Previous FEMA Guidelines

FEMA (ICODS) – 1986

1999/2004
Development of Draft Guidelines

TASKS:

• Reviewed existing regulations and published guidelines of state and federal agencies.

• Conduct survey of state and federal agencies.

• Perform literature review of previous regulations and research.
The Early Period (before 1900)

- High water marks
- Smaller dams, less development
- “Nature has shown maximum flood potential”
- Extreme flood evaluation “impossible”
South Fork Dam, Johnstown, PA
2,209 lives lost

Source: http://www.jaha.org

**PMP** –
“*The theoretical greatest depth of precipitation for a given duration that is physically possible over a particular drainage area at a certain time of year*”

**PMF** –
“*The flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin under study*”

MPF vs PMF
Recognize uncertainties and the worst combination of events

FEMA, 2004

Site-Specific PMPs

Statewide studies
Failure of Teton Dam
FEMA ICODS-Federal Guidelines for Dam Safety

- First guidelines for federal agency dam owners and dam owners regulated by federal agencies

“*When flooding could cause significant hazards to life or major property damage, the flood selected for design should have virtually no chance of being exceeded. If lesser hazards are involved, a smaller flood may be selected for design. However, all dams should be designed to withstand a relatively large flood without failure even when there is apparently no downstream hazard involved under present conditions of development*” [FEMA, 1979].

- Consider using risk-based analyses for prioritizing dam rehabilitations
### ASCE Committee on Spillway Design Flood Selection

Summary of ASCE Committee’s Spillway Design Flood Selection Process [ASCE, 1988]

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Spillway Design Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dams where failure consequences include loss of life or other social and economic losses that warrant the use of the PMF as the spillway design flood.</td>
<td>PMF</td>
</tr>
<tr>
<td>2</td>
<td>Dams where the social and economic consequences of failure are not large enough to require use of the PMF as the spillway design flood.</td>
<td>PMF unless quantitative risk assessment shows smaller flood is justified</td>
</tr>
<tr>
<td>3</td>
<td>Small dams where the cost of construction is small and the failure damage is low and confined to the owner.</td>
<td>10- to 100-year flood¹</td>
</tr>
</tbody>
</table>

---

**Table 3-3. Data types and extrapolation ranges for hydrologic hazard analysis (Reclamation, 1999b)**

<table>
<thead>
<tr>
<th>Type of data used for hydrologic hazard analysis</th>
<th>Range of credible extrapolation for Annual Exceedance Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>At-site streamflow data</td>
<td>Typical: 1 in 100, Optimal: 1 in 200</td>
</tr>
<tr>
<td>Regional streamflow data</td>
<td>Typical: 1 in 500, Optimal: 1 in 1,000</td>
</tr>
<tr>
<td>At-site streamflow and at-site paleoflood data</td>
<td>Typical: 1 in 4,000, Optimal: 1 in 10,000</td>
</tr>
<tr>
<td>Regional precipitation data</td>
<td>Typical: 1 in 2,000, Optimal: 1 in 10,000</td>
</tr>
<tr>
<td>Regional streamflow and regional paleoflood data</td>
<td>Typical: 1 in 15,000, Optimal: 1 in 40,000</td>
</tr>
<tr>
<td>Combinations of regional data sets and extrapolation</td>
<td>Typical: 1 in 40,000, Optimal: 1 in 100,000</td>
</tr>
</tbody>
</table>

Risk-Informed Decision Making Period (2000-Present)

Advances in Risk-Based Hydrologic Hazard Methods


**USSD Paper**

1. Failure modes identification
2. Index Prioritization
3. Portfolio Risk Assessment
4. Quantitative Risk Assessment

- Identifying dam deficiencies, prioritizing repair or resolution
- Select acceptable spillway design capacity for dams
Supplemented PMF standard with IDA

Moved to portfolio management
ER 1110-2-1156 (October 2011) provides guidelines for assessing tolerable risk.

Generalized and Project Specific Tolerability of Risk Framework (Adapted from HSE 2001)
Common dam safety risk management framework & policies
2011 Hydrologic Safety of Dams Survey

Completed by All State and Major Federal Agencies
State of the Practice: Federal Agencies
Federal Agencies Involved with Dams

27,252 Dams
2,700 Dams
2,524 Dams
669 Dams
49 Dams
## Table 2-5  Minimum auxiliary spillway hydrologic criteria

