Proposed scientific approach for achieving site closure of aquatic contaminated sites

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Aquatic contaminated sites

• 1674 aquatic contaminated sites listed in the FCSI as of Spring 2011
  – 14% of these are in Steps 7 to 10 of the FCSAP framework

• Site closure will be a key question for these sites in the future

Photo credit: Joseph Hollick
Site closure for FCSAP aquatic contaminated sites

- **Site closure** is attained when:
  - The remedial goals have been achieved
  - The contaminated site no longer poses unacceptable human health and ecological risks
  - These conditions are expected to continue into the foreseeable future

- A site closure process and reporting framework for FCSAP is currently under development

- There is a need for a scientific basis to determine site closure, particularly for aquatic contaminated sites
Long-term monitoring (LTM) and site closure

- Site closure is closely linked with LTM plan design

- Quantifiable measurement endpoints and action levels that indicate when a monitoring objective has been successfully achieved are essential to attain site closure
Approach

Framework for site closure

1. Identify monitoring plan objectives
2. Develop monitoring plan hypotheses
3. Formulate monitoring decision rules
4. Design the monitoring plan
5. Conduct monitoring analyses
6. Establish decisions based on results

Literature Review: Long-Term Monitoring and Site Closure

Scientific Literature
Guidance Documents
Case Studies
Policy
6 step process for developing LTM (USEPA 2004)

- Step 1: Identify monitoring plan objectives
- Step 2: Develop monitoring plan hypotheses
- Step 3: Formulate monitoring decision rules
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- Step 6: Establish decisions based on results

• From “Guidance for monitoring at hazardous waste sites: framework for monitoring plan development and implementation”

• Modified framework to facilitate development of aquatic LTM that can achieve site closure
6 step process for developing LTM (USEPA 2004)

- Step 1: Identify monitoring plan objectives
- Step 2: Develop monitoring plan hypotheses and identify monitoring tools
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1. **Determine monitoring objectives**

General LTM monitoring objectives for assessing remedy performance and ecosystem recovery were identified.

### Remedial Strategies

1. Monitored Natural Recovery

### Aquatic ecosystem impacts

1. Bioaccumulation
2. Toxicity
3. Community structure
4. Physical impacts
5. Habitat recovery
6. Aquatic productivity
7. Species at Risk

- Similar approach to a recent US guidance document for contaminated sediment management (SPAWAR and ENVIRON, 2010) with additional content

Site specific information used to identify the appropriate subset of monitoring objectives.
Examples of general monitoring objectives

Capping as a remedial solution
**Remedy performance monitoring objectives**

**Remedy performance** – is the remedial strategy functioning as designed?

<table>
<thead>
<tr>
<th>Monitoring Goal</th>
<th>Monitoring Objective 1</th>
<th>Monitoring Objective 2</th>
<th>Monitoring Objective 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ensure the remedy is performing as designed to reduce risk levels.</td>
<td>• Is the chemical integrity of the capping material maintained over time and following disruptive events?</td>
<td>• Is the physical integrity of capping material maintained over time and in variable site conditions?</td>
</tr>
</tbody>
</table>
Ecosystem recovery – are risks to human health and the environment decreasing?

Example – bioaccumulation of contaminants in the aquatic food web

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<th>Monitoring Objective 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Ensure that risks to human health and ecological receptors are decreasing</td>
<td>• Assessment of bioaccumulation potential to benthic and/or pelagic species</td>
<td>• Assessment of exposure of bioavailable chemicals to humans via consumption of aquatic organisms</td>
</tr>
</tbody>
</table>
6 step process for developing LTM (USEPA 2004)

Step 1: Identify monitoring plan objectives

Step 2: Develop monitoring plan hypotheses and identify monitoring tools

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Step 4: Design the monitoring plan

Step 5: Conduct monitoring analyses

Step 6: Establish decisions based on results
2. Identify appropriate monitoring tools

- Selection of appropriate monitoring indicators and metrics

Interactive Sediment Remedy Assessment Portal (ISRAP; SPAWAR and ENVIRON, 2010): [http://www.israp.org](http://www.israp.org)

Additional remedial strategy (*in-situ* remediation) and ecosystem recovery objectives (e.g., habitat recovery, aquatic productivity, Species at Risk recovery)

Monitoring tools can then be compared using screening criteria (e.g., complexity, cost, uncertainty in addressing need) to facilitate selection.
Site-specific conceptual models and hypotheses regarding the expected outcomes and mode of action of the remedial strategy should also be developed to support decisions.
Ecosystem recovery – are risks to human health and the environment decreasing?

