Levee Risk Assessments

Overview of the USACE Semi-Qualitative Risk Assessment Process for Levees

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Levee Risk Assessments

Where?
Prioritization of systems

Why?
To inform levee safety activities

Who?
Cadre / District / Sponsor

When?
District / cadre availability

What?
Screening & Higher-level RAs
What is RISK

<table>
<thead>
<tr>
<th>P (Loading)</th>
<th>P (Failure)</th>
<th>P (Consequences)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Flood" /></td>
<td><img src="image2" alt="Seismic" /></td>
<td><img src="image3" alt="Earthquake" /></td>
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<tr>
<td><img src="image4" alt="Earthquake" /></td>
<td><img src="image5" alt="Earthquake" /></td>
<td><img src="image6" alt="Earthquake" /></td>
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Levee Risks Assessments – Where?
Screening Level Risk Assessment (LST)

• To quickly characterize the risk of the USACE portfolio in a consistent manner
• Set priorities for program activities
• Identify risk drivers and recommendations
• Inform Interim Risk Reduction Measures
• Provide basis to communicate information about levees in a risk context
Higher Level Risk Assessment

Why?

• Better understand and communicate life safety and economic risks for those living and working in leveed areas

• Gives Corps Districts and Sponsors a better understanding of their levee system

• Provides an in-depth look at levee system performance and vulnerabilities over a full range of loadings
Higher Level Risk Assessment

Some project-specific reasons:

- Used to inform/help make risk-based decisions for:
  - Planning/Feasibility
  - Design/Construction
  - Interim Risk Reduction Measures
  - Permit Review
- Identify O&M, monitoring, emergency management, training, and other ongoing needs.
- Prioritize modifications and repairs being taken/planned by sponsors.
- Verify and compare with LST results. Revise LSAC as appropriate.
- Determine if further investigation/data collection is needed.
A levee activity consisting of a Potential Failure Mode Analysis (PFMA), and a risk assessment.

- Based on a range of flood events.
- Based on existing data and limited development of estimated consequences.
- Apply a higher level of rigor than LST to further identify and refine project risks, assess the LSAC, and recommend prioritization of activities.
- Assess risks in a semi-quantitative manner using a risk matrix to portray severity of risks.
Levee Risk Assessments
Who does them?

Risk Cadre:
• Geotechnical Engineer
• Hydraulic Engineer
• Geologist
• Structural Engineer
• Consequence Specialist

District (as availability allows):
• Geotechnical Engineer
• Hydraulic Engineer
• Geologist
• Structural Engineer
• Consequence Specialist (HEC)

Local Sponsor:
• Representative familiar with O&M, system performance, concerns

RMC:
• Senior Advisor and Technical Advisor
Risk Assessment Process Overview

1. Scoping
2. Data Gathering
3. Potential Failure Modes Analysis
4. Conclusions
5. Expert Elicitation/Risk Estimate
6. Communicate Results
7. Review, Assign LSAC, and Finalize Report
8. Recommendations
Risk Assessment Process
Overview

• Collect and review all available background information.
• Conduct a site visit focused on vulnerabilities.
• Review loading conditions and baseline consequences.
• Brainstorm potential failure modes.
• Categorize risk drivers and non-risk drivers.
• Discuss, evaluate, and classify risk for risk drivers.
• Document justification for non-risk drivers.
• Document major findings and key background information (i.e., “build the case”).
1. Site Recon/Data Collection
2. Reach Breakdown
3. Modeling and Mapping of Inundation Consequence Estimates
4. Potential Failure Modes Analysis
5. Estimate of Warning Times, Breach Formation, Life Safety and Economic Consequences
6. Develop Risk Estimates (Performance and Consequences)
7. Report Writing/Building the Case
8. Reviews
Detachment of soils particles at a free, unfiltered surface in which the process gradually works its way towards the upstream side of the embankment or its foundation until a continuous pipe is formed.
Generic Sequence of Events

Reservoir/flood level within partition of interest

Initiation: Flaw exists (continuous crack, high permeability zone, etc.)

