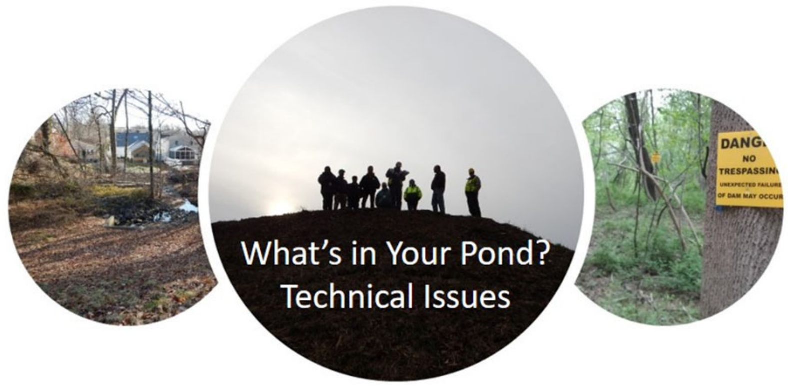


5 MINUTE BREAK

Maryland Department of the Environment

Hazard Classification and Hazard Creep

Scott Bass, P.E.

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

COMAR – Permit Requirement

- 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 <u>shall obtain a permit from the Administration before commencing any work</u>."*

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
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.*

MD Pond Code 378 Dam Breach Guidance

USDA
NATURAL RESOURCES
CONSERVATION SERVICE
MARYLAND

CONSERVATION PRACTICE
STANDARD

POND

CODE 378
(Reported in No.)

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.
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.

   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.
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.

$Q_{max} = 3.2\ H_w^{2.5}$ where,

Q_{max} = the peak breach discharge, cfs.

H_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.

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

Class	Depth of Flow (d) ft.
"a"	$d \leq 1.5$
"b" & "c"	$d > 1.5$

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

MD Pond Code 378 Continued

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:

Class	**Depth of Flow (d) ft.**
“a”	$d \leq 1.5$
“b” & “c”	$d > 1.5$

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

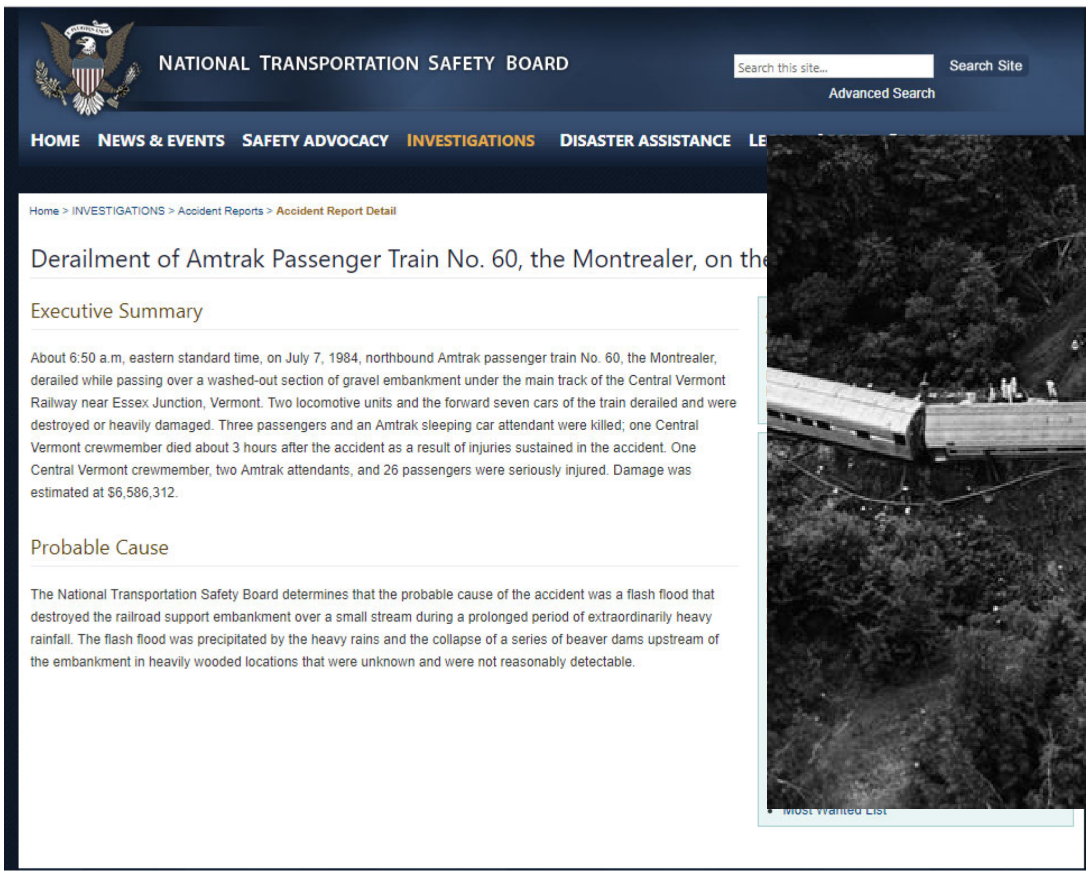
Source: Google Maps

Dam Longevity

- 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."



