

RAC

Engineers & Economists

Dam Safety Workshop
Bangkok, Thailand
April 5, 2011

Utah State
UNIVERSITY

/DSRM

WORKSHOP ON DAM SAFETY : **Flood Failure Modes**

Reference:

Loren R. Anderson. 2554. เอกสารประกอบการอบรม "การวิเคราะห์เพื่อออกแบบและประเมินความปลอดภัยเขื่อน", ระหว่างวันที่ 5,7 และ 8 เมษายน 2554, จัดโดย ศูนย์วิจัยและพัฒนาวิศวกรรมปฐพีและฐานราก มหาวิทยาลัยเกษตรศาสตร์ ร่วมกับ Thai Geotechnical Society (TGS), ณ โรงแรมมิราเคิล แกรนด์ คอนเวนชั่น, กรุงเทพฯ.

Loren R. Anderson

Institute for Dam Safety Risk Management - Utah State University
and RAC Engineers & Economists

Failure Modes Identification

- A critical part of any Risk Assessment
- Group of experienced dam engineers and engineering geologists
- Group should include people with
 - Knowledge of day to day operation of the dam
 - Experience in dams risk assessment
- Access to detailed data on the dam
- Must find the “oddball failure mode”
- Result is a list of Failure Modes and an Event Tree

Hills Creek Risk Assessment

Summary of engineering
