ICE WaRM
International Centre of Excellence in Water Resources Management

Kleinschmidt

Dam Breach Parameters

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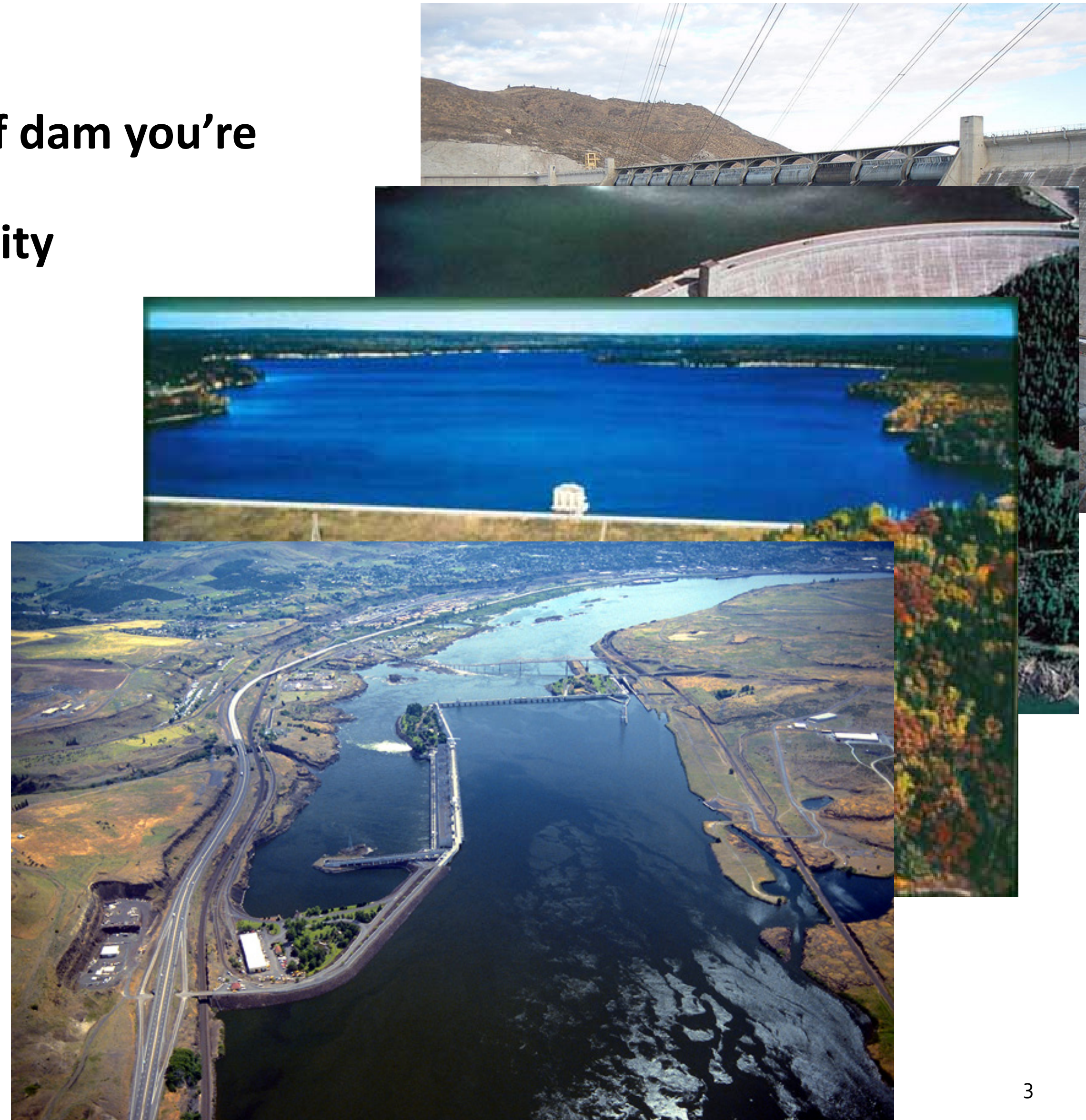
Purpose

- **To develop a breach outflow hydrograph that can be routed downstream to determine flood inundation, flood wave arrival timing, and ultimate consequences.**

- **Options:**
  - Use parametric equations for peak discharge and formation time to approximate a breach hydrograph.
  - Use physically based breach models.
  - Use parametric equations and guidelines for breach width, side slopes, and formation time to develop the breach within a flood routing model.

