5 MINUTE BREAK
Hazard Classification and Hazard Creep

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MDE Dam Safety

Hydrology and Hydraulics
What’s in your pond?

- A dam, probably.

- What’s *DOWNSTREAM* of your pond?
COMAR – Dam Definition

- COMAR - 26.17.04.02
  - "Dam" means any obstruction, wall, or embankment, together with its abutments and appurtenant works, if any, in, along, or across any stream, heretofore or hereafter constructed for the purpose of storing or diverting water or for creating a pool upstream of the dam, as determined by the Administration.
Hazard Classification Designations

Based on CONSEQUENCES OF FAILURE, not on condition of dam

- **Low Hazard**
  - No loss of life, little to no economic impact, impact to low volume rural routes

- **Significant Hazard**
  - 1-6 lives in jeopardy (Population at Risk), economic impacts, roadway impacts to main thoroughfares
  - Requires Emergency Action Plan (EAP)

- **High Hazard**
  - Loss of life likely
  - Requires EAP
• Code of Maryland Regulations (COMAR) 26.17.04.03
  – “...A person who proposes to construct, reconstruct, repair, or alter a dam, reservoir, or waterway obstruction, or change in any manner the course, current, or cross section of a stream or body of water within the State except tidal waters, including any changes to the 100-year frequency floodplain of free-flowing streams shall obtain a permit from the Administration before commencing any work.”
Permit Application

- Joint Federal/State Application for the Alteration of any Floodplain, Waterway, Tidal or Nontidal Wetland in Maryland

- [https://mde.maryland.gov/programs/Water/WetlandsandWaterways/PermitsandApplications/Pages/nontidal_permits.aspx](https://mde.maryland.gov/programs/Water/WetlandsandWaterways/PermitsandApplications/Pages/nontidal_permits.aspx)
  
  - No Permit

- Exemption

- Permit

- ALL PERMIT APPLICATIONS MUST INCLUDE A DAM BREACH ANALYSIS, OR ASSESSMENT AND DISCUSSION OF APPROPRIATENESS OF EXISTING DAM BREACH ANALYSIS
Dam Safety Permit Exemptions

• Approval from the appropriate Soil Conservation District (SCD)

• All
  – Drainage Area < 640 Acres,
  – Height < 20 feet, as measured from the upstream toe to the top of dam,
  – Storage Volume < 50 acre feet, as measured to the top of dam,
  – Low Hazard Classification – Most difficult determination

• Note: Exemption from a Dam Safety Waterway Construction Permit does not relieve the applicant from obtaining other necessary State, Federal, or local permits.
Structure Hazard Classification - Documentation of the classification of dams is required. Documentation is to include but is not limited to location and description of dam, configuration of the valley, description of existing development (houses, utilities, highways, railroads, farm or commercial buildings, and other pertinent improvements), potential for future development, and recommended classification. It is also to include results obtained from breach routings, if breach routings are used as part of the classification process. The class ("a", "b", and "c") as contained in this document is related to the potential hazard to life and property that might result from a sudden major breach of the earth embankment. Structure classification and land use for runoff determination must take into consideration the anticipated changes in land use throughout the expected life of the structure. The classification of a dam is the responsibility of the designer, and subject to review and concurrence of the approving authority.

This standard establishes the minimum acceptable quality for the design and construction of ponds if:

1. Failure of the dam will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or interruption of the use or service of public utilities.

\[ Q_{\text{max}} = 3.2 H_{\text{w}}^{2.5} \]

where,

- \( Q_{\text{max}} \) = the peak breach discharge, cfs.
- \( H_{\text{w}} \) = depth of water at the dam at the time of failure, feet. This is measured to the crest of the emergency spillway or to design high water, if no emergency spillway exists. Use "nonstorm" conditions downstream of the dam.

The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point on a profile taken along the centerline of the dam, excluding the cutoff trench. If there is no emergency spillway, the top of the dam becomes the upper limit for determining the storage and the effective height.