NATIONAL TRANSPORTATION SAFETY BOARD

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Derailment of Amtrak Passenger Train No. 60, the Montrealer, on the

Executive Summary

About 6:50 a.m, eastern standard time, on July 7, 1984, northbound Amtrak passenger train No. 60, the Montrealer, derailed while passing over a washed-out section of gravel embankment under the main track of the Central Vermont Railway near Essex Junction, Vermont. Two locomotive units and the forward seven cars of the train derailed and were destroyed or heavily damaged. Three passengers and an Amtrak sleeping car attendant were killed; one Central Vermont crewmember died about 3 hours after the accident as a result of injuries sustained in the accident. One Central Vermont crewmember, two Amtrak attendants, and 26 passengers were seriously injured. Damage was estimated at $6,586,312.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was a flash flood that destroyed the railroad support embankment over a small stream during a prolonged period of extraordinarily heavy rainfall. The flash flood was precipitated by the heavy rains and the collapse of a series of beaver dams upstream of the embankment in heavily wooded locations that were unknown and were not reasonably detectable.

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

May 2018 Guidance Document

Guidance for Completing a Dam Breach Analysis for Small Ponds and Dams in Maryland

DRAFT

MARYLAND
DEPARTMENT OF THE ENVIRONMENT
1800 Washington Boulevard, Suite 540
Baltimore MD 21230-1718

May 2018

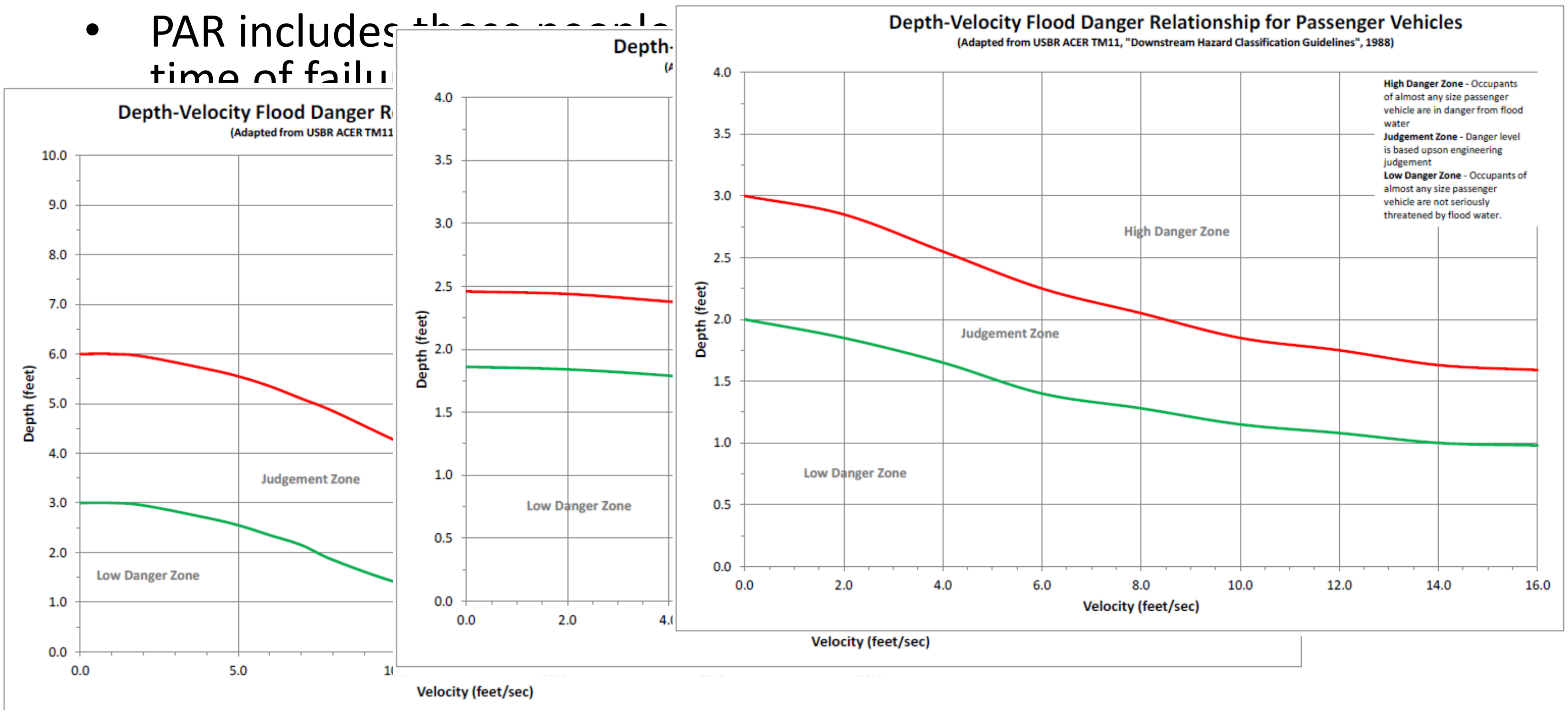
May 2018 Guidance Document
Determining a Hazard due to Dam Breach

