Looking at Dam Safety from a Resiliency Perspective

February 23, 2017
Discussion Outline

• Dam Safety 101 (10 min)

• Fort Hood Overview (5 min)

• Resiliency Framework (5 min)

• Fort Hood Dam Safety Program (15 min)
  • Prepare
  • Absorb
  • Recover
  • Adapt
  • Lessons Learned
Dam Safety 101

- Dam terminology & schematics
- Regulatory framework
- “Hazard” classification

**Dam Safety Checklist**

- Collect as-built drawings, design report, etc.
- Organize geotechnical data
- Identify purpose/mission
- Perform inspections
- Analyze hydrologic capacity
- Develop breach analysis
- Exercise EAP
- Develop O&M Manual
- Coordinate with State
- Coordinate with IMCOM
Embankment Dam Terminology

- Rt. Abutment
- Downstream Slope
- Dam Crest
- Principal Spillway
- Riser w/ Trash Rack
- Upstream Slope
- Control Section
- Left Abutment
- Bench
- Toe/Embankment
- Stilling Basin
- Outlet
- Groin
- Emergency Spillway
- Impoundment
- Flow
“Disruptions” for Dams

- **Flood Events**
  - 5-yr flood ~ 4.4 in/24 hrs
  - 100-yr flood ~ 8.9 in/24 hrs
  - **Probable Maximum Flood (PMF)** ~ 43 in/24 hrs

- **Seismic Events**

- **Relentless force of water**
  - Seepage
  - Wave action

- **Examples of Disruptions**
  - Wave erosion Slope slides
  - Spillway erosion
  - Overtopping damage
Assistant Chief of Chief of Staff for Installation Management (ACSIM)

Installation Management Command (IMCOM)

Engineer Research and Development Center (ERDC)

Installation/Directorate of Public Works (DPW)
## Dam Safety Regulatory Guidelines

### Federal
- AR 420-1 – Army Facilities Management, Chapter 7, Section VI: Dams
- DA PAM 420-1-3 – Transportation Infrastructure and Dams
- AR 405-90 – Disposal of Real Estate
- FEMA 93 – Federal Guidelines for Dam Safety
- FEMA 64 – Emergency Action Planning for Dam Owners
- FEMA 333 – Hazard Potential Classification for Systems of Dams
- FEMA 65 – Earthquake Analyses and Design of Dams
- FEMA 94 – Selecting and Accommodating Inflow Design Floods for Dams

### State
- Georgia Department of Natural Resources
- Florida Department of Environmental Protection
- North Carolina Department of Environmental Quality
- South Carolina Department of Health and Control
- Alabama – *no state dam safety program*
## Hazard Classification Definitions

<table>
<thead>
<tr>
<th>Hazard Classification</th>
<th>Federal – Army (DA PAM 420-1-3)</th>
<th>State – TCEQ (TAC Chpt. 299)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Hazard</td>
<td>No loss of human life (PAR = 0)</td>
<td>No loss of human life (PAR=0)</td>
</tr>
<tr>
<td></td>
<td>Low economic losses</td>
<td>Minimal economic loss</td>
</tr>
<tr>
<td></td>
<td>Low environmental losses</td>
<td>Damage to minor highways</td>
</tr>
<tr>
<td>Significant Hazard</td>
<td>No loss of human life (PAR = 0)</td>
<td>Loss of human life (PAR&lt;6)</td>
</tr>
<tr>
<td></td>
<td>Some economic loss</td>
<td>Appreciable economic loss</td>
</tr>
<tr>
<td></td>
<td>Some environmental damage</td>
<td>Damage to secondary highways</td>
</tr>
<tr>
<td></td>
<td>Disruption of lifeline facilities</td>
<td>Damage to public utilities</td>
</tr>
<tr>
<td>High Hazard</td>
<td>Loss of human life (PAR &gt; 0)</td>
<td>Loss of human life (PAR&gt;6)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Serious economic loss</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Damage to main highways</td>
</tr>
</tbody>
</table>
USACE – SAD – Dams Inventory

USACE – South Atlantic Division (SAD)
Savannah District
  - Ft. Jackson – 7 dams
  - Ft. Gordon – 11 dams
  - Ft. Stewart – 9 dams
  - Ft. Benning – 6 dams
  - Ft. Bragg – 22 dams
  - Civil Works – 9 dams
Mobile District
  - Ft. Rucker – 1 dam
  - Civil Works – 33 dams
Jacksonville District
  - Civil Works – 4 dams
Charleston District
  - Civil Works – 1 dam
Wilmington District
  - Civil Works – 10 dams
Fort Hood Overview

- On-post population = 62,179
  - Military Assigned = 35,804
  - Active Deployed = 2,815
- Total Area = 342 sq. mi.
  - Cantonment = 34 sq. mi.
  - Training Areas = 308 sq. mi.
- $35.4 Billion economic impact on Texas economy
Fort Hood Dam Safety Setting

- **51 dams (1 breached)**
- **Hazard Class.**
  - 7 – High
  - 5 – Significant
  - 38 – Low
- **Size Class.**
  - 0 – Large
  - 7 – Intermediate
  - 43 - Small

Adjacent Communities

Main Cantonment

Training Areas
Fort Hood Stormwater Setting
RESILIENCE means “the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions.”