2. The product of the storage times the effective height of the dam is less than 3,000. Storage is the volume, in acre-feet, in the reservoir below the elevation of the crest of the emergency spillway.

3. For dams in rural areas, the effective height of the dam (as defined above) is 35 feet or less and the dam is hazard class "a". For dams in urban areas, the effective height of the dam is 20 feet or less and the dam is hazard class "a".

Ponds exceeding any of the above conditions shall be designed and constructed according to the requirements of Technical Release 60.
The classification of a dam is determined only by the potential hazard from failure, not by the criteria. Classification factors in the National Engineering Manual, as supplemented, are given below:

Class “a” - Structures located in rural, agricultural or urban areas dedicated to remain in flood tolerant usage where failure may damage non-inhabited buildings, agricultural land, floodplains or county roads.

Class “b” - Structures located in rural, agricultural, or urban areas where failure may damage isolated homes, main highways or minor railroads or cause interruption of use or service of relatively important public utilities.

Class “c” - Structures located where failure may cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

“Rural areas” is defined as those areas in which residents live on farms, in unincorporated settlements, or in incorporated villages or small towns. It is where agriculture, including woodland activities, and extractive industries, including seafood harvesting, provides the primary employment base for residents and where such enterprises are dependent on local residents for labor.

Non-rural areas shall be classified as urban.

Where breach analysis has indicated that only overtopping of downstream roads will occur, the following guidelines will be used:

<table>
<thead>
<tr>
<th>Class</th>
<th>Depth of Flow (d) ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>“a”</td>
<td>d ≤ 1.5</td>
</tr>
<tr>
<td>“b” &amp; “c”</td>
<td>d &gt; 1.5</td>
</tr>
</tbody>
</table>

Use and importance of the roadway shall be considered when making a classification.
Hazard Creep

- Applicant: “No study needed - it was approved as low hazard in 1970”
  - Wrong – need to evaluate if new study is needed, at the very least

Lesson: Use “Ultimate” development for Danger Reach studies
• Applicant: “No study needed – as the dam hasn’t overtopped in 100 years.”
  – Wrong – design standards have changed, and some dams never see the storm they were designed for (until they do!).
Dam Purpose

• “This doesn’t need a study, because it is primarily a transportation structure.”
Past Guidance – Hazard Classifications for Smaller Ponds and Dams

HAZARD CLASSIFICATIONS
FOR SMALLER PONDS & DAMS

By
Bruce W. Harrington, P.E.
MD Dept. of The Environment
Dam Safety Division

• Applicable to dams:
  – < 15 feet in height
  – < 20 acre-feet of storage
  – < 640 acre drainage area

• Simple “Brim-Up” analysis “may be necessary”

• Use NWS Simple DMBRK Equation for peak Q

HAZARD CLASSIFICATIONS
&
DANGER REACH STUDIES FOR DAMS

By
Bruce W. Harrington, P.E.
MD Dept. of The Environment
Dam Safety Division

• Incremental Flood analysis
  – Sunny Day
  – 100-year
  – Brim Full
  – Half PMF
  – PMF

• Compute Dam Failure Hydrograph using HEC-1 or NWS Dam Break Model (Dams <75 feet tall required to use NWS model).

• Route downstream
The factors that must be considered in order to determine the hazard classification of a dam include, but are not limited to:

- **The population-at-risk (PAR):**
- Depth and velocity of flow against habitable buildings;
- Depth and velocity of flow over roads;
- Depth and velocity of flow in the presence of unprotected persons;
- Isolation of a population from emergency services;
- Damage to critical infrastructure;
- Economic loss; and
- Environmental damage.
Population-at-Risk

- PAR includes those people present in the inundation flood zone at the time of failure, including permanent residents and transient individuals such as recreationists or the traveling public, who, if they took no action to evacuate, may experience an increased hazardous flooding condition due to dam breach based on depth and velocity of the floodwave.