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
  time of failu



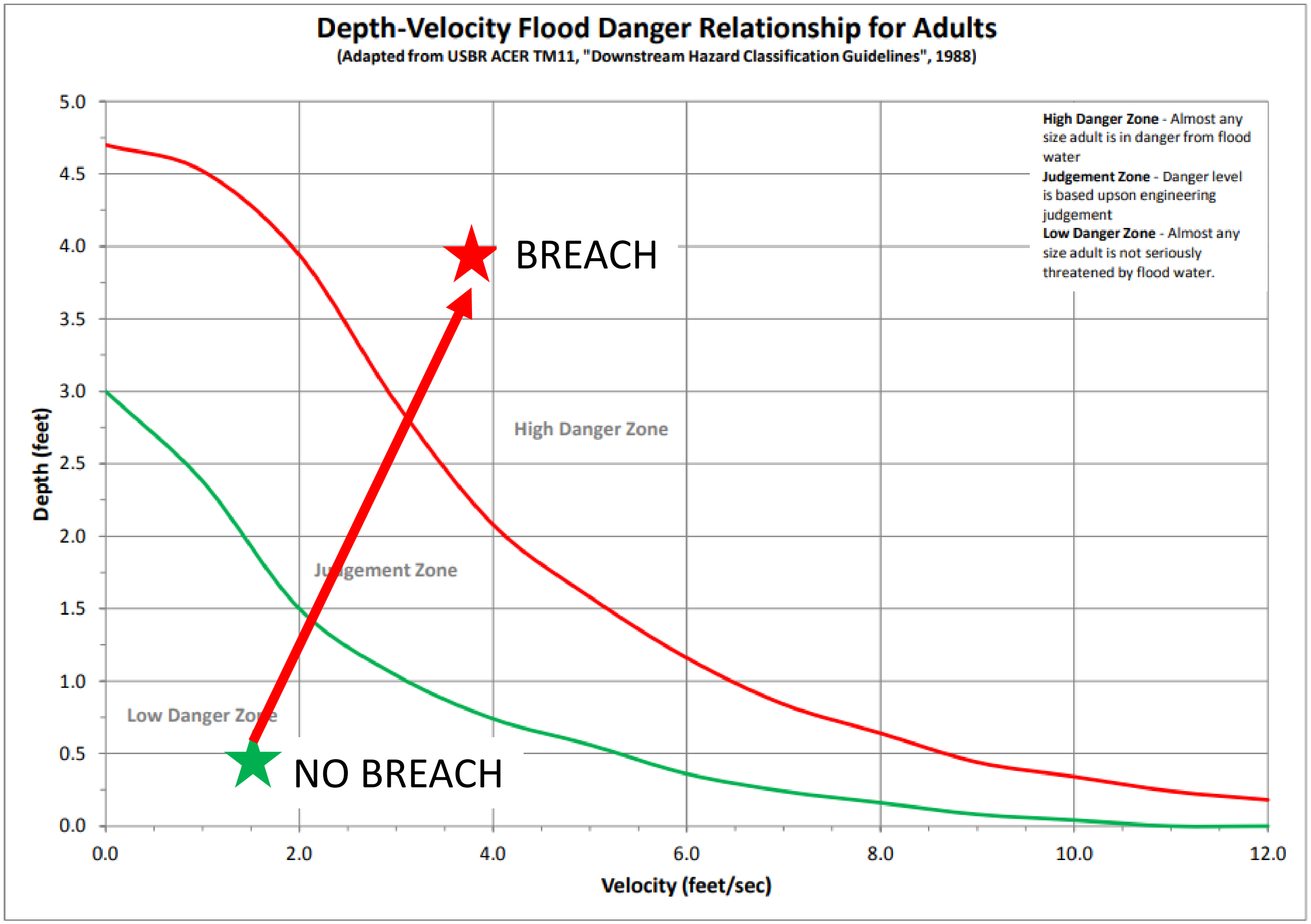
Loss of Life

- 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.