Presidential Executive Order 13653, Preparing the U.S. for Impacts of Climate Change (NOV 2013)

USACE's Principles of Resilience

http://www.usace.army.mil/Portals/2/docs/Sustainability/Building%20Resilience/Resilience-Def-Principles.png
Determine Lake Purposes & Uses

- Data research
- Stakeholder meetings

**Bar Chart: Dam/Lake Purpose**

- Water Supply: 8
- Flood Control: 6
- Erosion/Sediment Control: 29
- Recreation: 13
- Wildlife Habitat: 5
Dam Safety Inspections

• Physical condition assessment
• Assessment of O&M activities
• Developed scoring system for components:
  – Embankment
  – Principal spillway
  – Emergency spillway

Condition Scores (2013 Inspection)

- >80: 16, 31%
- 60<<80: 27, 53%
- <60: 7, 14%
- NA: 1, 2%

Dam Safety Inspections

“Red”
“Green”
“Amber”

- >80
- 60<<80
- <60
- NA
Geotechnical Investigations/Analyses

- Investigations
  - Lack of design & construction data
  - Characterize embankment & foundation
  - Drilling/lab testing

- Analyses
  - Slope stability
  - Seepage
  - Alternatives evaluation
Field Surveys

- Topographic surveys
  - Lack of design & construction data
  - Characterize dam configuration
  - Informs H&H analyses

- Bathymetric surveys
  - Indicates lake sediment/water storage
  - Indicates lake usefulness
  - Aids prioritization
Administrative Requirements

Program Action Items

% of Total

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Inspection Report 100%
Standard Operating Procedures 34%
Emergency Action Plan 14%
Operation & Maintenance Plan 0%
Record Drawings 52%
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Presidential Executive Order 13653, Preparing the U.S. for Impacts of Climate Change (NOV 2013)

USACE’s Principles of Resilience

- Prepare
- Adapt
- Absorb
- Recover
Hydrologic Capacity Analyses

- **Federal IDF analysis**
  - Controlled 80% of dams
- **State IDF analysis**
- **Assessed** 5-, 10-, 25-, 50-, and 100-yr events
- **Evaluated spillway engagement**
- **Rehabilitation alternatives analysis:**
  - Dam raise
  - Spillway capacity
  - Geotech considerations
  - Combinations

<table>
<thead>
<tr>
<th>Hydrologic Capacity Analyses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pass</strong></td>
</tr>
<tr>
<td><strong>Fail</strong></td>
</tr>
</tbody>
</table>

- **Pass** 30
- **Fail** 20
Sample Breach Inundation Map

Legend

Probable Maximum Flood
- Maximum Inundation Elevation (feet)
- Inundation Area

Sunny Day Dam Failure
- Maximum Inundation Elevation (feet)
- Inundation Area

Lake/Dam
Downstream Inundation Area

Emergency Action Planning & Coordination with Adjacent Communities
Breach Inundation Mapping

Breach Mapping

Hazard Classification

Design Flood Determination
RESILIENCE means "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

Presidential Executive Order 13653, Preparing the U.S. for Impacts of Climate Change (NOV 2013)

USACE’s Principles of Resilience

- Prepare
- Adapt
- Absorb
- Recover
Operation and Maintenance
Rehabilitation Projects

3. PROVIDE TOE DRAIN CLEANOUTS AT 200-FT MAXIMUM SPACING
5. DESIGNER MAY CONSIDER CENTRIFUGALLY CAST FIBERGLASS REINFORCED POLYMER MORTAR PIPE DIRECTLY JACkED WITHOUT A CASING.
RESILIENCE means "the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

Presidential Executive Order 13653, Preparing the U.S. for Impacts of Climate Change (NOV 2013)

USACE’s Principles of Resilience

- Prepare
- Adapt
- Absorb
- Recover
Risk-Based Decision Framework

**Risk Informed View of Infrastructure Safety**

\[ \text{Risk} = f(\text{Hazard, Performance, Consequences}) \]

- **What are the hazards and how likely are they to occur?**
  - Think: “Storm Loading” and “Physical Condition”

- **How will the infrastructure perform in the face of these hazards?**
  - Think: “Hydrologic Capacity” and “Geotechnical Stability”

- **Who and what are in harms way? How susceptible to harm are they? How much harm is caused?**
  - Think: “Breach Mapping” and “Hazard Classification” and “Infrastructure Impacts”