Types of Dams

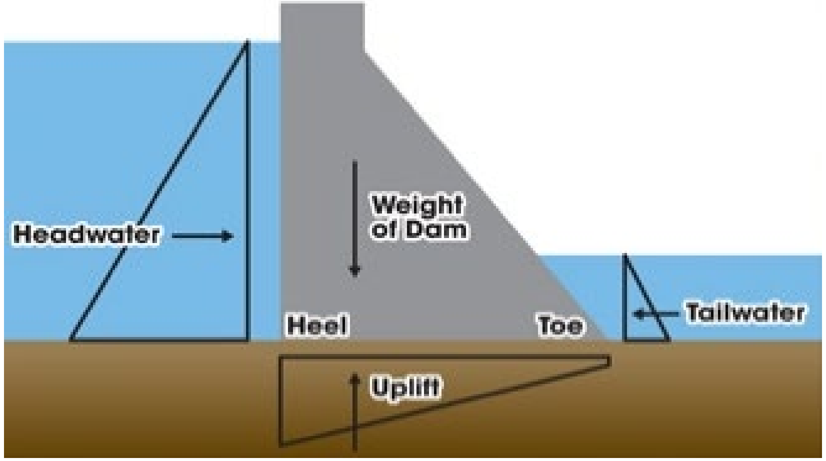
- **Know what kind of dam you're breaching**
  - **Concrete Gravity**
  - **Concrete Arch**
  - **Embankment**
  - **Combination**



Types of Failures

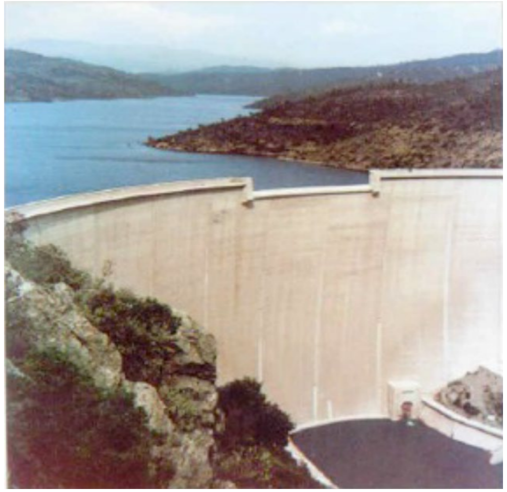
- **Concrete Gravity Dams**
  - **Composed of multiple monoliths**
  - **Foundational failure**
    - **Sliding, shifting, sinking of one or more monoliths**
  - **Extreme overtopping**
    - **Sliding shifting, toppling of one or more monoliths**

Austin Dam (Pennsylvania)



Types of Failures

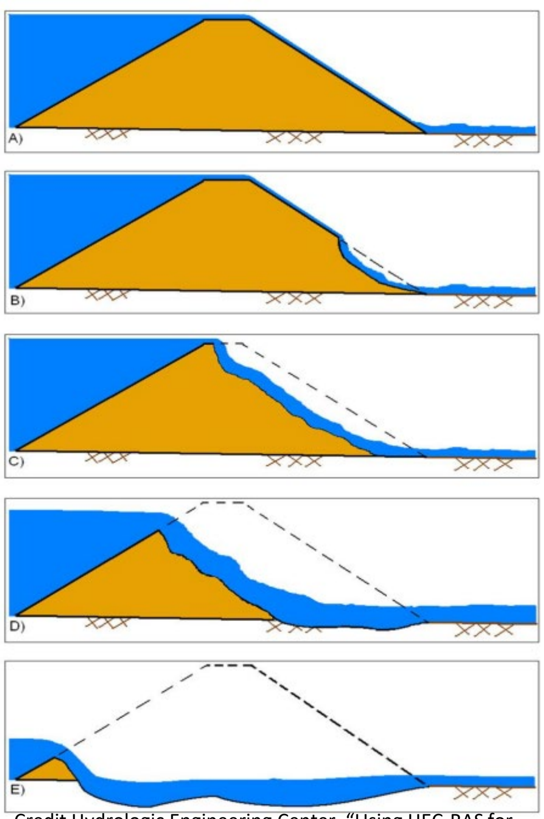
- **Concrete Arch Dams**
  - **Composed of multiple monoliths**
  - **Very thin (relative to gravity dams)**
  - **Arch translates force from impoundment to abutments**
  - **If strength of arch is compromised, breach could include entire dam section.**



