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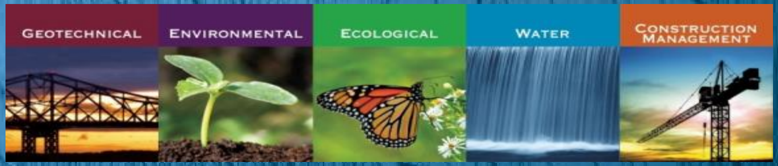

Dams and Dam Failures

Anders Bjarngard, P.E. and Yixing Yuan, Ph.D.

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WEST MICHIGAN CHAPTER
Chartered 1993
Air & Waste Management Association

SBM
STATE BAR OF MICHIGAN
ENVIRONMENTAL LAW SECTION

Air & Waste Management Association
East Michigan Chapter

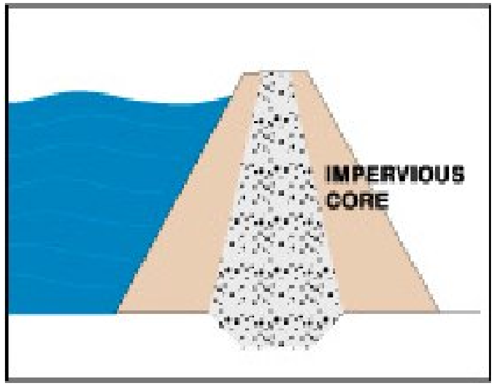
Annual Joint Conference
(Virtual)
November 17, 2020

National Dam Statistics from ASDSO

- The average age of the more than 90,000 dams in the United States is 57 years old
- There are more than 15,000 high-hazard dams in the National Inventory of Dams (17%)
- To rehabilitate the nation's non-federal dams it would cost more than $65 billion and over $20 billion for just the most critical ones
- Over 80% of state-regulated dams have Emergency Action Plans (EAPs)

Types of Dams

- **Earthfill (about 90 percent)**
- Rockfill
- Gravity
- Arch
- Masonry
- Concrete
- Roller-Compacted Concrete
- Timber Crib and Other



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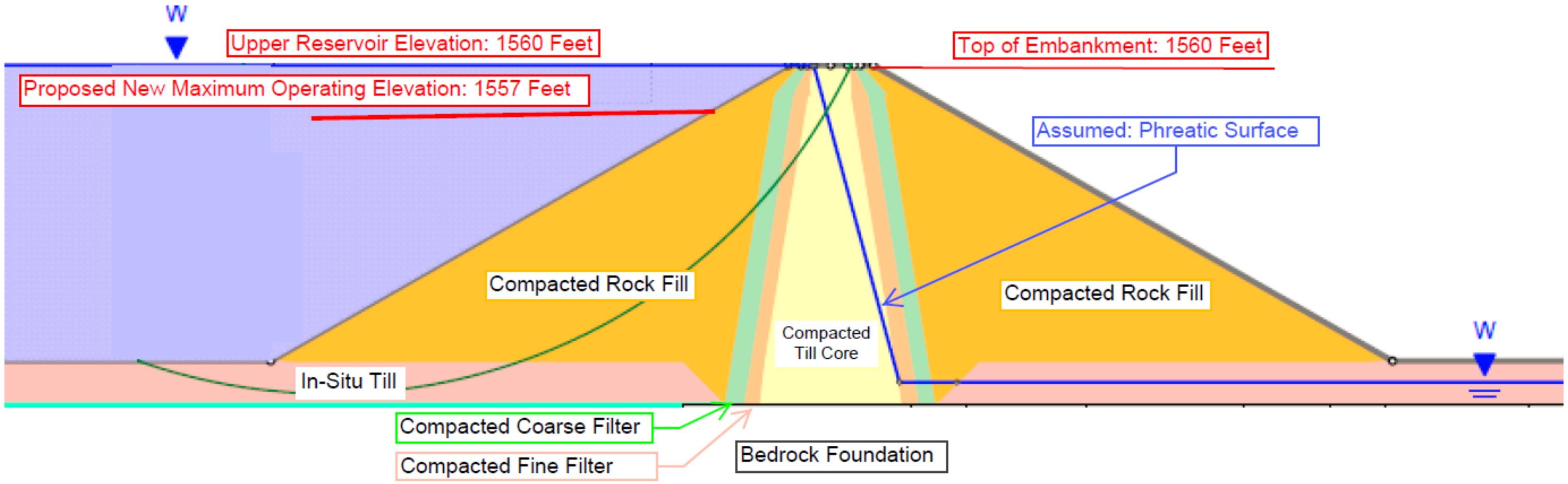

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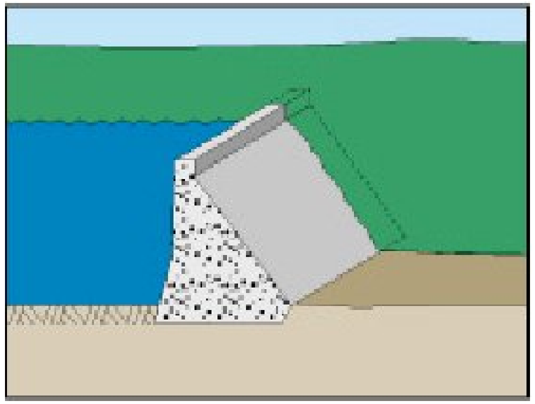

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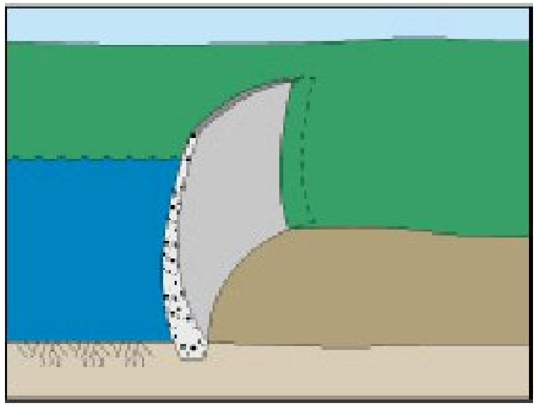
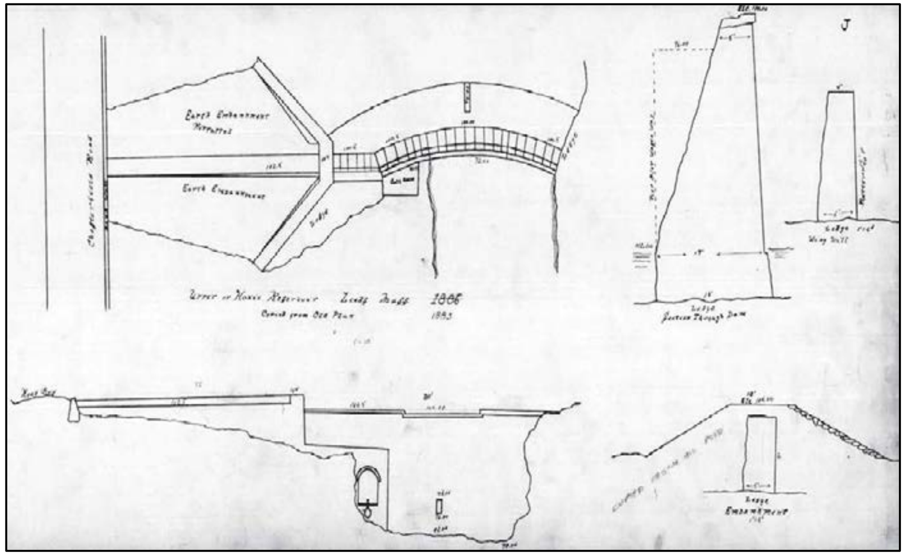