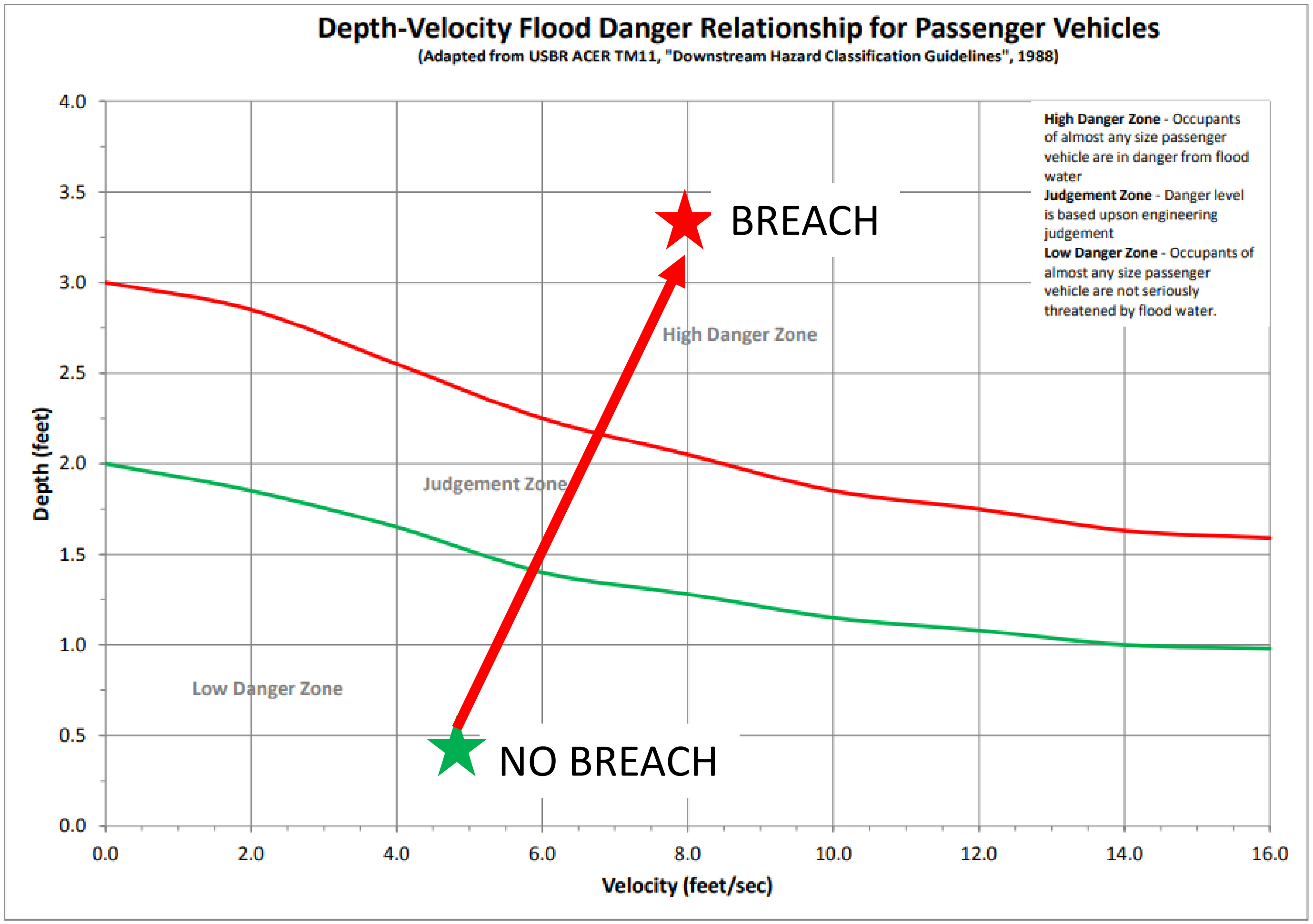
Hazard Associated with Flowing Water

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

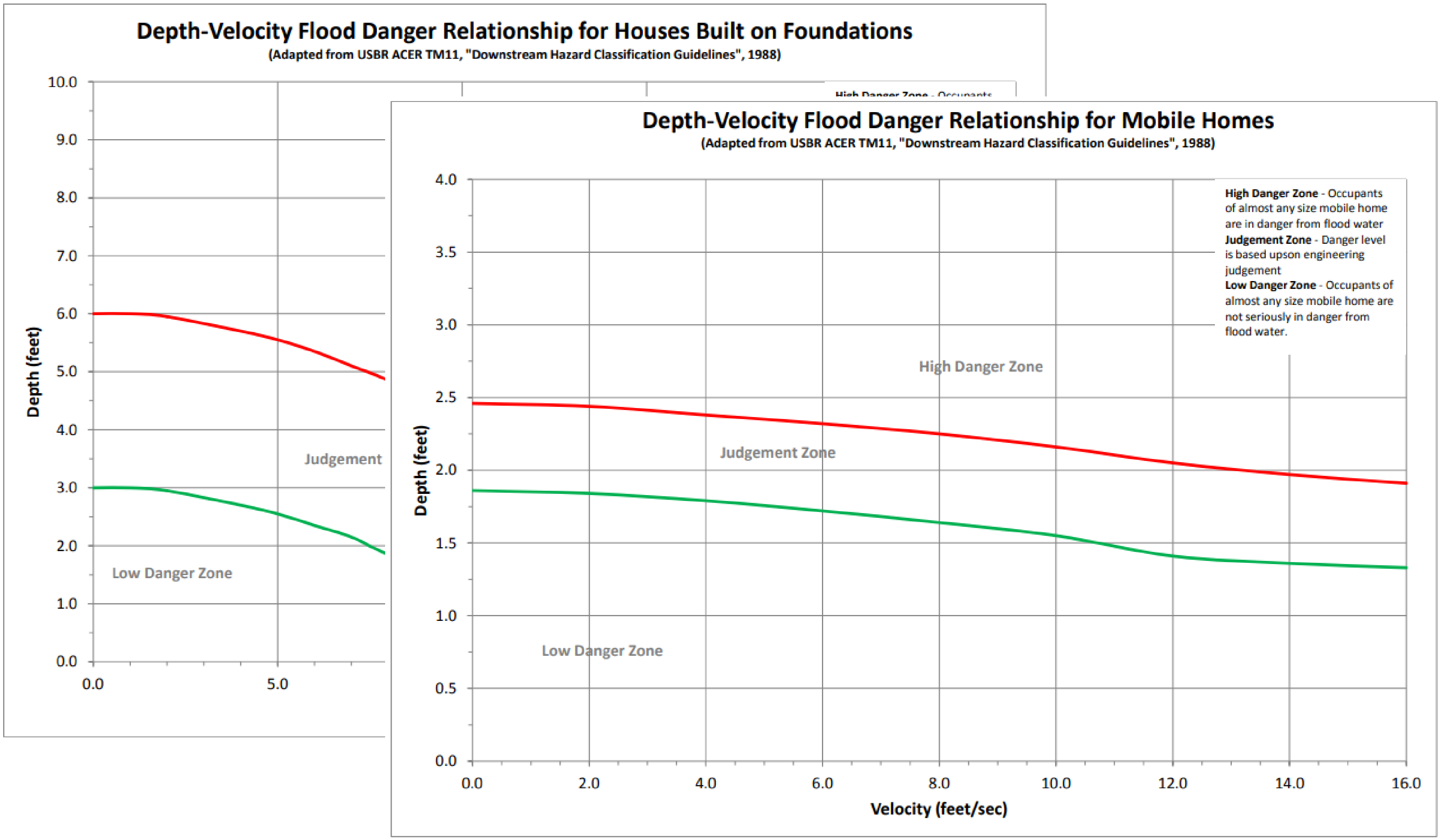
Danger to People



Danger to the Traveling Public



Danger to Buildings



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

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Dam Name:	Beaver Dam	Prepared by:	JTR
Location:	Baltimore, MD	Date:	6/6/1966
Breach Scenario:	Brim Full		

Height of Dam (ft):	15
Breach Bottom Elevation:	0
Height of water above breach bottom (ft):	15
Reservoir Storage Volume at Failure (acre-feet):	9
Reservoir Surface Area at Failure (acres):	1.5
Failure Scenario:	Overtopping
Discharge through spillways at failure (Q_o, cfs):	65

Breach Parameters

Froelich (2008)

Avg. Breach Width (ft):	24.1	Breach Side Slopes:	1.0	H:1V
Breach Bottom Width (ft):	9.1	K_o Factor:	1.3	
Time of failure (hrs):	0.13			

Froelich (1995)

Avg. Breach Width (ft):	32.4	Breach Side Slopes:	1.4	H:1V
Breach Bottom Width (ft):	11.4	K_o Factor:	1.0	
Time of failure (hrs):	0.14			

MacDonald & Langridge-Monopolis (1984) [For Piping Scenario Only when Storage Volume is less than 100 acre-feet]

Avg. Breach Width (ft):	5.5	Breach Side Slopes:	0.5	H:1V
Breach Bottom Width (ft):	-2.0	Upstream Slopes:	2.5	H:1V
Time of failure (hrs):	0.10	Downstream Slopes:	2.0	H:1V
	Storage less than 100 ac-ft	Crest Width (ft):	15	

VALUES USED FOR ANALYSIS (To be Entered by Engineer)

Avg. Breach Width (ft):	32.4	Breach Side Slopes:	1.4	H:1V
Breach Bottom Width (ft):	11.4	(based on on selected values)		
Time of failure (hrs):	0.25			

