OPTIMIZATION

Accelerating Site Closeout, Improving Performance, and Reducing Costs

Concepts and Practice in Optimization of Long-Term Monitoring Programs

presented by
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Innovative Technology in the Public Interest™
Current Guidance for Monitoring Programs

OSWER Directive No. 9355.4-28

GUIDANCE FOR MONITORING AT HAZARDOUS WASTE SITES

FRAMEWORK FOR MONITORING PLAN DEVELOPMENT AND IMPLEMENTATION

U.S. Environmental Protection Agency
Office of Superfund Remediation and Technology Innovation

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What is Monitoring?

“… the collection and analysis of repeated observations or measurements to evaluate changes in conditions and progress toward meeting a management objective.”

“[Environmental] monitoring is the collection and analysis of data (chemical, physical, and/or biological) over a sufficient period of time and frequency to determine the status and/or trend in one or more environmental parameters or characteristics.”
Why Monitor?

- RCRA and CERCLA Statutory Requirements
  - Identify potential threats to human health and the environment
  - Evaluate remedy performance
Types of Monitoring Programs

- **Characterization Monitoring**
  - Site characterization

- **Detection Monitoring**
  - Detect releases from RCRA facilities

- **Compliance Monitoring**
  - Assess movement of contaminants to designated compliance points

- **Long-term Monitoring**
  - Evaluate remedy performance after a response action has been put in place
Development and Application of Monitoring Program

1. Identify Monitoring Objectives
2. Develop Monitoring Hypotheses
3. Formulate Monitoring Decision Rules
4. Design Monitoring Plan
5. Implement Monitoring Plan
6. Management Decision
Components of Monitoring Program

- Program Objectives
- Monitoring Program Hypotheses (Conceptual Site Model)
- Decision Rules
- Monitoring Plan
  - Sampling Locations (Network)
  - Sampling Schedule (Frequency)
  - Data Collection and Analysis Methods
  - Data Quality Objectives and QA/QC
  - Reporting
- Management Decision
Characteristics of Long-Term Monitoring Data

- Constituent Concentrations Detected in Samples Collected at One or More Locations at Several Different Periods of Time
- Variable in Space and Through Time
Concentration Data – Spatial and Temporal Variability
Variability – Implications for Monitoring

Because Environmental Data are Variable in Space and Through Time, an Effective Monitoring Program Must Recognize the Dynamic Nature of System and Account for Natural and Anthropogenic Variability
Effective Groundwater Monitoring Program

- Program is “Effective” if it Achieves the Stated Objectives

- “Optimal” Site-Specific Monitoring Strategy Will Maximize the Amount of Relevant Information Obtained While Minimizing Incremental Costs

- “Relevant” information effectively addresses the temporal and spatial objectives of monitoring
Important Question

What are the Objectives of Monitoring?

- Evaluate temporal trends in contaminant concentrations within or outside of remediation zone as a means of monitoring the progress of remediation (Temporal Objective)

- Evaluate the extent to which continued contaminant migration is occurring, particularly if a potential exposure point for a susceptible receptor exists (Spatial Objective)
What is Optimization?

“... the procedure or procedures used to make a system or design as effective or functional as possible.”
Why Optimize?

- NRC (1999) Estimates that Groundwater Has Been Contaminated at 300,000 to 400,000 Sites in the US
- Projected Total Costs for Remediating Groundwater -- $500B to $1T
- Costs of Monitoring May Reach ~40% of Total Costs of Groundwater Remedy; Annual Costs at Individual Sites May Be $1,000s to More than $1M
Optimization and Application of Refined Monitoring Program

1. Identify / Refine Monitoring Objectives
2. Develop / Refine Monitoring Hypotheses
3. Formulate Optimization Decision Rules
4. Implement Optimized Monitoring Plan
5. Optimize Monitoring Plan
6. Management Decision
Monitoring Program Optimization

Process:

Monitoring Program Optimization

- Qualitative Review
- Temporal Statistical Analysis
- Spatial Statistical Analysis
Qualitative Review

- Hydrogeology
- Contaminants of Concern (COCs)
- Contaminant Distribution
- Remedial System Operation
- Regulatory Compliance
- Proximity to Other Wells
- Sampling Frequency
Qualitative Review

(Temporal Questions)

- Comparison of Groundwater Flow Velocity With Sampling Frequency?
- Do Contaminant Concentrations Display Significant Temporal Changes?
- Would a Rapid Change in Contaminant Concentrations Alter a Course of Action?
- Is Well Important for Monitoring Remedial System Operation?
Qualitative Review
(Spatial Questions)