Purposes of Dams

- Power
- Water supply
- Flood Control
- Recreation
- Agriculture (Irrigation)
- Navigation
- Mine Tailings
- Water Source for Canals
- Historic Ice Harvesting

Purposes of Dams

- **No Longer Serving Intended Purpose…Remove it**



- Upper Roberts Meadow Reservoir Dam was constructed in 1883 as a water supply reservoir for City of Northampton
- High Hazard Dam in Poor/Unsafe Condition since 1970's

Dam Removal

- Sluice 10,000cyds of sediment using staged dam removal
- Dormant seeds in sediment typically reestablish quickly

Benefits:

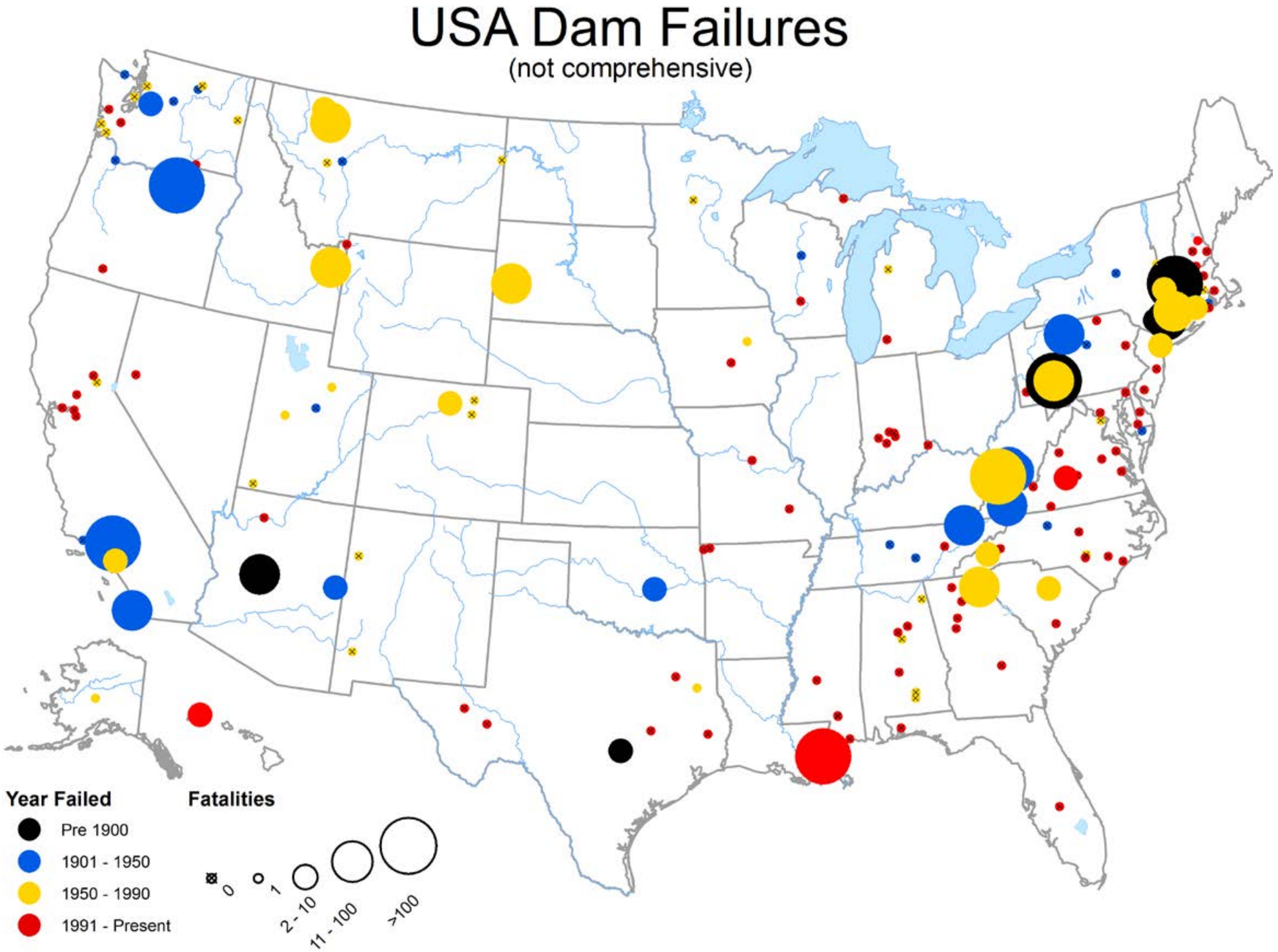
- Eliminated the potential of uncontrolled flood damage resulting from a dam failure
- Removed liability for the rate payers of the City
- Established public access to a previously restricted watershed land
- Restored stream connectivity and trout habitat
- Restored natural movement of sediment

Watch out for:

- Contaminated sediments
- Downstream flooding
- Upstream impacts
- Invasive species

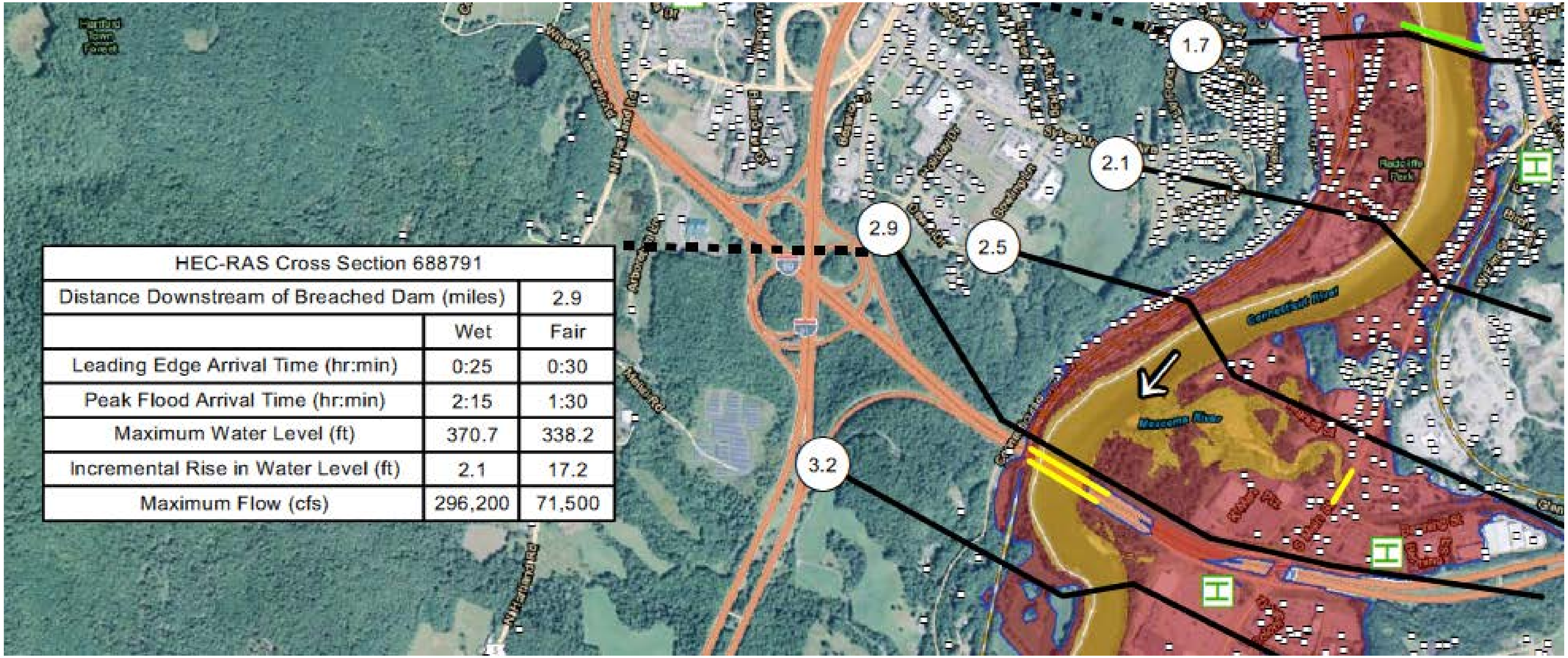
Understanding Dam Failures

(ASDSO)