- Monitoring Goal: Ensure that risks to human health and ecological receptors are decreasing
- Monitoring Objective: Assessment of bioaccumulation potential to benthic and/or pelagic species
- Indicator: Brown bullhead
- Metric: Whole body contaminant concentrations

Indicator selection should reflect site remedial goals, risk assessment outcomes, and available baseline information
6 step process for developing LTM (USEPA 2004)

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3. Develop decision rules for interpreting data

- Decision rules are pass/fail statements that are used to evaluate monitoring data. They include:

  - Quantitative action levels against which monitoring results are compared and which result in an action when met or exceeded
  - Temporal considerations (monitoring frequency, anticipated timeframe until completion)
  - Actions to consider when the action level is not met

Quantitative exit criteria are key to attaining site closure and represent the successful completion of a monitoring objective.
Defining monitoring targets

Ecosystem recovery – are risks to human health and the environment decreasing?

- **Monitoring Goal**: Ensure that risks to human health and ecological receptors are decreasing
- **Monitoring Objective**: Assessment of bioaccumulation potential to benthic and/or pelagic species
- **Indicator**: Brown bullhead
- **Metric**: Whole body contaminant concentrations

Target action levels should be strongly linked with the site remedial goals and risk assessment outcomes
Examples of LTM exit criteria for aquatic sites

- Regulatory or risk-based action levels

<table>
<thead>
<tr>
<th>Monitoring objective</th>
<th>Indicator</th>
<th>Exit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioaccumulation in aquatic organisms</td>
<td>Fish tissue concentrations</td>
<td>95 UCL is below the risk-based threshold for upper trophic level consumers for 3 consecutive sampling periods</td>
</tr>
</tbody>
</table>

- Equivalence to pre-remediation or reference conditions

<table>
<thead>
<tr>
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<th>Exit criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessment of benthic ecological recovery over time</td>
<td>Macroinvertebrate community analyses</td>
<td>No significant differences in benthic community structure between test and reference sites</td>
</tr>
</tbody>
</table>
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Step 6: Establish decisions based on results
4. **Decide on an acceptable level of uncertainty and design program**

- Robust monitoring program design incorporating statistical power analysis is important to ensure that the monitoring program can detect effects if present.
- Need to decide on the tolerance for decision errors for the monitoring program.

<table>
<thead>
<tr>
<th>Decision made by applying the statistical hypothesis test to the monitoring data</th>
<th>True condition (reality)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exit criteria are met</td>
</tr>
<tr>
<td>Decide that the exit criteria have been met</td>
<td>Correct decision</td>
</tr>
<tr>
<td>Decide that the exit criteria have not yet been met</td>
<td>Industry risk</td>
</tr>
</tbody>
</table>

- Balance environmental risk with resource limitations to determine the level of effort required for the monitoring program.
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5. Conduct monitoring analyses
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6. Evaluate monitoring data and make decisions

- Uses an adaptive site management approach

- Did the data meet the data quality objectives (DQOs) for monitoring plan design?
  - If the DQOs are met, evaluate the monitoring data using the decision rules

- Assess the reasons for any deviations and adjust the monitoring plan and/or site actions accordingly

- When the exit criteria are met for a monitoring objective, related monitoring activities can be concluded

- Are all of the exit criteria met?
  - If yes, proceed with site closure
Decision framework for assessing site closure

1. **Estimate Additional Site Activity Time Needed to Meet Decision Rule (Based on Trend Analysis)**
   - If YES, go to **Site closure**
   - If NO, continue with next step.

2. **Are data trending toward meeting the decision rules?**
   - If YES, go to **Have all DQOs and exit criteria for the decision rules been met?**
   - If NO, go to **Conduct Causative Factor and Uncertainty Analyses**

3. **Conduct Causative Factor and Uncertainty Analyses**
   - If YES, go to **Management Decision: Revise Site Activity and/or Monitoring Program Accordingly and Implement (Steps 1-5)**
   - If NO, go back to **Are data trending toward meeting the decision rules?**

4. **Have all DQOs and exit criteria for the decision rules been met?**
   - If YES, go to **Management Decision: Site Closure**.
   - If NO, go back to **Are data trending toward meeting the decision rules?**

5. **Management Decision: Site Closure**
   - Conclude Site Activity and Monitoring Program

6. **Prepare Decision Document, Including Uncertainty Description**
   - Proceed Along Appropriate Regulatory Process for Site Closure

Conclusions

• Quantitative exit criteria are key for developing monitoring programs capable of achieving site closure
  – Allow for evaluation of the successful completion of a monitoring objective

• Site closure is attained when all the exit criteria have been met

• In some cases, site closure cannot be achieved
  – When contaminants remain on site at levels that exceed risk-based guidelines
  – On-going monitoring required
Next steps

- Peer review of the Phase I report “Developing long-term monitoring programs that lead to site closure for FCSAP aquatic contaminated sites: state of science review and technical guide”

- Future deliverables:
  - a concise framework for LTM and site closure of aquatic contaminated sites
  - a fact sheet providing a quick overview of the guidance
  - a checklist for site custodians and FCSAP expert support that may be used to review the FCSAP Final Site Closure Report
Questions?