Best Practices in Dam and Levee Safety Risk Analysis

III-1. Consequences - USACE

23 June 2015
Objectives

- Participants will become familiar with USACE approach for estimating loss of life
Why the Different Approaches?

• Empirical approaches tie important parameters to historic events
  – Characteristics of built infrastructure, population, etc
  – Historic record doesn’t include scenario for typical USACE flood control dam (large dam above major population center)
  – Limited number of parameters make it harder to understand risk drivers and recommend appropriate risk reduction measures

• Simulation approaches (LifeSim/FIA) consider interaction of people with water throughout event
  – Provide higher resolution for risk reduction associated with “non-structural” measures
Life Loss Estimation – Essential Elements

• Initial distribution of people
• Redistribution of people
  – Warning
  – Response
  – Evacuation potential
• Flood characteristics
  – Arrival time, depth, velocity
• Shelter provided by final location
• Fatality rates

Evacuation Effectiveness
**Scalable Risk Assessment** (Initially a Screening Level Effort) -> LSOG recommends risk characterization and follow on activities informed by available risk information.**

Is more information required to recommend risk characterization and follow on activities?

Yes -> Levee Safety Risk Management Study

No -> Communicate Levee System Benefits and Inundation Risk (Incremental and Non-breach Risk)

LSAC 1, 2, 3, & 4?

Yes -> LSAC 1, 2, 3, & 4?

No -> Plan Non-routine Activities

LSAC 1, 2, & 3 In Order of Priority

LSAC 1, 2, 3, & 4 In Order of Priority

IRRM activities may inform decision to proceed with Recon Phase.

Proceed to Recon Phase?

Yes

Recon Phase

No

Interim Risk Reduction Measures

Proceed to Study Phase?

Yes

In Order of Priority

No

Routine O&M, Monitoring, & Incident Reporting

Inspections (Routine) (Periodic) (Special)

National Levee Database

Incident or inspection finding triggers formal LSAC review?

Yes

11June 2013

All levees

No

Levee Safety Risk Management Study

Yes

In Order of Priority

No

Recon Phase

Levee Safety Portfolio Risk Management Process

• “One size fits all approach” no good

• Decision Driven
  – Methods used dictated by available resources and potential investment

**Regardless of the assigned risk characterization, levees found to no longer be serving a beneficial Federal flood risk management purpose will be so flagged, considered to be in ‘inactive status’, and are exempt from the Levee Safety Portfolio Management Process.**
USACE Life Loss Estimation Methods – Decision Driven

• Screening - **Minimal resource requirement**
  – Dams - Modified DSO-99-06 Method
  – Levees - Jonkman’s Method

• Higher-level Risk Assessments
  – HEC-FIA
    • Screening validation, issue evaluation and periodic assessments
    • **Moderate resource requirement**
  – LifeSim
    • Support studies when HEC-FIA simplifications lead to too much uncertainty
    • **Larger resource requirement**

Scalable methods – effort from one applicable to more rigorous method
Initial Distribution of People
Redistribution of People

1. Hazard Identified
2. Hazard Communicated to EMA
3. Warning Issued
4. Warning Diffusion Time
5. Warning Issuance Delay
6. First Alert/Warning Received
7. Mobilization Time or PAI Delay
8. Protective Action Initiated

- Hazard Communication Delay
- Protective Action Initiated Delay
Redistribution of People

Step 1: Threat Recognition and Warning Issuance

- Flow into leveed area
- Failure mode initiates
- Muddy flow observed
- Voluntary Warning Issuance
- Intervention Attempted
- Mandatory Warning Issuance
- Collapse of Embankment

Time

0-4 hrs
0-2 hrs
Redistribution of People

Step 2: Warning Diffusion

• What factors most influences how quickly an alert or warning spreads through a community?
  – Number and mix of warning channels
  – Frequency of distribution
  – Ability to wake people up
  – Modern technologies
Redistribution of People

Step 2: Warning Diffusion

Warning System Type (Rogers et al 1988)
Redistribution of People

Step 3: Protective Action Initiation

• What factors most influence how quickly someone takes the recommended protective action after receiving a warning?
  – Message content and style
  – Message spoken by person
  – Messages are frequently repeated
Message Content