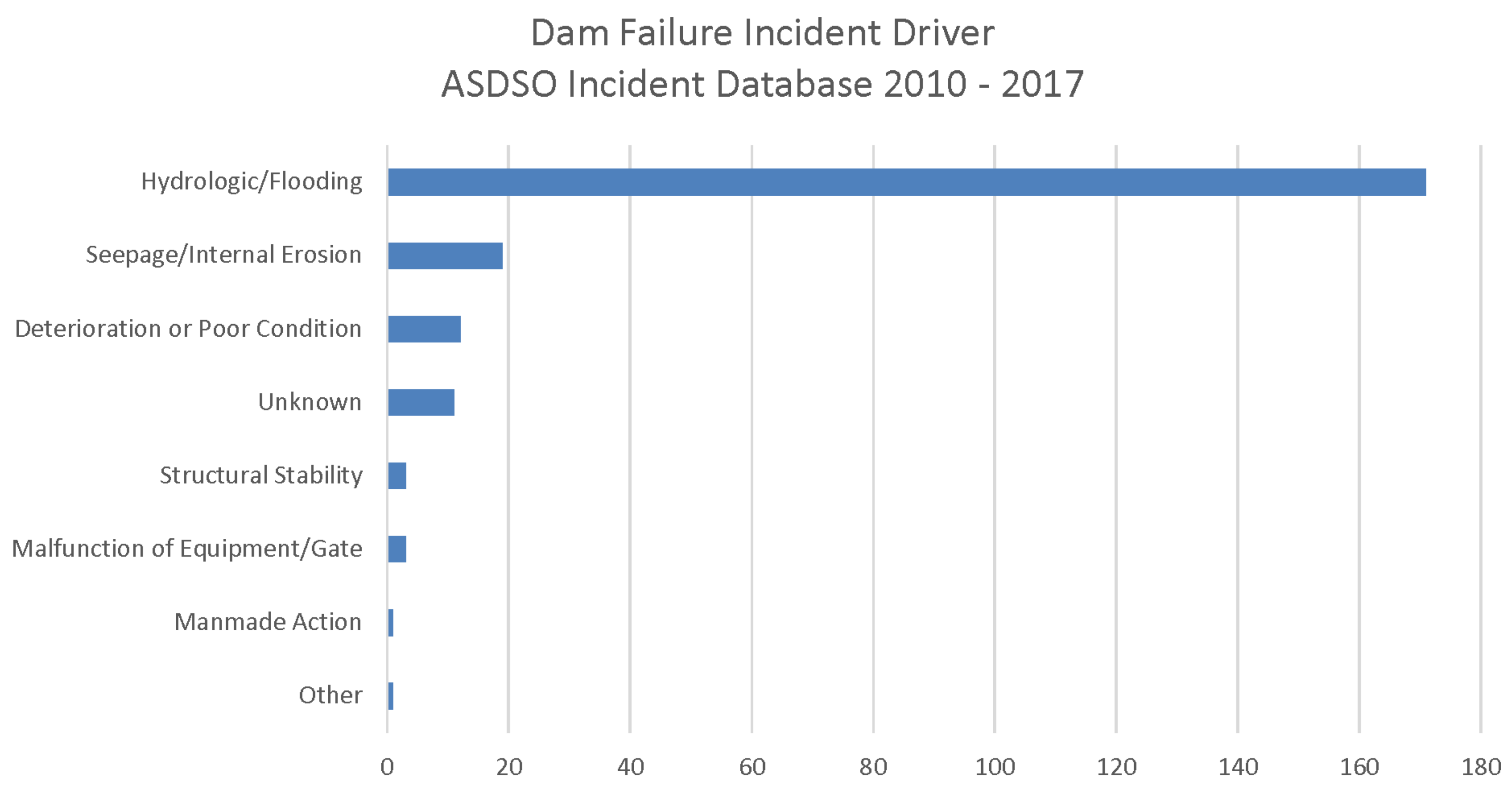


Emergency Action Plans and Inundation Mapping

- Inundation Area (Fair Weather and/or Wet Weather)
- Flooding Information (timing, rise in water level, flow, etc.)



HEC-RAS Cross Section 688791		
Distance Downstream of Breached Dam (miles)		2.9
	Wet	Fair
Leading Edge Arrival Time (hr:min)	0:25	0:30
Peak Flood Arrival Time (hr:min)	2:15	1:30
Maximum Water Level (ft)	370.7	338.2
Incremental Rise in Water Level (ft)	2.1	17.2
Maximum Flow (cfs)	296,200	71,500