Initiation: Erosion starts (particle detachment)

Continuation (open, filtered/unfiltered, or constricted exit exists)

Progression (continuous stable roof and/or sidewalls)

Progression (constriction or upstream zone fails to limit flows)

Progression (no self-healing by upstream zone)

Unsuccessful detection and intervention

Breach (uncontrolled release of retained water)
Backward Erosion Piping
Typical Event Tree

1. An unfiltered seepage exit exists at the downstream toe?
2. A continuous path of fine to medium, uniform sand exists?
3. Sufficient exit gradient exists to initiate backward erosion piping at the unfiltered seepage exit?
4. A continuous stable roof forms over the developing pipe?
5. Sufficient global gradient exists for progression of the pipe to the reservoir?
6. Detection and intervention are unsuccessful?
7. Breach occurs by gross enlargement, crest collapse, and overtopping?

Unsuccessful Intervention

Detection

Progression: Hydraulic Cond.

Progression: Mechanical Cond.

Initiation

Flaw: Continuous Path

Flaw: Unfiltered Exit

Reservoir Loading

Toe drains, no confining layer, and blowout or defects in confining layer

Confining layer is penetrated by burrows, cracks, or objects resulting in an unfiltered seepage exit?

Sufficient uplift pressure exists at base of confining layer to crack it and create an unfiltered seepage exit?
- **Remote**: Annual failure likelihood is more remote than 1/1,000,000. Several events must occur concurrently or in series to cause failure, and most, if not all, have negligible likelihood such that the failure likelihood is negligible.

- **Low**: Annual failure likelihood is between 1/1,000,000 and 1/100,000. The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to initiation.

- **Moderate**: Annual failure likelihood is between 1/100,000 and 1/10,000. Fundamental condition or flaw is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “less likely” than “more likely.”

- **High**: Annual failure likelihood is between 1/10,000 and 1/1,000. Fundamental condition or flaw is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward “more likely” than “less likely.”

- **Very High**: Annual failure likelihood is between 1/1,000 and 1/100. Direct evidence or substantial indirect evidence to suggest it is likely to occur.

- **Failure Progression Likely**: Annual failure likelihood is between 1/100 and 1/10. Performance suggests failure is initiating and likely to progress in near future.

- **Failure Progression Observed**: Annual failure likelihood is more frequent (greater) than 1/10. Performance confirms progression towards failure is occurring.
Incremental Life Safety Risk Matrix for Dams and Levees

Average Incremental Life Loss, $\bar{N}$

<table>
<thead>
<tr>
<th>Likelihood of Failure</th>
<th>Average Incremental Life Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote</td>
<td>Low</td>
</tr>
<tr>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Very High</td>
<td>Extremely High</td>
</tr>
</tbody>
</table>

Average Incremental Direct Economic Loss, $\bar{\$}$

<table>
<thead>
<tr>
<th>Likelihood of Failure</th>
<th>Annual Probability of Failure (APF), $f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extreme</td>
<td>$10^0$</td>
</tr>
<tr>
<td>High</td>
<td>$10^{-1}$</td>
</tr>
<tr>
<td>Moderate</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Low</td>
<td>$10^{-3}$</td>
</tr>
<tr>
<td>Remote</td>
<td>$10^{-4}$</td>
</tr>
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Failure Progression Observed

Failure Progression Likely
Myths

Risk analysis is just a means to justify no action

Risk analysis eliminates good engineering practice

Need to have massive amounts of data to do analysis

Risk numbers are just a guess, so results aren’t valid
Continued investment in dam safety modifications

Framework for thinking beyond traditional engineering

Experience

Combines: available data, analysis, experience and judgment

Better discussion and analysis of issues
Risk Assessment Products

- **Risk drivers** – resulting in being able to prioritize actions and determine sense of urgency of implementing actions

- **Consequences** should non-performance (breach) or overtopping occurs

- Understanding of **areas of uncertainties and confidence** in decisions

- **Information for making risk management decisions** – levee sponsor, community, and individual residents
Risk Assessment Outcomes

- Gives Corps Districts and Sponsors a better understanding of their levee system.
- Provides an in-depth look at levee system performance and vulnerabilities over a full range of loadings.
- Used in making risk-informed decisions for planning, design and construction.
- Use results to make recommendations and prioritize Levee Safety activities, O&M, additional studies/data collection, emergency response/planning needs, etc.
- Evaluate Interim Risk Reduction Measures (IRRM).
- Verify and compare with LST (Screening) results.
- Use Incremental Risk Matrices to inform LSAC.