- **Who?** – Source
- **What?** – Threat and consequence
- **Where?** – Locations at risk
- **How?** – Action to take
- **When?** – Timing of when to start and finish action
- **Why?** – How taking action will reduce consequence
Protective Action Initiation - Uncertainty

The graph illustrates the percentage of warned PAR (Protective Action Required) that has taken protective action over time. The x-axis represents the time after receiving a warning (in minutes), while the y-axis shows the percentage of warned PAR that has taken protective action. The graph includes uncertainty bounds and estimates at different likelihood levels:
Max Mobilization (PAI)

<table>
<thead>
<tr>
<th>Initial Perception</th>
<th>Maximum Mobilization % (Compliance)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Short Warning Time (&lt; 8 hrs)</td>
</tr>
<tr>
<td></td>
<td>Message Effectiveness</td>
</tr>
<tr>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Likely to impact me</td>
<td>51-59</td>
</tr>
<tr>
<td>Unlikely to impact me</td>
<td>28-34</td>
</tr>
</tbody>
</table>

- Message effectiveness based on results of interview with EMAs, using same scale as Protective Action Initiation
Redistribution of People

Step 4: Evacuation Potential

• Can people get to safety before water arrives?
LifeSim Methodology – Evacuation

- Dual regime modified Greenshields traffic simulation model (US-DOT).

In mathematical terms, the dual-regime modified Greenshields is expressed as follows:

\[ v_i = u_f, \quad 0 \leq k_i \leq k_{bp} \]

\[ v_i - v_0 = (u_f - v_0) \cdot \left(1 - \frac{k_i}{k_{jam}}\right)^\alpha, \quad k_{bp} \leq k_i \leq k_{jam} \]
LifeSim Evacuation

- Destination is chosen by shortest travel time
- Allows for One-Way roads
- Allows vehicles to turn around if road is flooded
- Allows a user defined percentage of vehicles to contain system information (smarter) and re-route if traffic jam is reached.
- Traffic density based on look-ahead distance not just current segment (which could be very short or long)
Life Loss Estimation – Essential Elements

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- Flood characteristics
  - Arrival time, depth, velocity
- Shelter provided by final location
- Fatality rates
Detailed Flood Characteristics
Life Loss Estimation – Essential Elements

- Initial distribution of people
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- Fatality rates
Shelter provided by final location

- Screening – not explicitly considered (built into fatality rates)
- Detailed – human, vehicle, structure stability criteria

<table>
<thead>
<tr>
<th>Building type</th>
<th>Partial damage</th>
<th>Total damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood-framed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unanchored</td>
<td>$v \cdot d \geq 2 \text{ m}^2/\text{s}$</td>
<td>$v \cdot d \geq 3 \text{ m}^2/\text{s}$</td>
</tr>
<tr>
<td>anchored</td>
<td>$v \cdot d \geq 3 \text{ m}^2/\text{s}$</td>
<td>$v \cdot d \geq 7 \text{ m}^2/\text{s}$</td>
</tr>
<tr>
<td>Masonry, concrete</td>
<td>$v \geq 2 \text{ m/s}$ &amp;</td>
<td>$v \geq 2 \text{ m/s}$ &amp;</td>
</tr>
<tr>
<td>&amp; brick</td>
<td>$v \cdot d \geq 3 \text{ m}^2/\text{s}$</td>
<td>$v \cdot d \geq 7 \text{ m}^2/\text{s}$</td>
</tr>
</tbody>
</table>
Fatality Rates - Detailed

![Graph showing relative frequency of exceedance for different zones: chance zone, compromised zone, and safe zone.](image)
Understanding Results

Results suggest EBS warning system causes more life loss than no warning if breach occurs between midnight and 5 AM.
Uncertainty

Life Loss

Warning Issuance Time (hr)

Breach
Cry Wolf Syndrome

- Asking the public to evacuate for a flood emergency that ultimately does not occur will reduce compliance the next time.
Traffic Accidents

• Traffic accidents increase during mass evacuations.

Traffic accidents decrease because traffic is moving at slower speeds, generally in a single direction, and people are more cautious and more considerate.