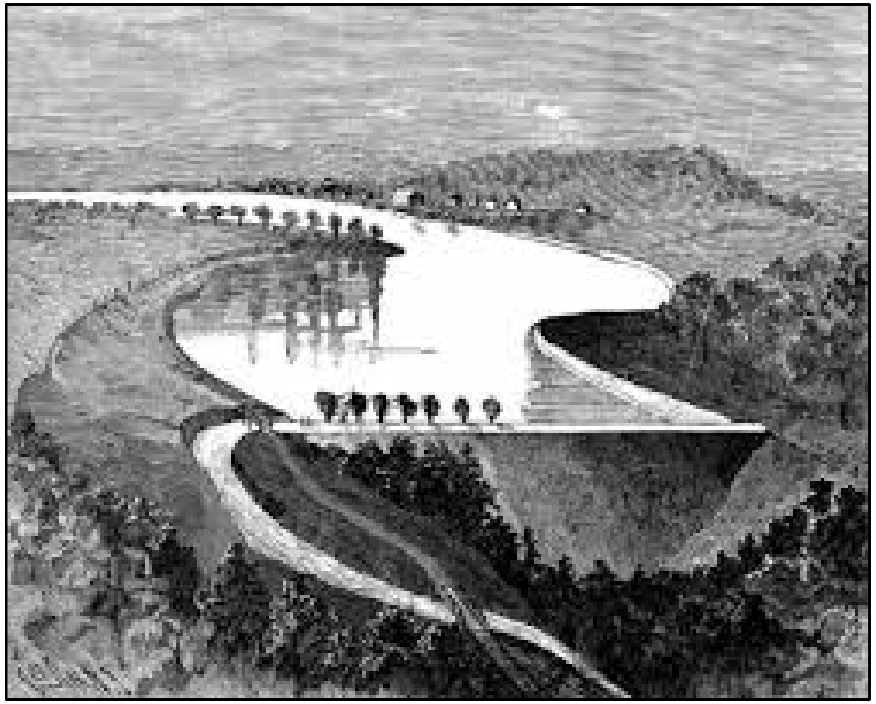


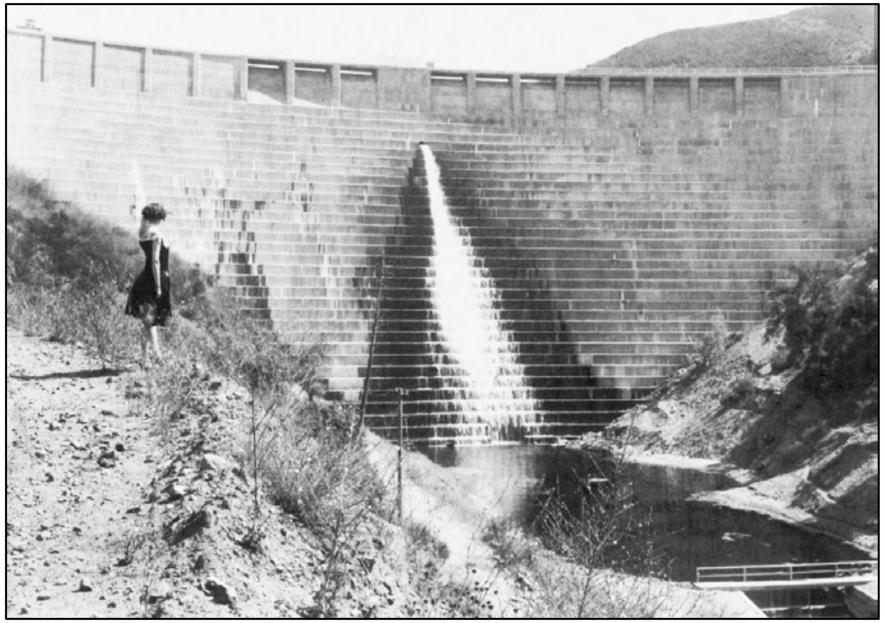
** From the ASDSO Dam Incident Database, dam failure incidents for the years 2010 through 2017. Incident data mostly obtained from the state dam safety programs and/or media reports. The incident data is not inclusive of all dam safety incidents.

South Fork Dam

Johnstown, PA (1889)

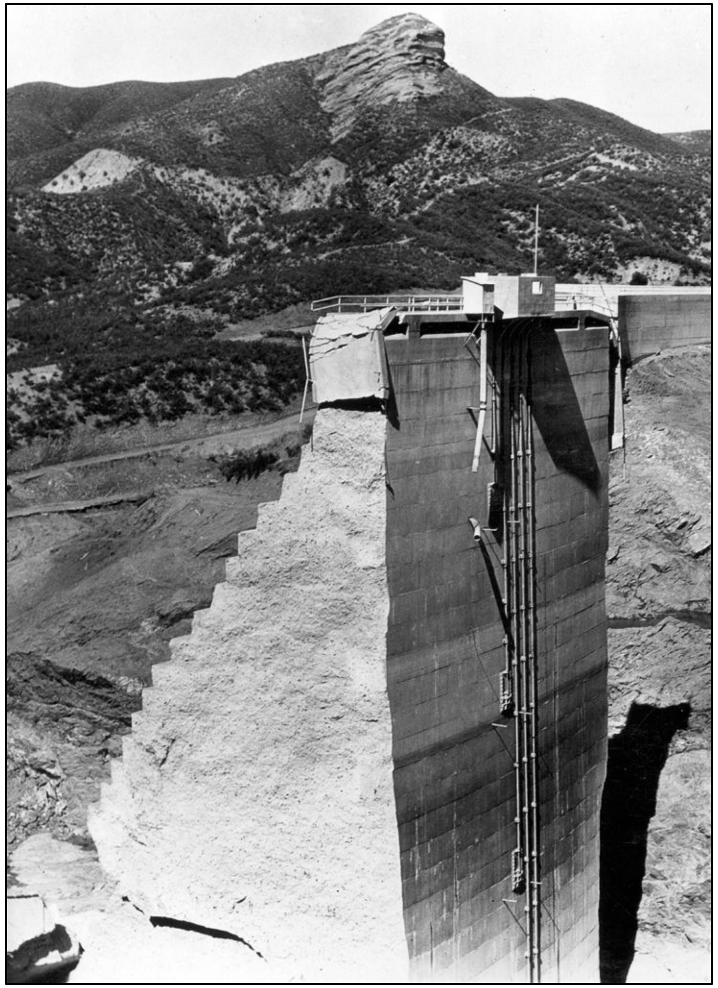
Loss of life 2,200

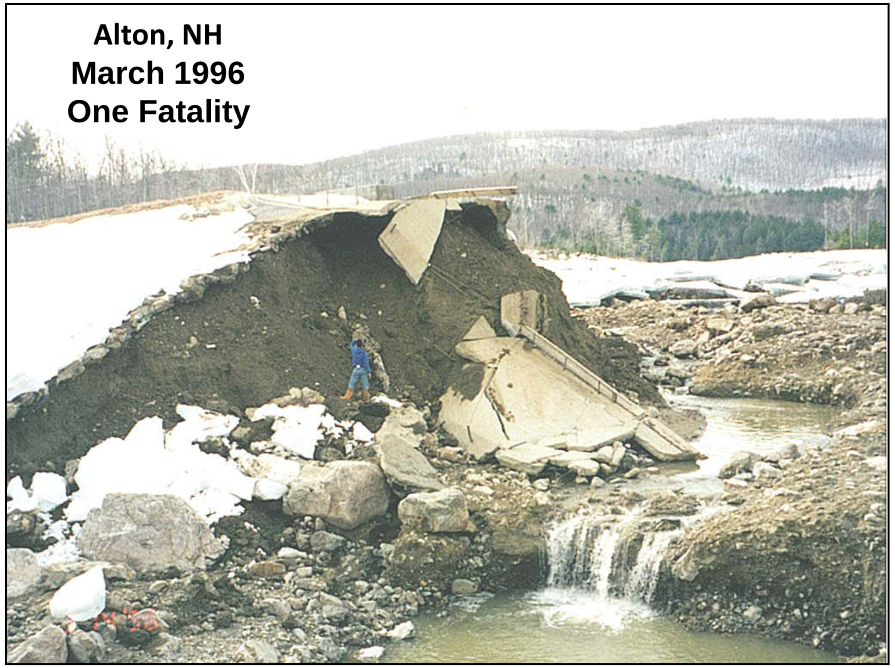




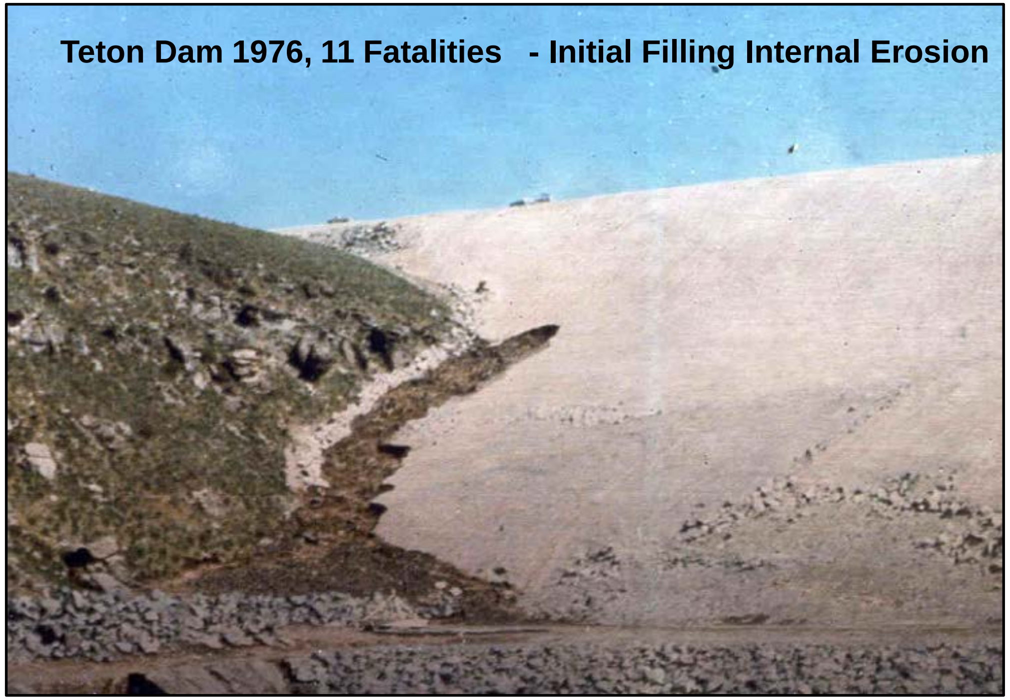
St. Francis Dam, CA (1928)