- Is Well Needed to Monitor “Background” Conditions?
- Is Well Important for Defining Contaminant Extent (Lateral or Vertical)?
- Is Well Important for Monitoring Remedial System Operation?
- Does Well Monitor Potential Exposure Point or Point of Compliance?
- Is Spatial Proximity to Other Wells such that Well is Redundant?
- Is Well Often Dry?
- Are Concentrations Consistently Below Targets?
Temporal Statistical Analysis

- Mann-Kendall Test
  - Evaluate contaminant concentration trends
  - Iterative process -- well by well, constituent by constituent evaluation
# Interpretation of Mann-Kendall Test

<table>
<thead>
<tr>
<th>MK Statistic (S)</th>
<th>MK &lt; 1</th>
<th>Decreasing Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>MK &gt; 1</td>
<td>Increasing Trend</td>
<td></td>
</tr>
<tr>
<td>CF &gt; 90%</td>
<td>Strong Trend</td>
<td></td>
</tr>
<tr>
<td>CF &lt; 90%</td>
<td>Weak Trend</td>
<td></td>
</tr>
<tr>
<td>COV &lt; 1</td>
<td>Stable Trend</td>
<td></td>
</tr>
<tr>
<td>COV &gt; 1</td>
<td>Fluctuating Trend</td>
<td></td>
</tr>
</tbody>
</table>

Source: GSI, 1998
Temporal Trend in TCE Concentrations
Continued Monitoring at Well With No Temporal Trend

Historic Results

Likely Future Results

Range in Concentrations
Temporal Trends and Relative Worth of Information

J.P. Morgan on trends:

“The market will fluctuate ... “
Temporal Statistical Analysis -- Decision Rules

- Monitoring Point Near Contaminant Source
- Monitoring Point Upgradient From Contaminant Source
- Monitoring Point Downgradient From Contaminant Source
- Sampling Frequency Considerations
Norton AFB -- CBA
Norton AFB -- CBA

Results of Temporal Trend Analysis

Legend

Mann Kendall Trend Results Zone A

- ND
- decreasing
- increasing
- no trend

Direction of Groundwater Movement
Spatial Statistical Analysis

- Uses Geostatistics or Other Techniques to Evaluate Relative Importance of Monitoring Wells in Evaluating Spatial Distribution of Network
  - Iterative process -- well by well, constituent by constituent evaluation
Spatial Statistical Analysis

- Develop Expression of Spatial Relationship Among Sampling Results at Different Locations
- Apply Spatial Relationship to Evaluation of Monitoring Network
  - Generate estimates of values (e.g., chemical concentrations) at every point in spatial area
  - Generate estimates of error (standard deviation) associated with each estimated value
  - Generate estimates of global error associated with realization
- Iteratively Remove Individual Wells and Re-Calculate Realization to Evaluate Relative Importance of Each Well
Norton AFB -- CBA

Kriging Standard Error (Current)
Norton AFB -- CBA

Kriging Standard Error (-MW194)
Norton AFB -- CBA

Kriging Standard Error (-MW198)
Spatial Statistical Analysis --
Decision Rules

- Relative Worth of Information from Each Monitoring Point
- Incremental Amount of Information to be Considered “Redundant”
- Other Considerations
Norton AFB -- CBA
Results of Geostatistical Analysis

Legend

Kriging Ranks
- 1-3 least information
- 4-7
- 8-10
- 11-14
- 15-18 most information

MW266
MW212
MW268
MW224
MW190
MW192
MW194
MW177
MW202
MW183
MW187
MW180
MW198
MW226
MW220
MW222

Direction of Groundwater Movement

Scale: 0 500 1,000 2,000 3,000 4,000 Feet

N
Apply Results of Qualitative, Temporal, Spatial Analyses

- Do Monitoring Results Continue to Support Monitoring Hypotheses?
  - Yes – proceed
  - No – examine/refine hypotheses (CSM)
- Develop/Apply Defensible Decision Rules
- Transparent Metrics
  - Can optimized program continue to achieve monitoring objectives?
- Management Decision
Components of Optimized Monitoring Program

- Refined Program Objectives
- Refined Monitoring Program Hypotheses (CSM)
- Optimized Decision Rules
- Optimized Monitoring Plan
  - Sampling Locations (Network)
  - Sampling Schedule (Frequency)
  - Data Collection and Analysis Methods
  - Data Quality Objectives and QA/QC
  - Reporting
- Better-Defined Management Decision
Thank You!

Concepts and Practice in Optimization of Long-Term Monitoring Programs

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