Check for: Time of Failure too long

Check for: Time of Failure less than recommended minimum value

Notes:

- The average breach width cannot be wider than The width of The stream valley at The particular elevation.
- The check for time of failures are based on minimum reasonable value (based on MDE experience) and the maximum reasonable valuesbased on expected erosion rate (Von Thun & Gillette (1990)).

Note: This spreadsheet is provided for the convenience of the engineering community in the State of Maryland. All results should be verified as accurate by the user.

Maryland Department of the Environment
Dam Safety Division

Dam Breach Worksheet for Earthen Dams
May 2018

Dam Name:	Beaver Dam	Prepared by:	JTR
Location:	Baltimore, MD	Date:	6/6/1966
Breach Scenario:	Brim Full		

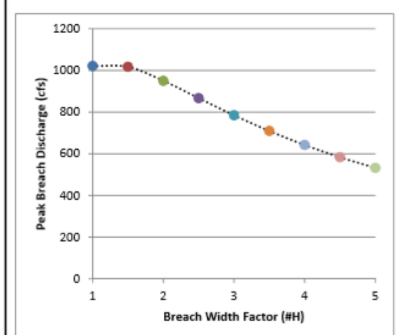
Peak Breach Discharge

National Weather Service Simple Dam Break Equation

Avg. Breach Width (ft) from previous sheet:	32.4
Time of failure (hrs) from previous sheet:	0.25
Height of water above breach bottom (ft):	15
Reservoir Surface Area at Failure (acres):	1.5
Discharge through spillways at failure (Q_o, cfs):	65

$$Q_b = Q_o + 3.1 B_r (C/(T_f + C/\sqrt{H}))^3$$

Q_b = Peak breach discharge plus discharge through spillways (cfs)
Q_o = Discharge through principal and emergency spillways with water surface at failure level
B_r = Avg. Breach Width (ft), typically 1 to 5 times height of dam
A_s = Reservoir Surface Area at with water surface at failure level (acres)
H = Height of water above breach bottom (ft)
T_f = Time to failure (hrs)
C = $23.4 * A_s / B_r$