Loss of life 420





Alton, NH
March 1996
One Fatality



Teton Dam 1976, 11 Fatalities - Initial Filling Internal Erosion

Folsom Dam

1995
Tainter Gate Failure

Taum Sauk

2005

Instruments/Overtopping

Ka Loko

March 2006

Criminal Charges, 7 dead

Oroville Dam – February 2017
Evacuation of 180,000

Wikipedia.org

Edinville Dam

May 2020

American Rivers.org

Junfu Han and Kelly Jordan, Detroit Free Press

Prevention

1. Dam Breach/Removal
2. Operations and Maintenance
3. Improvements to meet changing load conditions and regulatory requirements, particularly increased intensity and frequency of storm events
4. Preparedness with Inundation Mapping and EAPs

OPTIONS FOR INCREASING SPILLWAY CAPACITY

Hydrologic and Hydraulic Analyses to determine

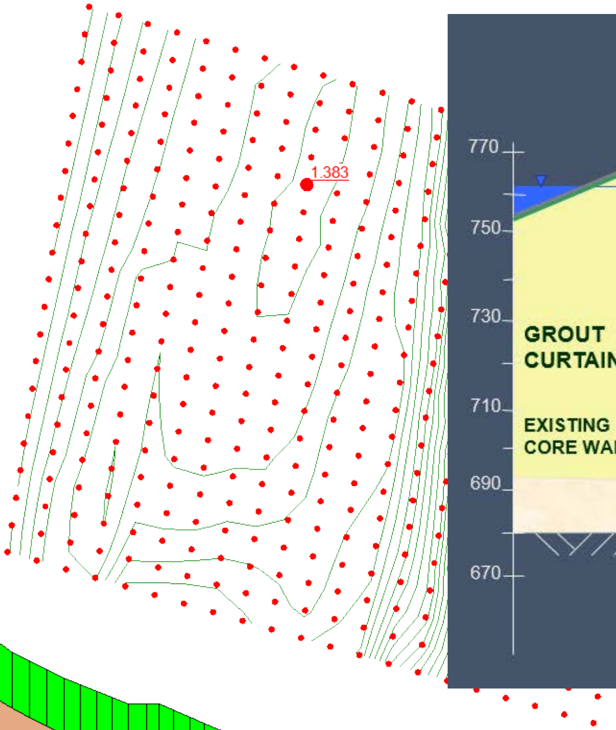
Outflow for design and capacity of structures

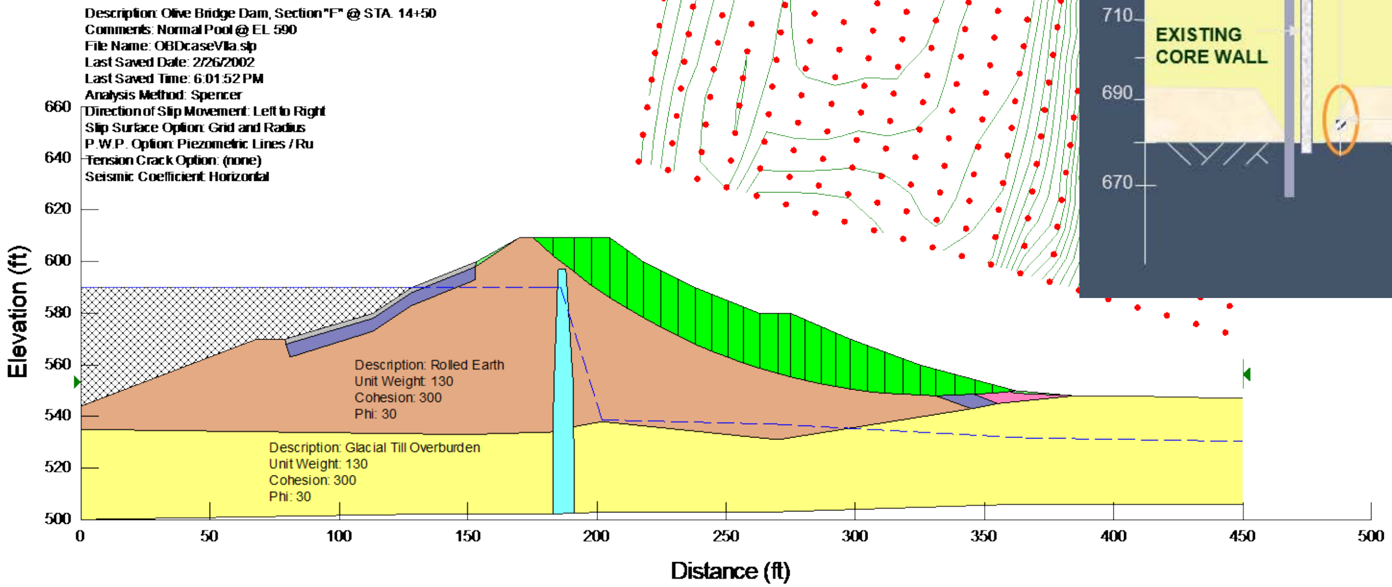
OPTIONS FOR INCREASING SPILLWAY CAPACITY

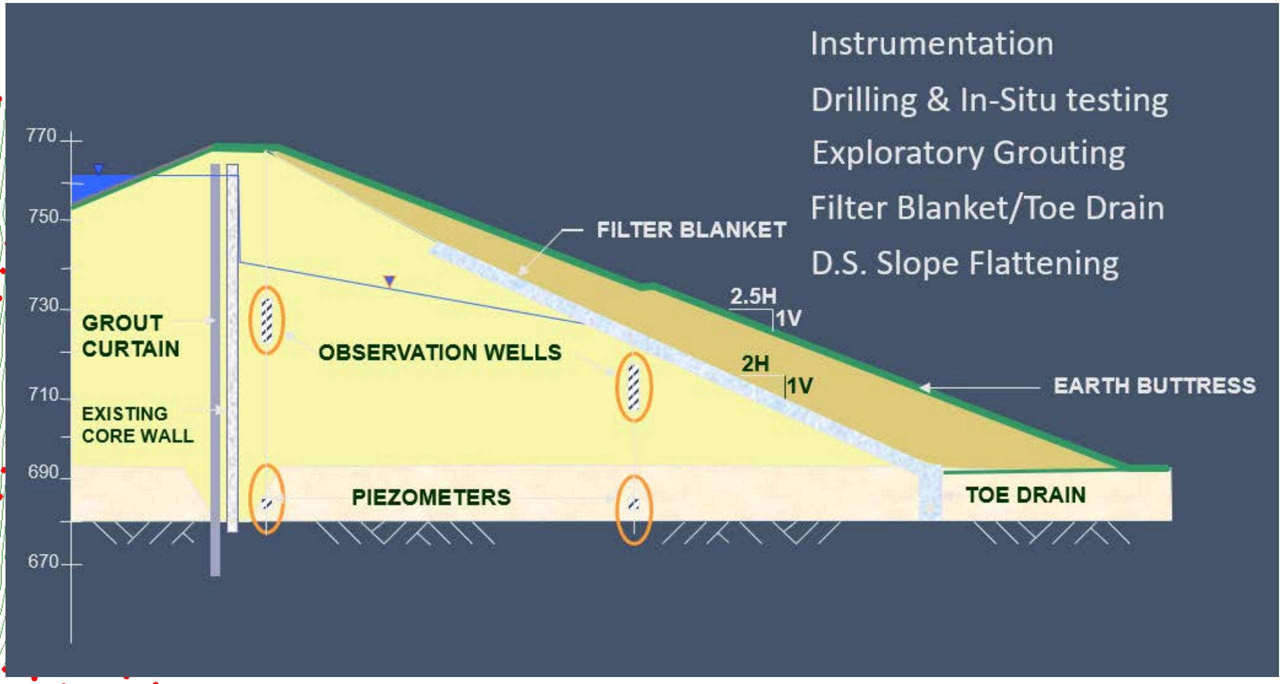
1. Improve or enlarge existing spillway
2. Construct an auxiliary spillway
3. Raise the dam crest/Lower the lake
4. Protect the dam for overtopping
5. Some combination of options