assessment and identified failure
modes for Hills Creek Dam



















Participant Brainstorming

- Generate a list of potential flood failure modes

Hills Creek Failure Modes

- **Flood**
 - **Overtopping**
 - **Wave Action**
 - **Toe Erosion**
- **Earthquake**
- **Normal Operating Conditions (Flood-Internal)**

Flood Failure Modes (General)

- **Flood**
 - **Overtopping**
 - **Exceed the PMF**
 - **Inadequate Spillway Capacity**
 - **Gates fail to operate**
 - **Fuse Plug fails to perform as designed**
 - **Operation Error of Gates / Inflow**
 - **Plugging**
 - **Wave Action / Over Wash**
 - **Toe Erosion**
 - **Spillway Wall Overtopping / Failure**

Flood Failure Modes

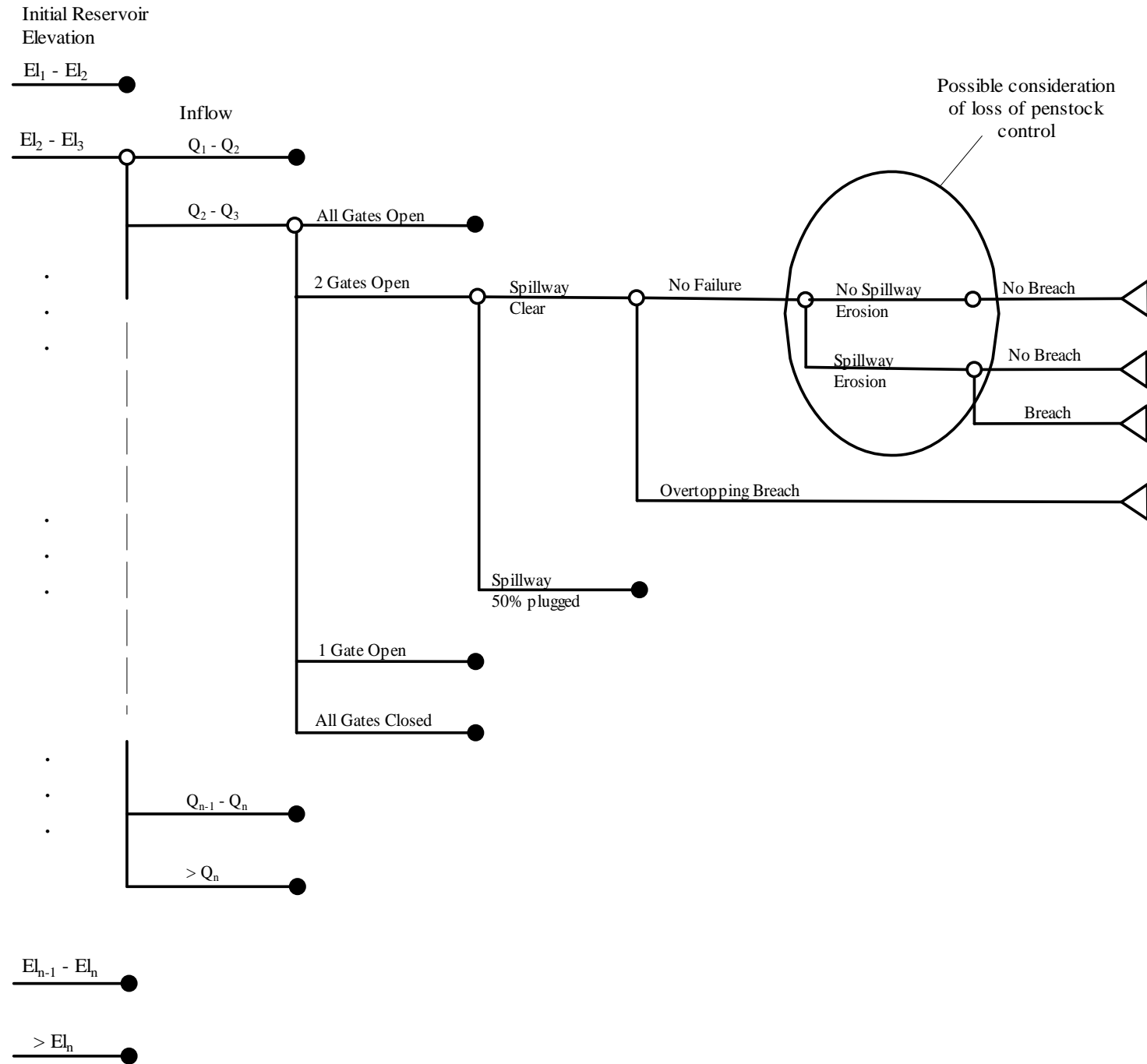
Failure Mode	Code	Effect
Overtopping due to inadequate spillway capacity	FFM-1	Erosion of the downstream slope causing a breach
Landslide into the reservoir	FFM-2	Overtopping of the dam leading to a breach of the dam
Toe erosion from spillway flow	FFM-3	Undercutting spillway and embankment toe leading to a breach of the dam