Malpasset Dam (France)

Types of Failures

- **Embankment Dams**
  - **Earth or rockfilled**
  - **Erosional Failure**
    - **Overtopping**
    - **Piping**



Credit Hydrologic Engineering Center, “Using HEC-RAS for Dam Break Studies”, August 2014

Breach Development Guidelines

Dam Type	Average Breach Width (B_{ave})	Horizontal Component of Breach Side Slope (H) (H:V)	Failure Time, t_f (hours)	Agency
Earthen/Rockfill	(0.5 to 3.0) x HD	0 to 1.0	0.5 to 4.0	USACE 1980
	(1.0 to 5.0) x HD	0 to 1.0	0.1 to 1.0	FERC
	(2.0 to 5.0) x HD	0 to 1.0 (slightly larger)	0.1 to 1.0	NWS
	(0.5 to 5.0) x HD*	0 to 1.0	0.1 to 4.0*	USACE 2007
Concrete Gravity	Multiple Monoliths	Vertical	0.1 to 0.5	USACE 1980
	Usually ≤ 0.5 L	Vertical	0.1 to 0.3	FERC
	Usually ≤ 0.5 L	Vertical	0.1 to 0.2	NWS
	Multiple Monoliths	Vertical	0.1 to 0.5	USACE 2007
Concrete Arch	Entire Dam	Valley wall slope	≤ 0.1	USACE 1980
	Entire Dam	0 to valley walls	≤ 0.1	FERC
	(0.8 x L) to L	0 to valley walls	≤ 0.1	NWS
	(0.8 x L) to L	0 to valley walls	≤ 0.1	USACE 2007
Slag/Refuse	(0.8 x L) to L	1.0 to 2.0	0.1 to 0.3	FERC
	(0.8 x L) to L		≤ 0.1	NWS

***Note:** Dams that have very large volumes of water, and have long dam crest lengths, will continue to erode for long durations (i.e., as long as a significant amount of water is flowing through the breach), and may therefore have longer breach widths and times than what is shown in Table 3. HD = height of the dam; L = length of the dam crest; FERC - Federal Energy Regulatory Commission; NWS - National Weather Service

Credit Hydrologic Engineering Center, "Using HEC-RAS for Dam Break Studies", August 2014

Parametric Equations

- Embankment Dams
- Need size, shape and formation time of the breach opening
- Several regression equations exist for width, side slope, formation time, and peak discharge
- Resources:
  - Wahl, Tony L., 1998. *Prediction of Embankment Dam Breach Parameters – A Literature Review and Needs Assessment*. Dam Safety Research Report DSO-98-004. U.S. Bureau of Reclamation.
  - Hydrologic Engineering Center, 2014. *Using HEC-RAS for Dam Break Studies*. Technical Document TD-39.