Embankment Dam Seepage and Stability Analyses and Typical Improvements

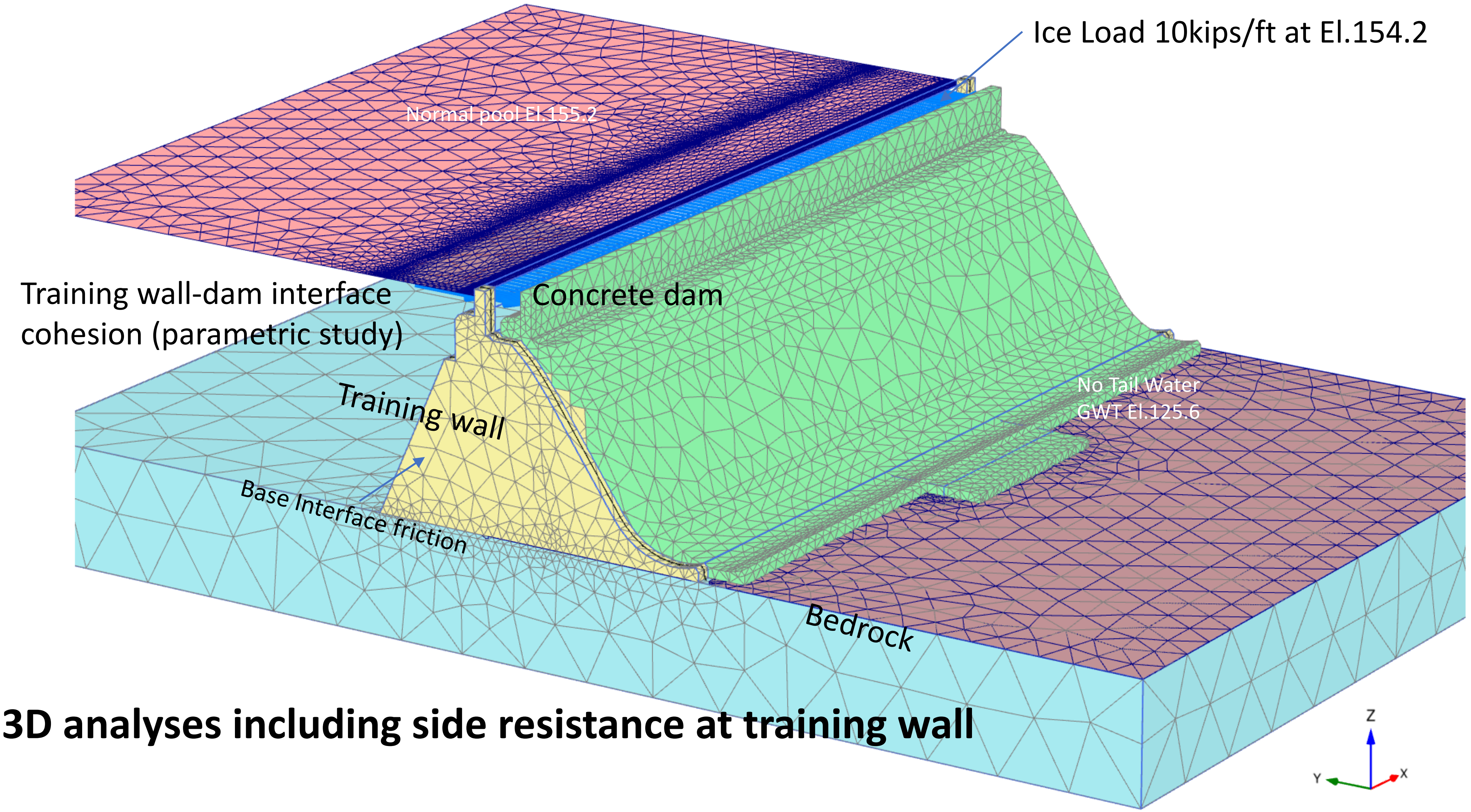
Seismic & Slope Stability Analyses







Gravity Dam Sliding Stability

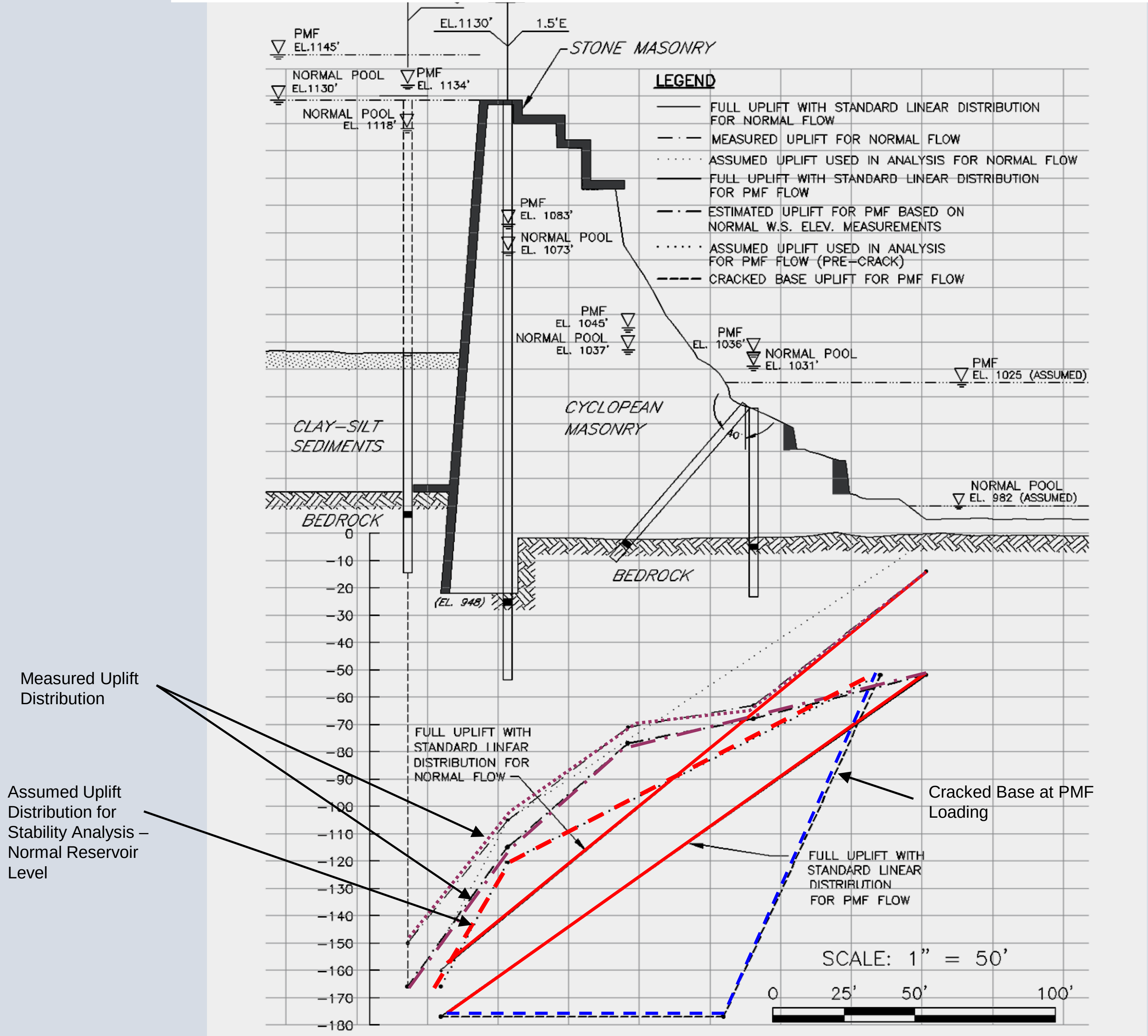


Plaxis 3D analyses including side resistance at training wall

Rock and Concrete Properties

Parameter	Material			
	Cyclopean Concrete	Sandstone Bedrock	Shale Bedrock	Concrete / Bedrock Interface
Unit Weight	143 pcf	163 pcf	167 pcf	
Angle of Internal Friction	45º	37º	24º (res.) 35º (peak)	45º
Cohesion/Shear Str.	450 psi	1,000 psi	70 psi	570 psi
Ult. Compressive Str.	4,500 psi	20,000 psi	10,000 psi	
Tensile Strength	180 psi	200 psi	25 psi	25 psi
Modulus of Elasticity	$2x10^6$	$4x10^6$	$3x10^6$	
Poisson’s Ratio	0.33	0.78	0.11	