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**Dam Safety Management in the United States**
1. Evaluate Dam Safety Risk
   – Based on breach analyses (low/significant/high hazard)
   – Based on input from Stakeholders

2. Evaluate benefit provided by Dam/Lake
   – Based on input from Stakeholders

3. Evaluate Needs:
   – Repairs (based on visual inspections)
   – Upgrades (based on hydrologic assessment, geotechnical studies, etc.)
   – Based on input from Stakeholders
   – Develop options based on Risk/Benefit combination
### Risk-Informed Decision Framework

<table>
<thead>
<tr>
<th>Higher Risk (Persons-at-Risk, Infrastructure, Loss of Function)</th>
<th>Higher Benefit</th>
<th>Lower Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category A</strong></td>
<td></td>
<td><strong>Category C</strong></td>
</tr>
<tr>
<td>• Rehabilitate/upgrade to current dam safety standards</td>
<td></td>
<td>• Intentional breach and/or decommission</td>
</tr>
<tr>
<td>• Continue O&amp;M activities</td>
<td></td>
<td>• Actively remove risk</td>
</tr>
<tr>
<td>• Continue investment</td>
<td></td>
<td>• Consider discontinuance of O&amp;M activities</td>
</tr>
<tr>
<td>• Examples:</td>
<td></td>
<td>• Consider stop investment</td>
</tr>
<tr>
<td>o Dam 46</td>
<td></td>
<td>o Dam 43</td>
</tr>
<tr>
<td>o Dam 47</td>
<td></td>
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<tr>
<td>o Dam 49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Dam 51</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Category B</strong></td>
<td></td>
<td><strong>Category D</strong></td>
</tr>
<tr>
<td>• Perform repairs to restore original intended design condition</td>
<td></td>
<td>• Discontinue O&amp;M activities</td>
</tr>
<tr>
<td>• Continue O&amp;M activities</td>
<td></td>
<td>• Stop investment</td>
</tr>
<tr>
<td>• Continue investment</td>
<td></td>
<td>• Abandon or allow natural breach to occur</td>
</tr>
<tr>
<td>• Will need to consider end-of-life costs, such as dredging or decommissioning for sediment control structures</td>
<td></td>
<td>• Alternative would be to consider intentional breach and/or decommission</td>
</tr>
<tr>
<td>• Examples:</td>
<td></td>
<td>o Dam 40</td>
</tr>
<tr>
<td>o Dam 07 through Dam 31</td>
<td></td>
<td>o Dam 04</td>
</tr>
<tr>
<td><strong>Focus Investment</strong></td>
<td></td>
<td><strong>Stop Investment/Decommission</strong></td>
</tr>
</tbody>
</table>

**Important Concept:** Consider using PAR estimation, Infrastructure Impacts, Loss of Function as risk-based prioritization criteria.
### Roadmap for Dam Safety Program

<table>
<thead>
<tr>
<th>Dam Inventory</th>
<th>Hazard Classification</th>
<th>Condition Status</th>
<th>Hydrologic Capacity</th>
<th>Cost Estimate</th>
<th>Prioritization Framework</th>
</tr>
</thead>
</table>

#### Dam Inventory

<table>
<thead>
<tr>
<th>Dam Name</th>
<th>Dam Type</th>
<th>Location</th>
<th>Elevation</th>
<th>Hazard Class</th>
<th>Condition</th>
<th>Hydrologic Capacity</th>
<th>Cost Estimate</th>
<th>Prioritization</th>
</tr>
</thead>
</table>

#### Hazard Classification

- **Small Dam**: Low risk
- **Large Dam**: High risk

#### Condition Status

- **Good**: Less than 10% chance of failure
- **Fair**: 10-50% chance of failure
- **Poor**: More than 50% chance of failure

#### Hydrologic Capacity

- **Safeguarded**: Capacity to prevent failure
- **Unclassified**: Insufficient data

#### Cost Estimate

- **$1,000,000**: Low maintenance costs
- **$10,000,000**: High construction costs

#### Prioritization Framework

- **Category I**: High priority
- **Category II**: Medium priority
- **Category III**: Low priority

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This table provides a comprehensive overview of dam safety, including inventory, hazard classification, condition status, hydrologic capacity, and cost estimates, along with a prioritization framework to guide decision-making.
Lessons Learned

1. Inspections do not constitute a dam safety program.
2. Understanding original purpose and need for the lake/dam is critical for future decision making.
3. Records-keeping is very important considering Government staff turnover.
4. Document research can provide valuable cost savings for future engineering studies.
5. Understanding off-site/downstream impacts from dams is critical in prioritizing work and coordinating with surrounding communities.
6. It is imperative to develop a technical understanding of your dams and associated regulations. Developing this understanding can be an educational process for Government staff.
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