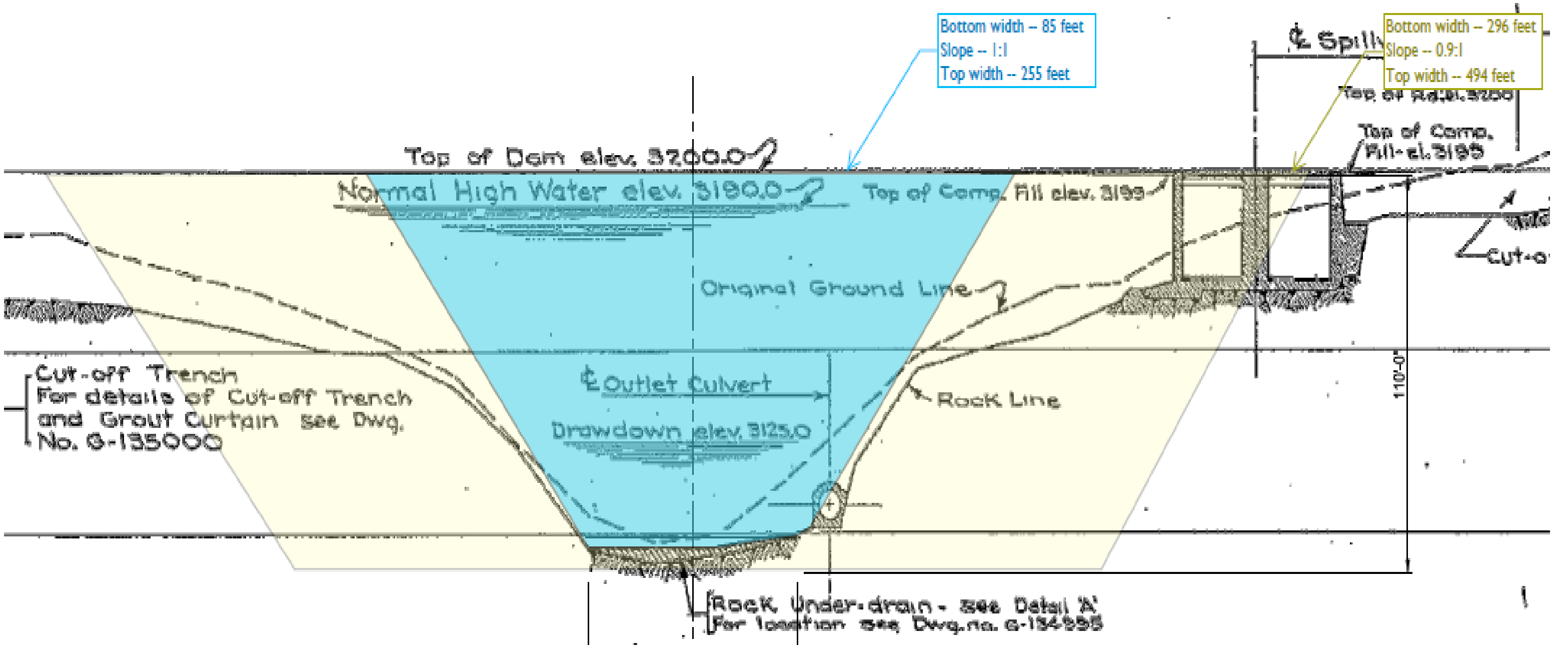
Table 2 - Breach Parameter relations based on dam-failure case studies. For explanations of symbols see the Notation section at the end of this report.

Reference	Number of Case Studies	Relations Proposed (S.I. units, meters, m^3/s, hours)
Johnson and Illes (1976)		$0.5h_d \le B \le 3h_d$ for earthfill dams
Singh and Snorrason (1982, 1984)	20	$2h_d \le B \le h_d$ 0.15 meters $\le d_{ovtop} \le$ 0.61 meters 0.25 hours $\le t_f \le$ 1.0 hours
MacDonald and Langridge-Monopolis (1984)	42	Earthfill dams: $V_{er} = 0.0261(V_{out} * h_w)^{0.769}$ [best-fit] $t_f = 0.0179(V_{er})^{0.364}$ [upper envelope] Non-earthfill dams: $V_{er} = 0.00348(V_{out} * h_w)^{0.852}$ [best-fit]
FERC (1987)		B is normally 2-4 times h_d B can range from 1-5 times h_d Z = 0.25 to 1.0 [engineered, compacted dams] Z = 1 to 2 [non-engineered, slag or refuse dams] t_f = 0.1-1 hours [engineered, compacted earth dams] t_f = 0.1-0.5 hours [non-engineered, poorly compacted]
Froehlich (1987)	43	$\overline{B}^* = 0.47K_o(S^*)^{0.25}$ K_o = 1.4 overtopping; 1.0 otherwise $Z = 0.75K_c(h_w^*)^{1.57}\left(\overline{W}^*\right)^{0.73}$ K_c = 0.6 with corewall; 1.0 without a corewall $t_f^* = 79(S^*)^{0.47}$
Reclamation (1988)		$B = (3)h_w$ $t_f = (0.011)B$
Singh and Scarlatos (1988)	52	Breach geometry and time of failure tendencies B_{top}/B_{bottom} averages 1.29
Von Thun and Gillette (1990)	57	B, Z, t_f guidance (see discussion)
Dewey and Gillette (1993)	57	Breach initiation model; B, Z, t_f guidance
Froehlich (1995b)	63	$\overline{B} = 0.1803\ K_o V_w^{0.32} h_b^{0.19}$ $t_f = 0.00254 V_w^{0.55} h_b^{(-0.90)}$ K_o = 1.4 for overtopping; 1.0 otherwise