Gravity Section Stability Analysis



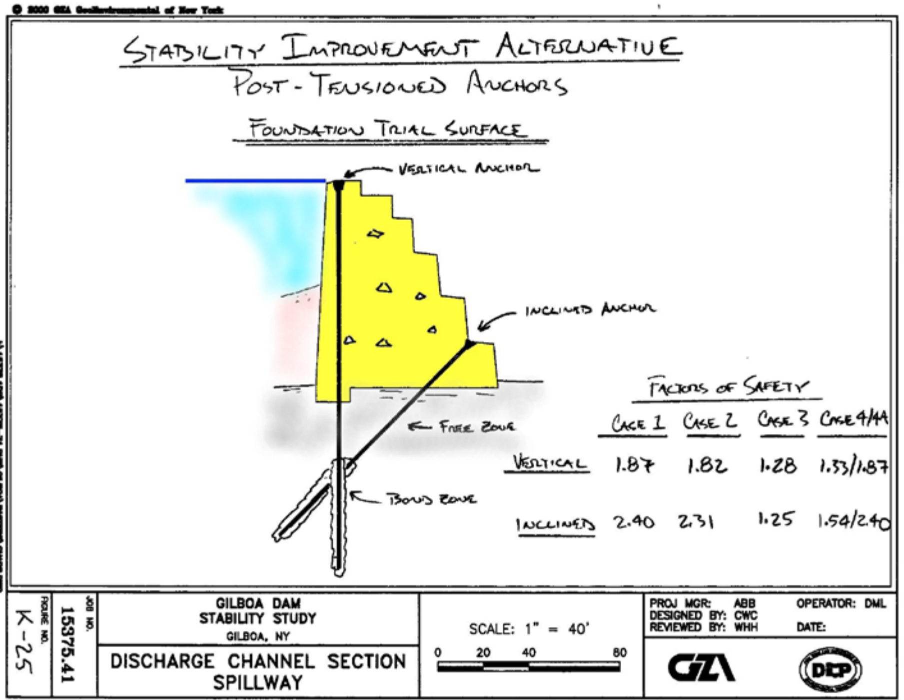
STABILIZATION OF OLD GRAVITY DAMS

Easy Fix -Mass Concrete Buttress!

- Designed to meet stability requirement
- Protects dam during an overtopping event

Other Methods

- Anchors
- Lower Pool

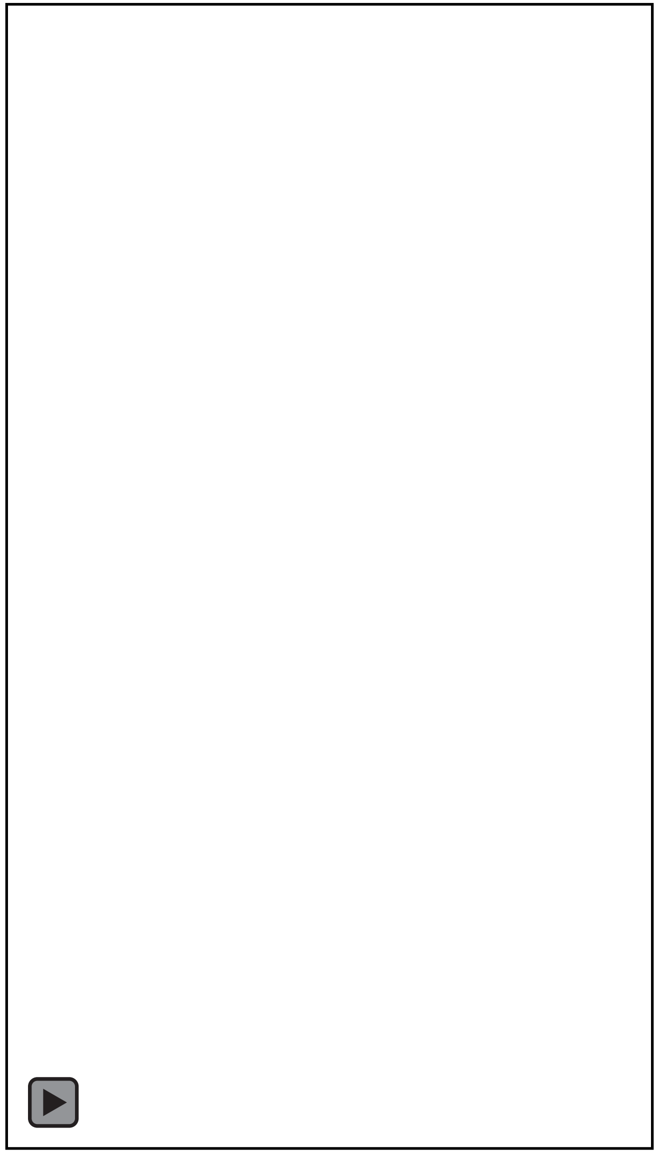


Computer Vision Analyses of Edenville Dam Failure Video

On May 19, 2020, due to the heavy rainfall in the areas near Midland, Michigan, the Edenville dam located on the confluence of the Tittabawassee River and Tobacco River failed

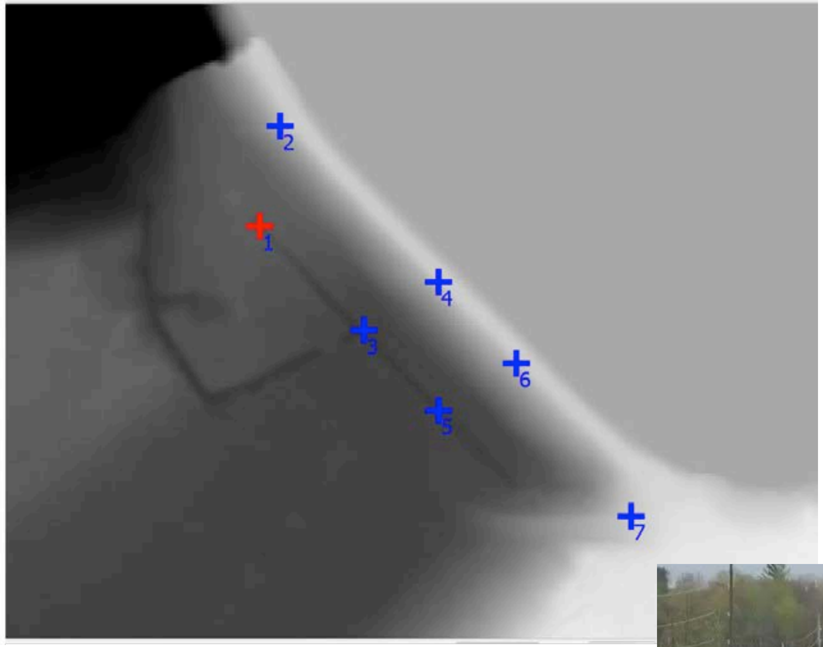
A local resident happened to witness this event from the left (eastern) end of the embankment and published a smartphone video on social media (Coleman, 2020)