- Hazardous conditions associated with depth and velocity of flow to houses, cars, and unprotected persons are defined by the U.S. Bureau of Reclamation in its document, ACER Technical Memorandum No. 11 (ACER 11) Downstream Hazard Classification Guidelines (USBR, 1988).
• The Department may assign a higher hazard classification based on loss of life rather than PAR.

• The evaluation of loss of life from a dam failure requires a significant amount of judgment, assumptions, and detailed analyses.

• Accordingly, the Department relies on PAR estimates. If it appears readily apparent that one or more lives will be lost from the failure of a dam, the dam is classified as high hazard, regardless of PAR. An example of this condition would be the severe and sudden inundation of a residence immediately downstream of a dam.

• An evaluation of the hazard classification of a dam must include a narrative that justifies the classification. The narrative shall include a discussion of the factors which informed the hazard classification.
Hazard Associated with Flowing Water

- Danger to People
- Danger to Buildings and Homes
- Danger to Traveling Public
Danger to People

Depth-Velocity Flood Danger Relationship for Adults
(Adapted from USBR ACER TM11, "Downstream Hazard Classification Guidelines", 1988)

- **High Danger Zone**: Almost any size adult is in danger from flood water.
- **Judgement Zone**: Danger level is based upon engineering judgement.
- **Low Danger Zone**: Almost any size adult is not seriously threatened by flood water.

**Legend:**
- **BREACH**
- **NO BREACH**

Graph showing depth-velocity relationship with markers for different hazard zones.
Danger to the Traveling Public

Depth-Velocity Flood Danger Relationship for Passenger Vehicles

(Adapted from USBR ACER TM11, "Downstream Hazard Classification Guidelines", 1988)

- **High Danger Zone**: Occupants of almost any size passenger vehicle are in danger from flood water.
- **Judgement Zone**: Danger level is based upon engineering judgement.
- **Low Danger Zone**: Occupants of almost any size passenger vehicle are not seriously threatened by flood water.

**Graph Outlines**
- **BREACH**
- **NO BREACH**

**Axes**
- Depth (feet) vs. Velocity (feet/sec)
Danger to Buildings

Depth-Velocity Flood Danger Relationship for Houses Built on Foundations
(Adapted from USBR ACER TM11, "Downstream Hazard Classification Guidelines", 1988)

Depth-Velocity Flood Danger Relationship for Mobile Homes
(Adapted from USBR ACER TM11, "Downstream Hazard Classification Guidelines", 1988)

- High Danger Zone: Occupants of almost any size mobile home are in danger from flood water.
- Judgement Zone: Danger level is based upon engineering judgement.
- Low Danger Zone: Occupants of almost any size mobile home are not seriously in danger from flood water.
Accepted Methods for Conducting a Dam Breach Analysis

1. Screening Level Analysis
2. Simplified Breach Analysis
3. Standard Breach Analysis
Screening Level Analysis

- Hydraulic Height < 20 feet
- Appropriate when it seems readily apparent that no hazard exists downstream, and thus the dam hazard level is estimated to be “low.”
- Should demonstrate that the lowest point of entry of all inhabitable structures, recreational areas, etc., located between the dam and a downstream major waterway, are at a relative elevation above the adjacent, receiving channel bottom that is equal to or greater than the height of the dam.
- Where a roadway or railroad crosses a stream below the dam before joining another significant waterway (e.g. having a drainage area equal to or greater than that which contributes to the dam), a Screening Level Breach Analysis is not typically acceptable.
Components of a Breach Analysis

1. Determine Breach and Non-Breach Flow

2. Route/Model that flow at ALL relevant locations

3. Analyze the change in downstream impacts between breach and non-breach conditions

4. Determine the Hazard Classification
Simplified Breach Analysis

• Applicability
  – Hydraulic Height < 20 feet
  – Drainage Area < 640 acres
  – Storage Volume < 20 acre-feet
  – Not a dam in series
Simplified Breach Analysis