<table>
<thead>
<tr>
<th>Class of Dam</th>
<th>Product of storage X effective height</th>
<th>Existing or planned upstream dams</th>
<th>Precipitation data for (^1)</th>
<th>Freeboard hydrograph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (^2)</td>
<td>less than 30,000</td>
<td>none</td>
<td>(P_{100})</td>
<td>(P_{100} + 0.12(P_{\text{MMP}} - P_{100}))</td>
</tr>
<tr>
<td></td>
<td>greater than 30,000</td>
<td></td>
<td>(P_{100} + 0.06(P_{\text{MMP}} - P_{100}))</td>
<td>(P_{100} + 0.26(P_{\text{MMP}} - P_{100}))</td>
</tr>
<tr>
<td></td>
<td>all</td>
<td>any (^3)</td>
<td>(P_{100} + 0.12(P_{\text{MMP}} - P_{100}))</td>
<td>(P_{100} + 0.40(P_{\text{MMP}} - P_{100}))</td>
</tr>
<tr>
<td>Significant</td>
<td>all</td>
<td>none or any</td>
<td>(P_{100} + 0.12(P_{\text{MMP}} - P_{100}))</td>
<td>(P_{100} + 0.40(P_{\text{MMP}} - P_{100}))</td>
</tr>
<tr>
<td>High</td>
<td>all</td>
<td>none or any</td>
<td>(P_{100} + 0.26(P_{\text{MMP}} - P_{100}))</td>
<td>PMP</td>
</tr>
</tbody>
</table>
Risk-informed decision-making

1. Failure modes identification
2. Index Prioritization
3. Portfolio Risk Assessment
4. Quantitative Risk Assessment
• Based upon FEMA’s Guidelines for Dam Safety

• Used risk-based hydrologic analysis as an aid in reviewing spillway designs

• Transitioning from a prescriptive approach to placing increasing emphasis on risk-informed decision making practices such as incremental damage analysis
Supplemented PMF standard with IDA
Moved to portfolio management
ER 1110-2-1156 (October 2011) provides guidelines for assessing tolerable risk
State of the Practice:
State Dam Safety Agencies
29 states use some sort of size classification
Variation exists in definition of dam size:

- Small ranges from 10 to 50 feet high
- Small ranges from 12.5 to 10,000 acre-feet
- Large ranges from 25 to 100 feet high
• 51% have separate criteria for new vs. existing dams

• 14% provide criteria for mine tailings and coal ash dams

• Fish habitat considered in Alaska

• Dam type, stage of construction, and environmental class considered in Missouri
Determining the Spillway Design Flood
Spillway Design Flood Criteria for New and Existing High Hazard Dams

<table>
<thead>
<tr>
<th>Spillway Design Criteria</th>
<th>Number of States Specifying Criteria for New Dams</th>
<th>Number of States Specifying Criteria for Existing Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring a Max Less Than 100% PMF</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Requiring up to 100% PMF</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Requiring Exactly 100% PMF</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>Requiring Incremental Damage Analysis</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No Answer/Other*</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

*Includes 1,000-year event as well as recommendations to use various federal criteria.
SIGNIFICANT HAZARD DAMS

Spillway Design Flood Criteria for New and Existing Significant Hazard Dams

<table>
<thead>
<tr>
<th>Spillway Design Criteria</th>
<th>Number of States Specifying Criteria for New Dams</th>
<th>Number of States Specifying Criteria for Existing Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring a Max up to 50% PMF</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Requiring Exactly 50% PMF</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Requiring Maximum between 50% PMF and 100% PMF</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>No Answer/Other*</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

*Includes 200-year event, 500-year event, 150% 100-year event, 25% PMP, 30% PMP, 40% PMP, and recommendations to use specific federal criteria.
Spillway Design Flood Criteria for New Low Hazard Dams

<table>
<thead>
<tr>
<th>Spillway Design Criteria</th>
<th>Number of States Specifying Criteria for New Dams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requiring Exactly 100-year Event</td>
<td>15</td>
</tr>
<tr>
<td>Requiring up to 100-year Event</td>
<td>2</td>
</tr>
<tr>
<td>Requiring up to 25% PMF</td>
<td>4</td>
</tr>
<tr>
<td>Requiring up to 50% PMF</td>
<td>9</td>
</tr>
<tr>
<td>Requiring up to 75% PMF</td>
<td>2</td>
</tr>
<tr>
<td>Requiring up to 100% PMF</td>
<td>2</td>
</tr>
<tr>
<td>Other*</td>
<td>9</td>
</tr>
<tr>
<td>Not Specified</td>
<td>6</td>
</tr>
</tbody>
</table>

*Includes 25-year event, 50-year event, 200% 100-year Event, 500-year event, 1000-year event, 10% PMP, 35% PMP, and NRCS criteria for low hazard dams.
Inconsistency in dam classification systems

+ 

Inconsistency in spillway design flood selection criteria

= 

Variation in hydrologic safety of dams across the country
Issues:

- Increased runoff and peak flows from upstream development
- “Hazard Creep” from downstream development
Use of Risk Information

31% allow       14% restrict       55% never considered

UNIQUE, RISK-INFORMED SDF CRITERIA
## Risk-based Criteria – Differences

Differences in SDF criteria for High Hazard dams:

- **CA** – Minimum SDF is 1,000-year
- **WA and MT** – Minimum SDF is 500-year

### Percent of Total Hazard Weighting

<table>
<thead>
<tr>
<th></th>
<th>CA</th>
<th>WA</th>
<th>MT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Characteristics of dam</td>
<td>33%</td>
<td>24%</td>
<td>0%</td>
</tr>
<tr>
<td>(capital value, height,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>storage, etc.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential loss of life</td>
<td>33%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>or estimated evacuation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential downstream</td>
<td>33%</td>
<td>26%</td>
<td>0%</td>
</tr>
<tr>
<td>damage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Perception of Risk-based Criteria

