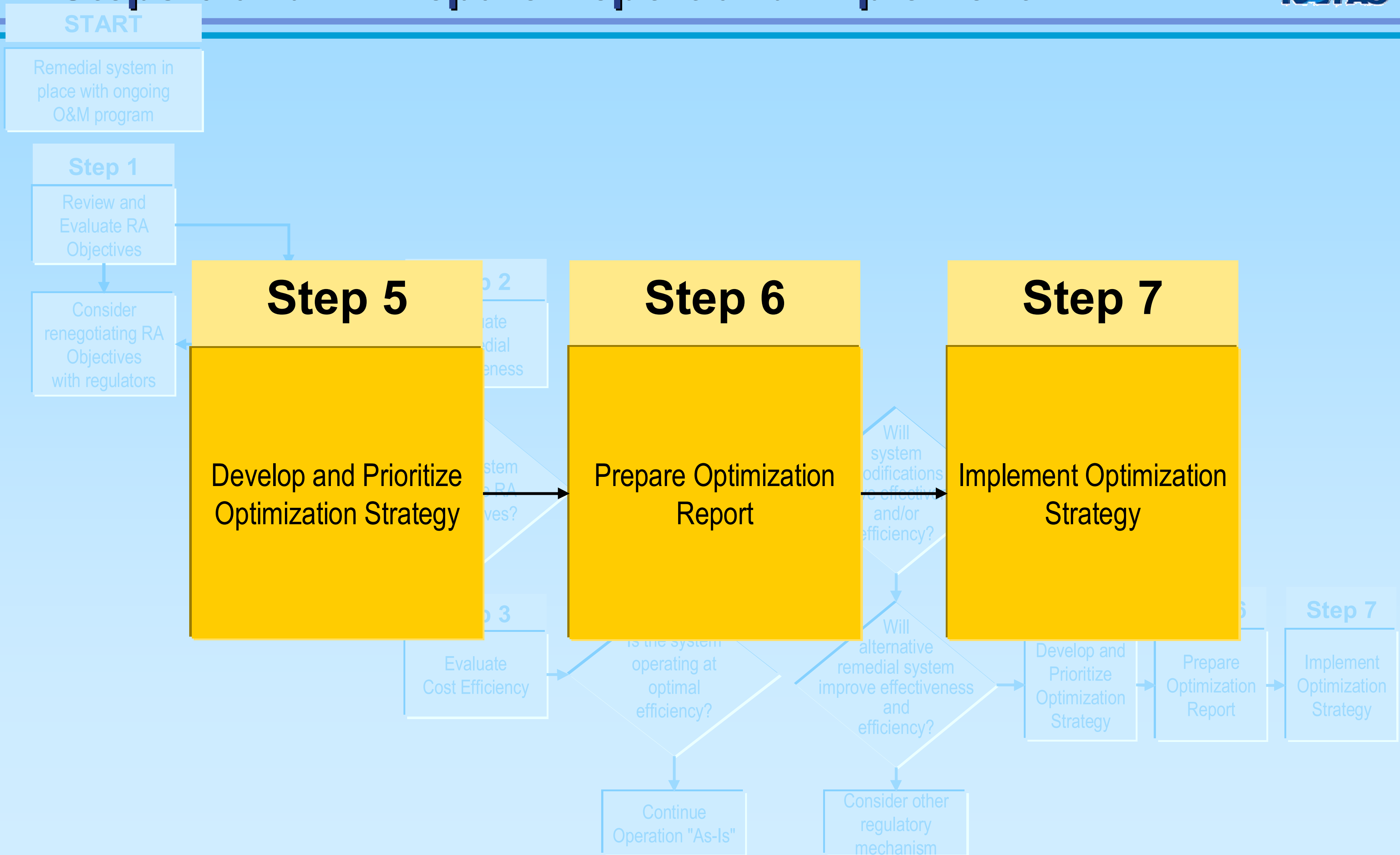
- Transition to less active or passive phase
  - Review performance data
  - Review criteria in exit strategy
  - Is transition justified?
- Revisit RA Objectives
- Consider alternate technologies
  - May be significant capital expense
  - Perform cost analysis



Optimization Reviews During RA Operation
Step 5: Develop and Prioritize Strategy

- **Evaluate cost-effectiveness of optimization strategy against status quo**
  - **Capital cost to implement**
  - **O&M cost change**
    - Annual
    - Cost per pound of product removed
    - Net present value
- **Consider other FS criteria for major changes in remedial approach**

Optimization Reviews During RA Operation
Steps 6 and 7: Prepare Report and Implement



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Summary

- **C**ontrol Scope of Remedial Activities
- **O**ptimize Remedial Approach
- **S**top Unnecessary Activities
- **T**urn To Alternatives

Summary (cont.)

- **C**ontrol Scope of Remedial Activities
  - –Update and use CSM to develop risk-based RAOs
  - –Focused DQOs to control monitoring costs
- **O**ptimize Remedial Approach
  - –Treatment trains to maximize efficiency and allow for transition to less active or passive system
  - –Design system with flexibility for changing conditions
  - –Design with life-cycle in mind and use appropriate implementation strategies
  - –Cost analysis for decision-making

Summary (cont.)

- **S**top Unnecessary Activities
  - Stakeholder acceptance of performance-based transition/exit strategies
  - Maintain appropriate performance and effectiveness database to justify transition/exit
  - Statistics, modeling, and data visualization tools to justify reduction in monitoring/remedial activities
- **T**urn To Alternatives
  - Reevaluate RAOs
  - Operational adjustments/design modification
  - Revisit available technologies