Brim - Full Analysis
- Determine Discharge from Dam that results from Brim-Full Condition

Stage-Discharge Table
- Hydraulic model - Determine Brim-Full Breach
- Empirical Method - Dam Breach Worksheet for Earthen Dams spreadsheet, available on the Dam Safety Division webpage.
- Parametric Method - HEC-1, HEC-HMS, HEC-RAS, etc. - Model Breach and Non-Breach flow downstream using cross-sections, equations, etc.
- Analyze Results and assign hazard classification

Breach Parameters

<table>
<thead>
<tr>
<th>Height of Dam (ft)</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of water above breach bottom (ft)</td>
<td>15</td>
</tr>
<tr>
<td>Reservoir Storage Volume at Failure (acre-feet)</td>
<td>5</td>
</tr>
<tr>
<td>Reservoir Surface Area at Failure (acres)</td>
<td>1.5</td>
</tr>
<tr>
<td>Discharge through spillways at failure (Qf, cfs)</td>
<td>65</td>
</tr>
</tbody>
</table>

Breach Height (2000)

| Avg. Breach Width (ft) | 24.1 |
| Breach Bottom Width (ft) | 9.5 |
| Time of failure (hrs) | 0.13 |

Breach Height (2055)

| Avg. Breach Width (ft) | 32.4 |
| Breach Bottom Width (ft) | 11.4 |
| Time of failure (hrs) | 0.14 |

Breach Parameters (1984)

| Avg. Breach Width (ft) | 5.5 |
| Breach Bottom Width (ft) | 2.0 |
| Time of failure (hrs) | 0.10 |

MacDonald & Langhigo (1984)

| Avg. Breach Width (ft) | 32.4 |
| Breach Bottom Width (ft) | 11.4 |
| Time of failure (hrs) | 0.25 |

VALUES USED FOR ANALYSIS (To be entered by engineer)

<table>
<thead>
<tr>
<th>Breach Width Factor</th>
<th>C</th>
<th>Qf (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ft]</td>
<td>[fac]</td>
<td>[cfs]</td>
</tr>
<tr>
<td>1.34</td>
<td>22.5</td>
<td>1397</td>
</tr>
<tr>
<td>1.94</td>
<td>30</td>
<td>1573</td>
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<td>2.54</td>
<td>37.5</td>
<td>1807</td>
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<td>3.14</td>
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<td>3.74</td>
<td>52.5</td>
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<tr>
<td>4.34</td>
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<td>3255</td>
</tr>
<tr>
<td>4.94</td>
<td>67.5</td>
<td>3801</td>
</tr>
</tbody>
</table>

Peak Breach Discharge

| Peak Breach Discharge: 3021.0 cfs |

Notes: This procedure is provided for the convenience of dam engineers working in the State of Maryland. All rules should be followed as a guide for the user.
Simplified Breach Analysis – HEC-RAS 2D
Simplified Breach Analysis – HEC-RAS 2D
continued
Standard Breach Analysis

Applicable when:

• A visual reconnaissance indicates that a clear hazard exists

• Screening Level or Simplified Breach Analysis not applicable
  – Dam > 20 feet tall, or
  – Volume > 20 acre-feet, or
  – Drainage Area > 640 acres, or

• Simplified Breach Analysis results led to additional scrutiny
  – Ex. Impacted a house

• Dams in series
Standard Breach Analysis

• Incremental Flood Analysis
  – Sunny Day
  – 100-Year
  – Brim Full
  – ½ PMF
  – PMF

• Conditions
  – Dam-in-place
  – Dam breaches at worst time
  – (No-dam in place is sometimes warranted)
Common Mistakes Continued

• Use single cross section to model flow depth and velocity at all points downstream
  – Wrong

• Need sufficient cross sections to determine depth and velocity at all critical locations

How can we determine depth of flow here with single cross section that is far upstream?
Model Flow Downstream

Need sufficient cross sections to determine depth and velocity at critical locations.
5 MINUTE BREAK