We volunteered to conduct an independent research in collaboration with Rutgers University (Prof. Ruo-qian Wang) by using innovative computer vision technique to extract quantitative data from this online footage



(Courtesy of Lynn Coleman, 2020)

Correlate image pixels with “real-world” dimension using 3D remote sensing DEM data



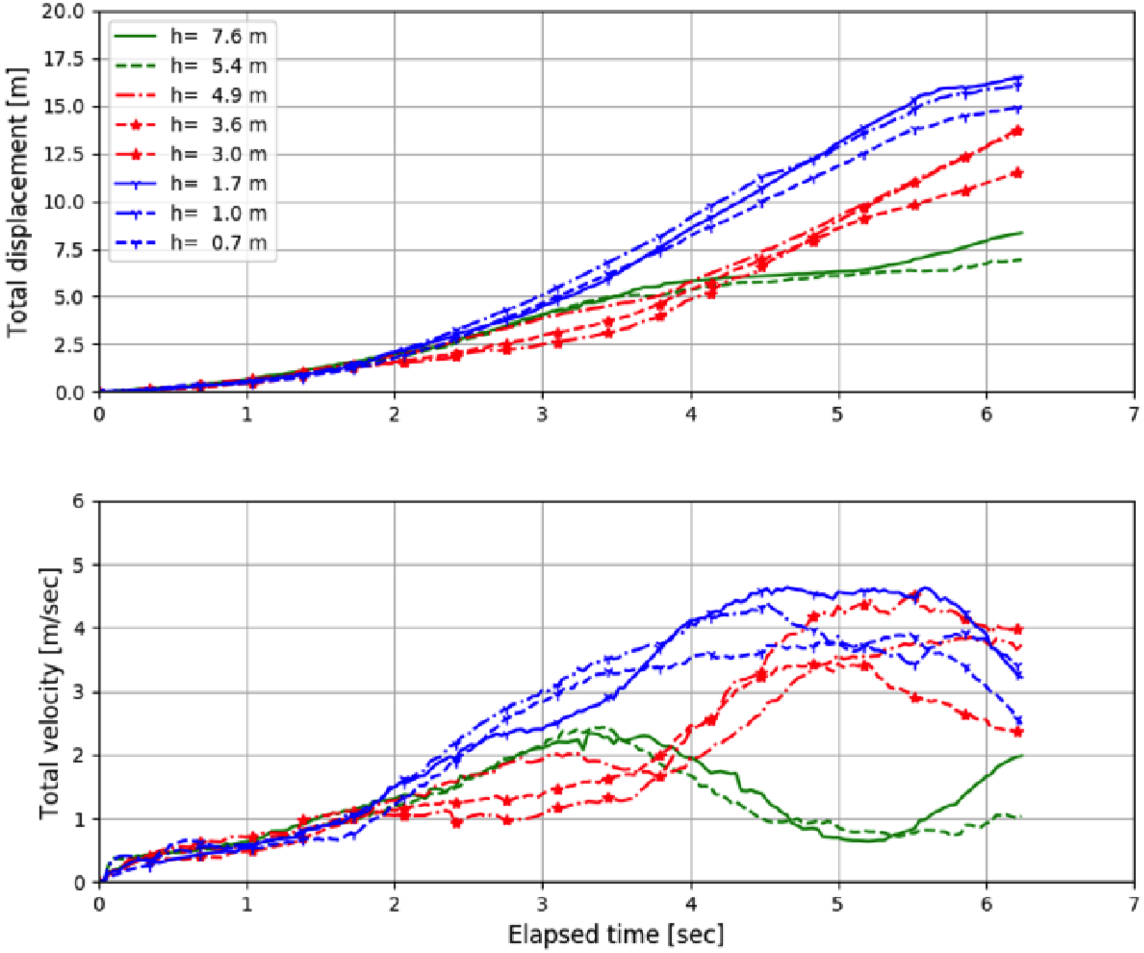
Now we can “read” dam height and length

Using optical flow technique to track dam failure motion

Placing a series of pixel tracker on the slope near failure sections, their trajectories highlight dam sliding mechanism

Data extraction and physical attributes analyses

Dam failure undergoes acceleration and deceleration process with max sliding velocity up to 5m/sec (11mph)



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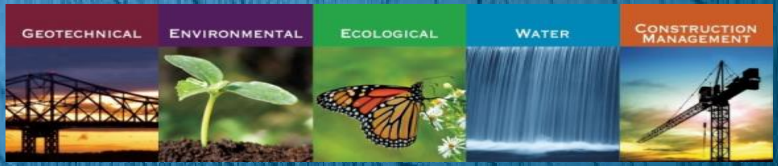
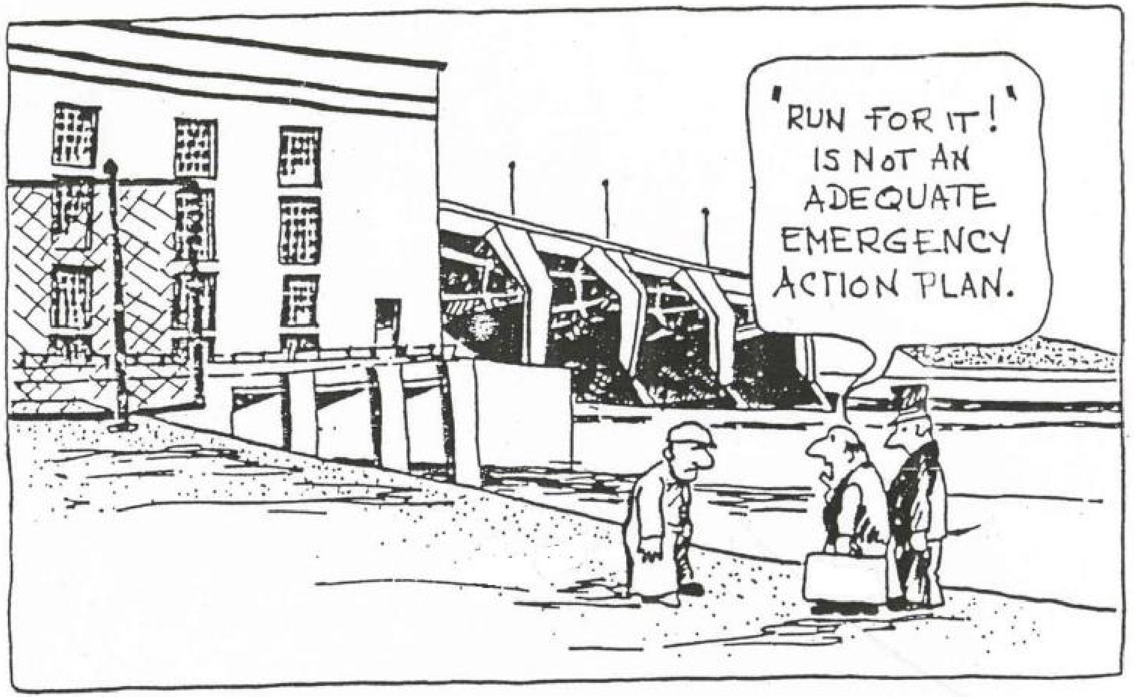


Thank You!

Anders Bjarngard, P.E. anders.bjarngard@gza.com
Yixing Yuan, Ph.D. yixing.yuan@gza.com



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