Flood Failure Modes

Failure Mode	Code	Effect
Mis-operation of spillway gates	FFM-4	Overtopping of the dam leading to a breach of the dam
Failure of spillway gates (inability to open including plugging)	FFM-5	Overtopping of the dam leading to a breach of the dam

Flood Event Tree

"Winter Storm"

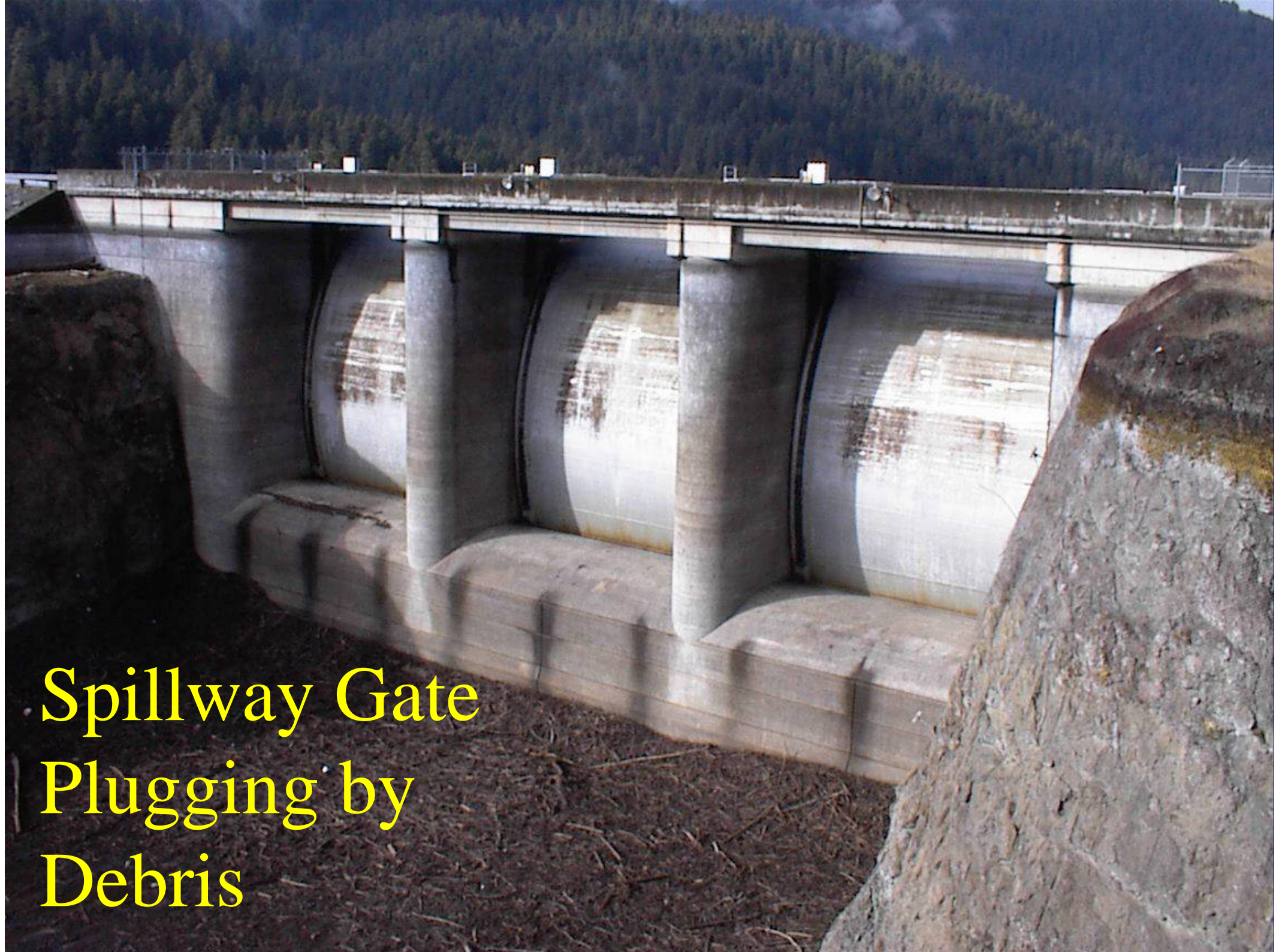


Spillway Toe Erosion









Spillway Gate
Plugging by
Debris

The Salt Lake Tribune

SALT LAKE TRIBUNE

WEDNESDAY ♦ OCTOBER 22, 2003

CLEARING A LOGJAM



TED S. WARREN/The Associated Press

TROY ALMLI OF THE WASHINGTON STATE Department of Transportation clears a massive jam of logs and other debris Tuesday under the U.S. Highway 2 overpass over the Snohomish River near Everett, Wash., 30 miles north of Seattle. The debris washed down the river during several days of heavy rain and localized flooding.







Pykes Creek Dam





Pykes Creek Dam




Taum Sauk Lake Hydroelectric Plant




- The upper reservoir of the Taum Sauk pumped storage plant in southeast Missouri breached at 5:13 AM CST, December 14, 2005. A wall of water 20 feet high moving at 3 miles per hour flowed down the Black River flooding Johnson's Shut-Ins State Park and threatening the towns of Lesterville and Annapolis as well as other communities downstream. Vehicles were washed downstream according to reports by the Missouri State Highway Patrol. The park cartaker's home at Johnson Shut-ins was removed from its foundation washed away. The five family members were inside the house that was surrounded by forest. The family survived, but the home and the surrounding woods were gone.





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UNITED STATES MARINE RESERVE










