Failure Modes and Root Causes of Water Quality Impacts

Characterizing, Predicting, and Modeling Water from Mine Sites
Failure Modes and Root Causes of Water Quality Impacts

- Identifies the underlying causes of water quality impacts at the case study mines
- Uses information gathered from the case studies and conducts a “failure modes” and “root cause" analysis
  - A failure is an outcome that is different than intended or predicted
  - A failure mode is the general type of failure that occurred or is predicted to occur (e.g., prediction failure, mitigation failure), while a root cause is the underlying, more specific, reason for the failure
Types of Characterization Failures

- Two Primary Characterization Failure Modes Identified
  - Hydrological Characterization Failures
  - Geochemical Characterization Failures

- Inaccuracies in hydrologic and geochemical characterization can lead to a failure to recognize or predict water quality impacts
### Root Causes of Characterization Failures

#### Hydrological Failures
- dilution overestimated
- lack of hydrological characterization
- amount of discharge overestimated
- size of storms underestimated
- Six of 25 mines had hydrological characterization failures

#### Geochemical Failures
- lack of adequate geochemical characterization
- sample size and/or representativeness
- 11 of 25 mines had geochemical characterization failures
Mitigation Failures

- Root Cause of Mitigation Failures
  - mitigation not identified, inadequate or not installed
  - waste rock mixing and segregation not effective
  - liner leak, embankment failure or tailings spill
  - land application discharge not effective.
- 16 of 25 mines had mitigation failures
### Table 8.2  Failure Analysis Spreadsheet – NEPA/EIS Case Studies
**Water Quality at Hardrock Mine Sites**

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Effects</th>
<th>Consequences</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrological Characterization</strong></td>
<td>Dilution overestimated</td>
<td>M</td>
<td>Greens Creek, Jerritt Canyon</td>
</tr>
<tr>
<td></td>
<td>Presence of water from springs or lateral flow not recognized</td>
<td>H</td>
<td>Black Pine, Mineral Hill, Royal Mountain King</td>
</tr>
<tr>
<td></td>
<td>Amount of water underestimated</td>
<td>M</td>
<td>Mineral Hill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>Ray, Zortman and Landusky</td>
</tr>
<tr>
<td><strong>Geochemical Characterization</strong></td>
<td>Sample representation, testing methods or interpretations inadequate</td>
<td>M</td>
<td>Greens Creek, Jamestown, McLaughlin, Royal Mountain King, Thompson Creek, Jerritt Canyon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>Grouse Creek, Beal Mountain, Black Pine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>Golden Sunlight, Zortman and Landusky</td>
</tr>
<tr>
<td><strong>Mitigation</strong></td>
<td>Mitigation Not identified, inadequate or not installed</td>
<td>M</td>
<td>Greens Creek, Jamestown, Thompson Creek, Jerritt Canyon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>Bagdad, Grouse Creek, Beal Mountain, Black Pine, Zortman and Landusky</td>
</tr>
<tr>
<td></td>
<td>Waste rock mixing and segregation not effective</td>
<td>M</td>
<td>Greens Creek, McLaughlin, Jerritt Canyon</td>
</tr>
<tr>
<td></td>
<td>Leachate contains acid drainage and other contaminants</td>
<td>L</td>
<td>Stillwater, Florida Canyon, Lone Tree, Rochester, Twin Creeks</td>
</tr>
<tr>
<td></td>
<td>Greater than design (e.g. exceedances) impacts to water resources</td>
<td>M</td>
<td>Jamestown, Royal Mountain King, Jerritt Canyon, Mineral Hill</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H</td>
<td>Bagdad</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>Golden Sunlight</td>
</tr>
</tbody>
</table>
Geochemical Characterization Failures

- Geochemical failures resulted from:
  - Assumptions made about geochemical nature of ore deposits and surrounding areas
  - Site analogs inappropriately applied to new proposal
  - Inadequate sampling
  - Failure to conduct and have results for long-term contaminant leaching and acid drainage testing procedures before mining begins.
  - Failure to conduct the proper tests, or to improperly interpret test results, or to apply the proper models
Failure Modes Root Causes Recommendations

- A more systematic and complete effort should be undertaken when collecting data
- Recognize the importance of thorough hydrological and geochemical characterization
- Utilize information in a conservative manner to identify and utilize mitigation measures
- Consider the likelihood and consequences of mitigation failures