Breach Width Factor	Breach Width (feet)	C	Q_b (cfs)
[H]	15	2.34	1021
[1.5H]	22.5	1.56	1017
[2H]	30	1.17	950
[2.5H]	37.5	0.94	867
[3H]	45	0.78	785
[3.5H]	52.5	0.67	709
[4.0H]	60	0.59	642
[4.5H]	67.5	0.52	584
[5.0H]	75	0.47	532

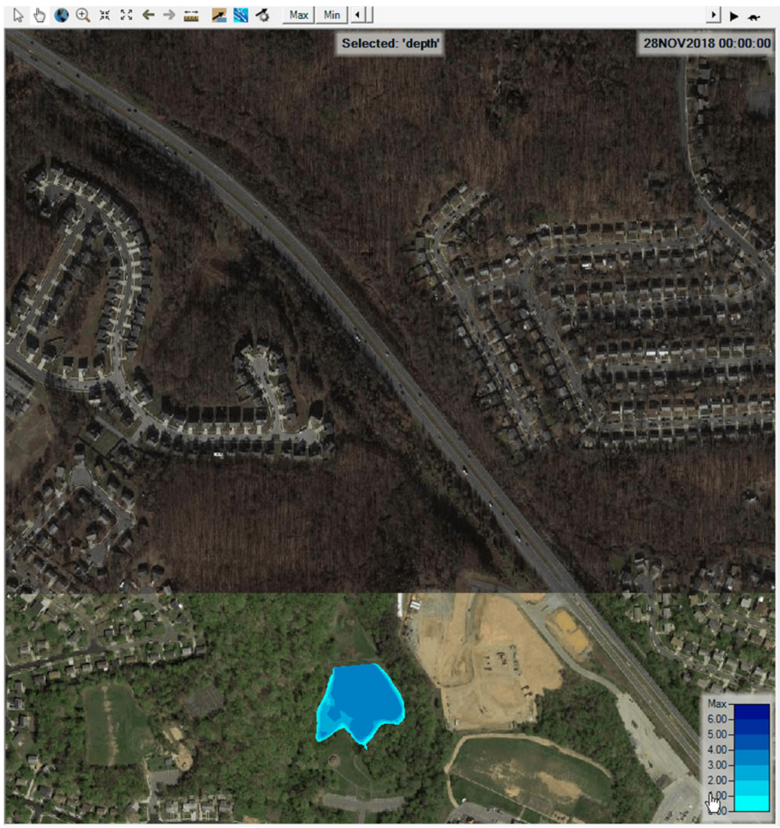
Peak Breach Discharge: 1021.0 cfs

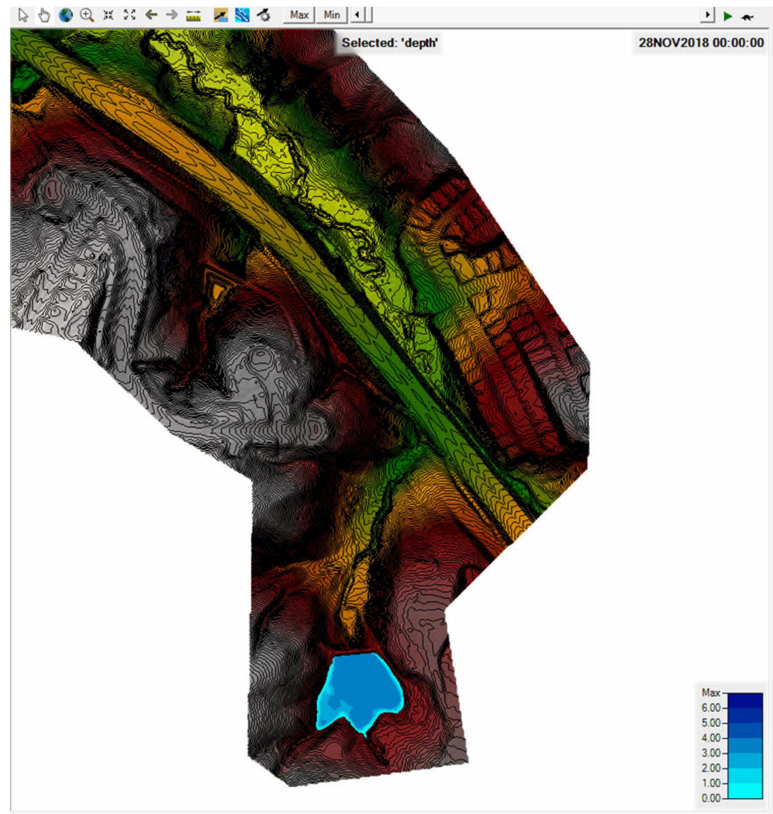
Note: This spreadsheet is provided for the convenience of the engineering community in the State of Maryland. All results should be verified as accurate by the user.