Figure 8. Summary of Regression equations for Breach size and Failure Time (Wahl 1998)

Physical Constraints

- Evaluate site-specific conditions that might affect breach development
  - Erosion-resistant foundation, Cutoff walls, adjoining structures

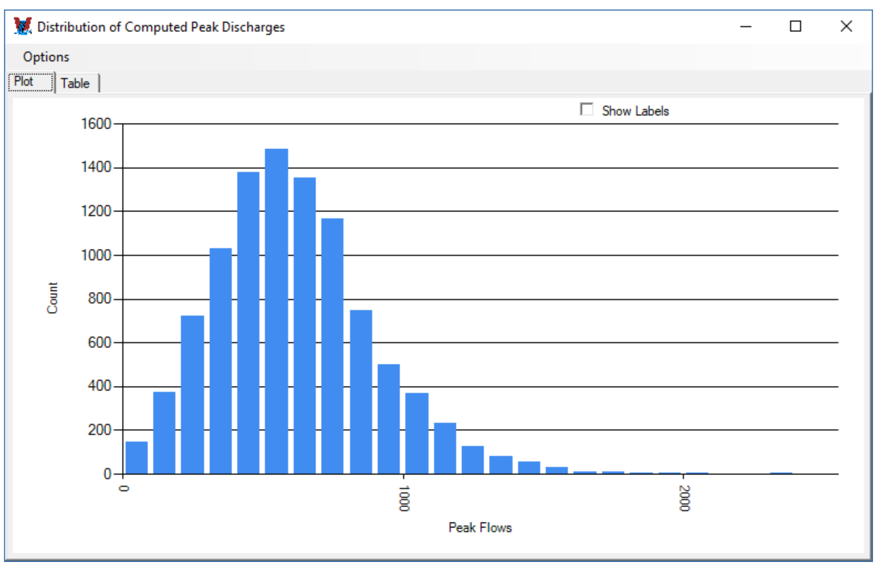


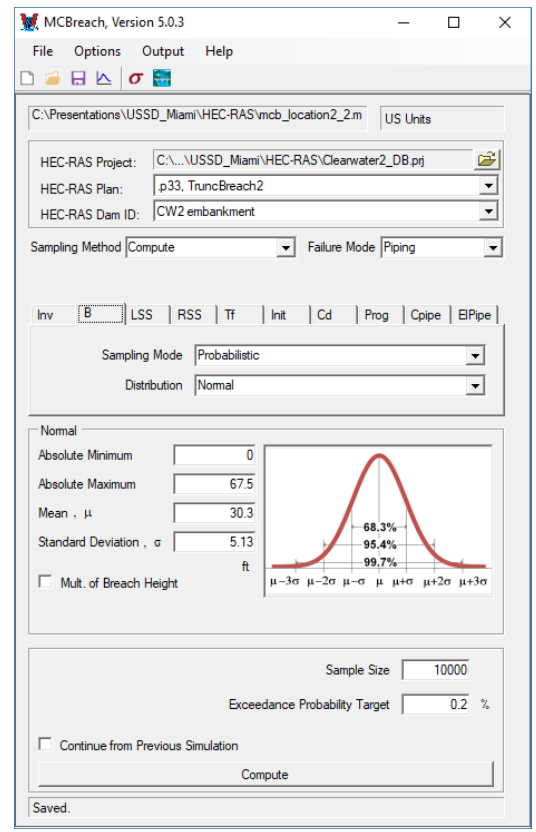
Physically Based Computer Models

- Can produce breach size, shape, and formation time, as well as breach outflow hydrograph
- Examples:
  - NWS-BREACH (BRCH-J)
  - WinDAM
  - HR-BREACH

Probabilistic Approach

- Acknowledge the high degree of uncertainty with breach development prediction
- Use Monte Carlo Method to predict exceedance probabilities of breach outflow hydrographs
- Automation
- McBreach, HR-BREACH





Thank You!

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