51% dam safety officials have concerns about risk analysis

- Time Consuming
- EXPENSIVE
- Unproven
- COMPLEX
- Inconsistent
- Morally Wrong
- Lack of Design Criteria
- Not defensible in a lawsuit
Development of Draft Guidelines

TASKS:

• Publication of FEMA P-919, *Summary of Existing Guidelines for Hydrologic Safety of Dams*

• Publicized efforts and obtained initial feedback thru multiple venues:
  • ASDSO 2011 “Soapbox Session”
  • USSD 2012 Annual Conference
  • ASFPM 2012 National Conference
  • ASDSO 2012 Annual Conference
Development of New Guidelines

**TASKS:**

- Authored draft guidance document
- Review process completed
  - Steering Committee
  - Research Work Group
  - State and Federal Agencies
  - National Dam Safety Review Board
- Final Guidance Document ready for publication by March 2013
What Is New:

- Eliminate size in dam classification system for IDF selection
- No differentiation between new and existing dams
- Eliminate use of percentage of PMF and composite criteria
- Multiple approaches based on level of effort (Investment)
- Spotlight on hazard creep
- Eliminate misuse of “emergency spillway” terminology
- Increased focus on benefits of risk based decision making

<table>
<thead>
<tr>
<th>Hazard Potential Classification</th>
<th>Loss of Human Life</th>
<th>Economic Loss, Environmental Loss, and/or Disruption of Lifeline Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Probable (one or more expected)</td>
<td>Yes (but not necessary for this classification)</td>
</tr>
<tr>
<td>Significant</td>
<td>None expected</td>
<td>Yes</td>
</tr>
<tr>
<td>Low</td>
<td>None expected</td>
<td>Low and generally limited to owner</td>
</tr>
</tbody>
</table>

Recommend discontinuing hazard classification based upon the size of a dam

Important to consider future downstream development
New versus Existing Dams

- Primary goal of IDF guidelines is to ensure public safety.
- Application of less stringent criteria for existing, “grandfathered” dams is discouraged.
Eliminate Use of Percentage of PMF and Composite Criteria

“The problem with such a criterion, based on an arbitrary percentage of a derived flood or an arbitrary combination of floods developed from differing concepts, is that it permits no direct evaluation of the relative degree of safety provided”

- National Research Council’s Committee of Safety Criteria for Dams, 1985
### Spillway Design Flood Criteria for New and Existing Significant Hazard Dams

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<tr>
<td>No Answer/Other*</td>
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</tr>
</tbody>
</table>

*Includes 200-year event, 500-year event, 150% 100-year event, 25% PMP, 30% PMP, 40% PMP, and recommendations to use specific federal criteria.

**SIGNIFICANT HAZARD DAMS**
Eliminate Use of Percentage of PMF and Composite Criteria

“Studies by the NWS indicate that the occurrence of a storm producing PMP is not equally probable nationwide. Thus, using a fraction of the PMF results in selecting a safety design flood which varies widely in exceedance probability... As long as the PMF is used to define a probable upper limit to flooding for use in a safety design, this is not a major concern...When selecting a safety design flood less than the PMF, use of a fraction of the PMF produces a variation in exceedance probability that results in an inconsistent national safety standard”

- ASCE Task Committee on Spillway Design Flood Selection, 1988
### Determining the Inflow Design Flood

#### Spillway Design Requirements Using Simplified Prescriptive Approach

<table>
<thead>
<tr>
<th>Hazard Potential Classification</th>
<th>Definition of Hazard Potential Classification</th>
<th>Minimum Inflow Design Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Probable loss of life due to dam failure or misoperation</td>
<td>PMF(^1)</td>
</tr>
<tr>
<td>Significant</td>
<td>No probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities due to dam failure or misoperation</td>
<td>1,000-year Flood(^2)</td>
</tr>
<tr>
<td>Low</td>
<td>No probable loss of human life and low economic and/or environmental losses due to dam failure or misoperation</td>
<td>100-year flood(^3)</td>
</tr>
</tbody>
</table>

Intentionally conservative requiring minimal analyses ...
Possible IDF Refinements

1. Incremental damage analysis

“The dam owner and designer should recognize that selecting an IDF less than the PMF always carries risk of litigation should the dam fail as a result of a hydrologic failure mode, regardless of whether or not the actual damages were a result of the dam failure.”
Possible IDF Refinements

1. Incremental damage analysis

2. Site-specific PMP study
Determining the Inflow Design Flood

Possible IDF Refinements

1. Incremental damage analysis

2. Site-specific PMP study

3. Risk-informed analysis

Striking a balance between what is theoretically desirable and what is practical based on current technologies and available resources
Hydrologic Design of Dams in the United States

*New Federal Guidelines for Selecting and Accommodating Inflow Design Floods for Dams*

Arthur C. Miller, PhD, PE
AECOM