Maryland Department of the Environment
Dam Safety Division

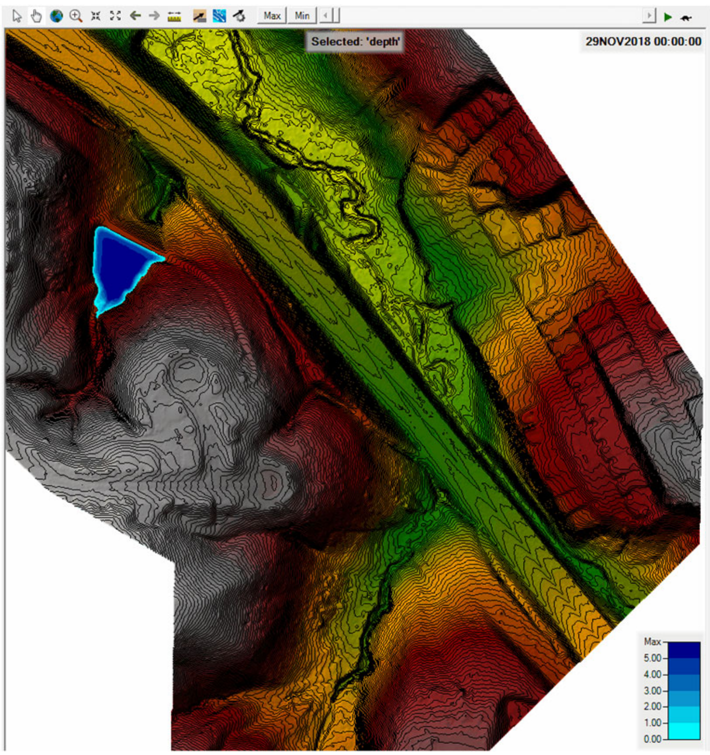
Dam Breach Worksheet for Earthen Dams
May 2018