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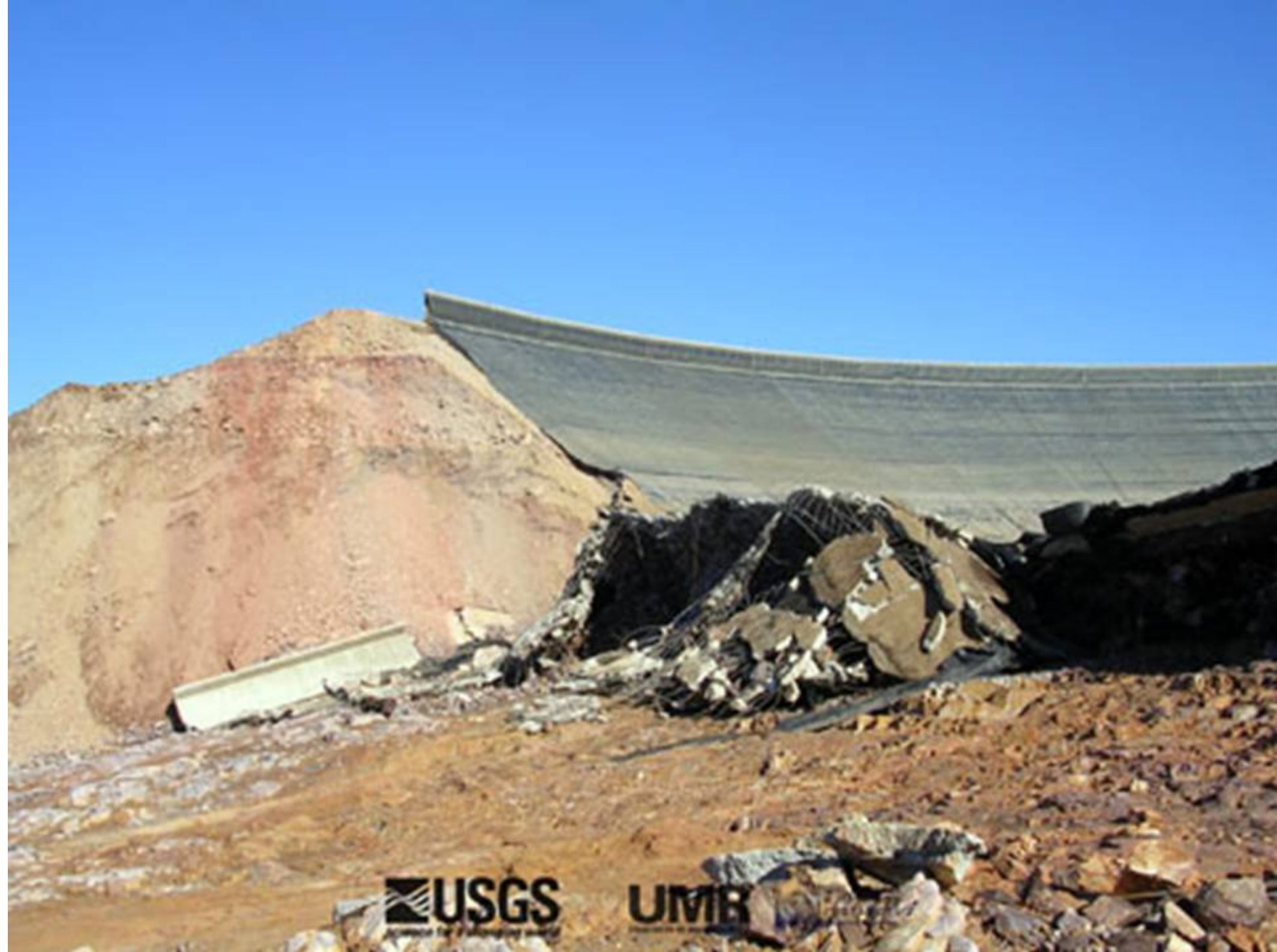


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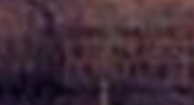






 **USGS**
United States Geological Survey

UMR
University of Missouri

 **University of Missouri**
Columbia, Missouri







 **USGS**

UMR

Cause of failure

The current working theory is that the reservoir's berm was overtopped when the routine nightly pump-back operation failed to cease when the reservoir was filled. According to AmerenUE, the gauges at the dam read differently than the gauges at the Osage plant at the Lake of the Ozarks, which monitors and operates the Taum Sauk plant remotely. The stations are linked together using a network of microwave towers, and there are no operators on-site at Taum Sauk.

- Low cloud levels prevented medical helicopters from flying to the aide of victims. It wasn't until the clouds cleared up that the helicopters could retrieve victims. Three victims, all children, taken to Farmington were they were then transported by ambulance to SSM Cardinal Glennon Children's Hospital in St. Louis. A spokesperson for the family has informed the media that they do not want the conditions of the children to be disseminated.

Risk Reduction Measures

- Must understand the failure modes
- Factors to Consider (Marcuson, 1993)
 - Proven Principle
 - Do No Harm!
 - Verification
 - Economy
 - Precedent
 - Minimize Public Dissatisfaction

StrumFlut Overwash

StrumFlut

AM 22-DEZEMBER

1954

Overtopping Model



Participants

List Risk Reduction Measures

Fuse Gate Spillway and Variations