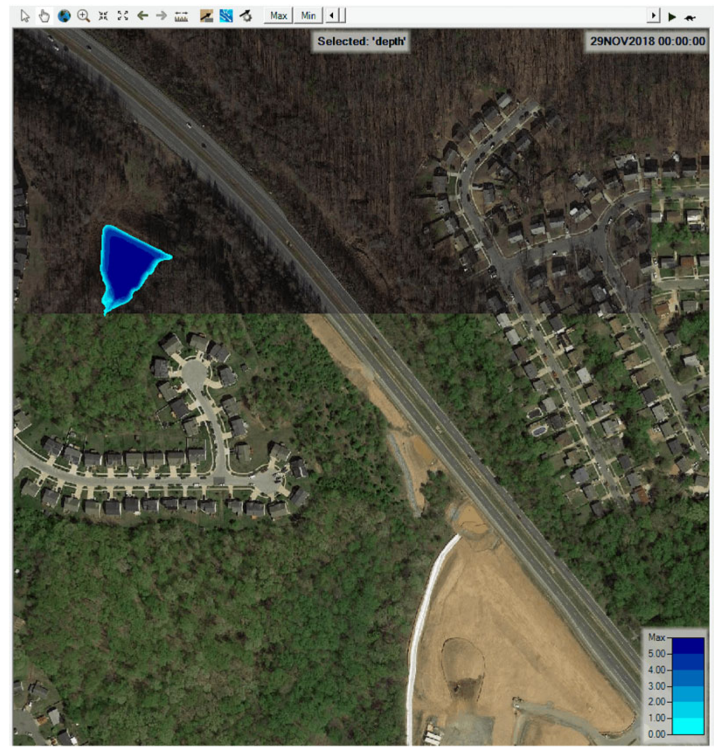
Simplified Breach Analysis – HEC-RAS 2D





Simplified Breach Analysis – HEC-RAS 2D continued





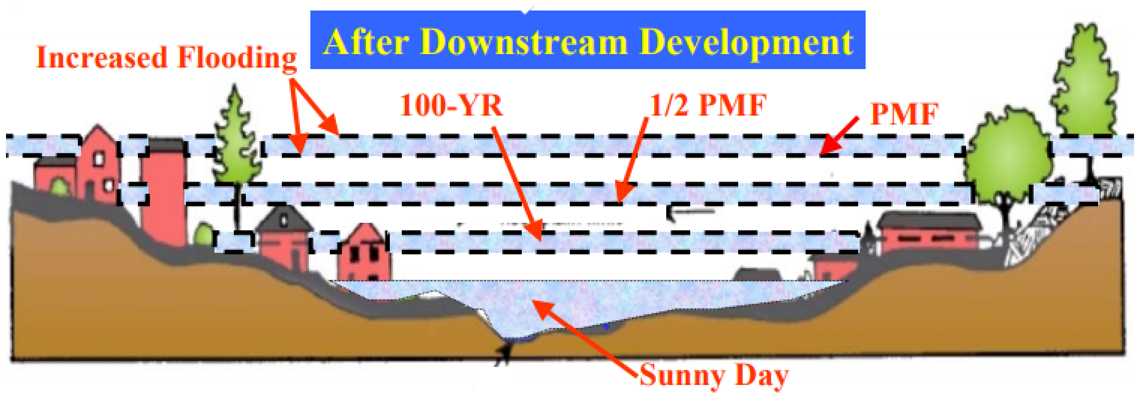
Standard Breach Analysis

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



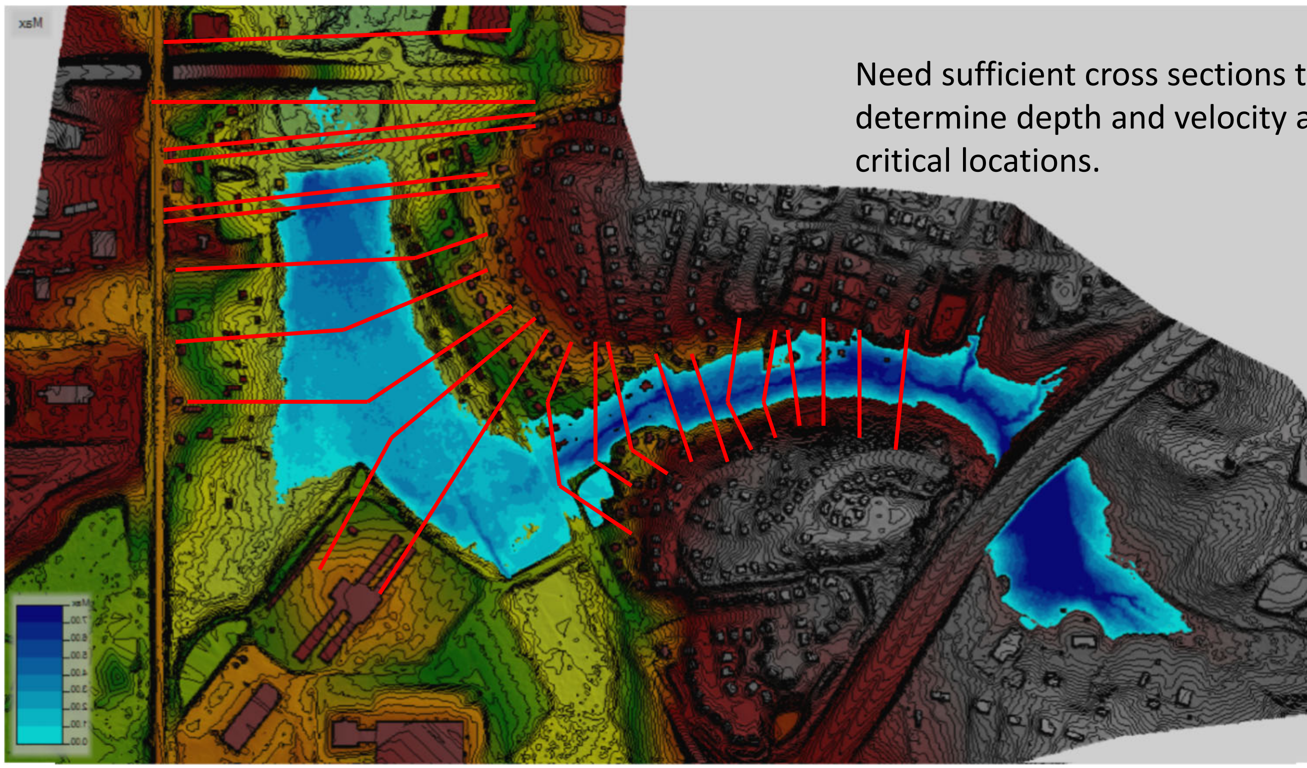
- Conditions
  - Dam-in-place
  - Dam breaches at worst time
  - (No-dam in place is sometimes warranted)

Common Mistakes Continued

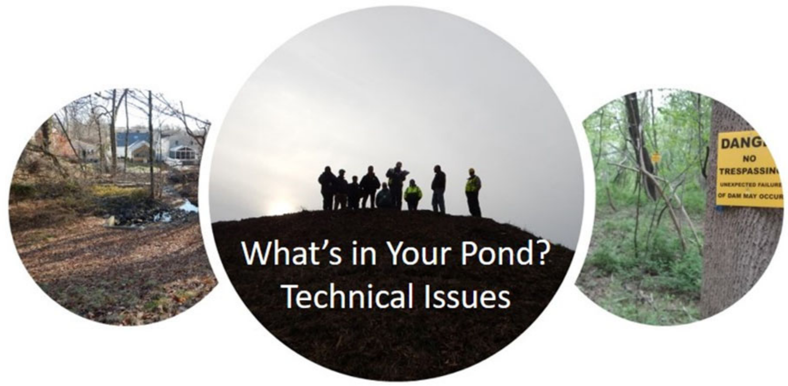
- Use single cross section to model flow depth and velocity at all points downstream
  - Wrong
    - Need sufficient cross sections to determine depth and velocity at all critical locations

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