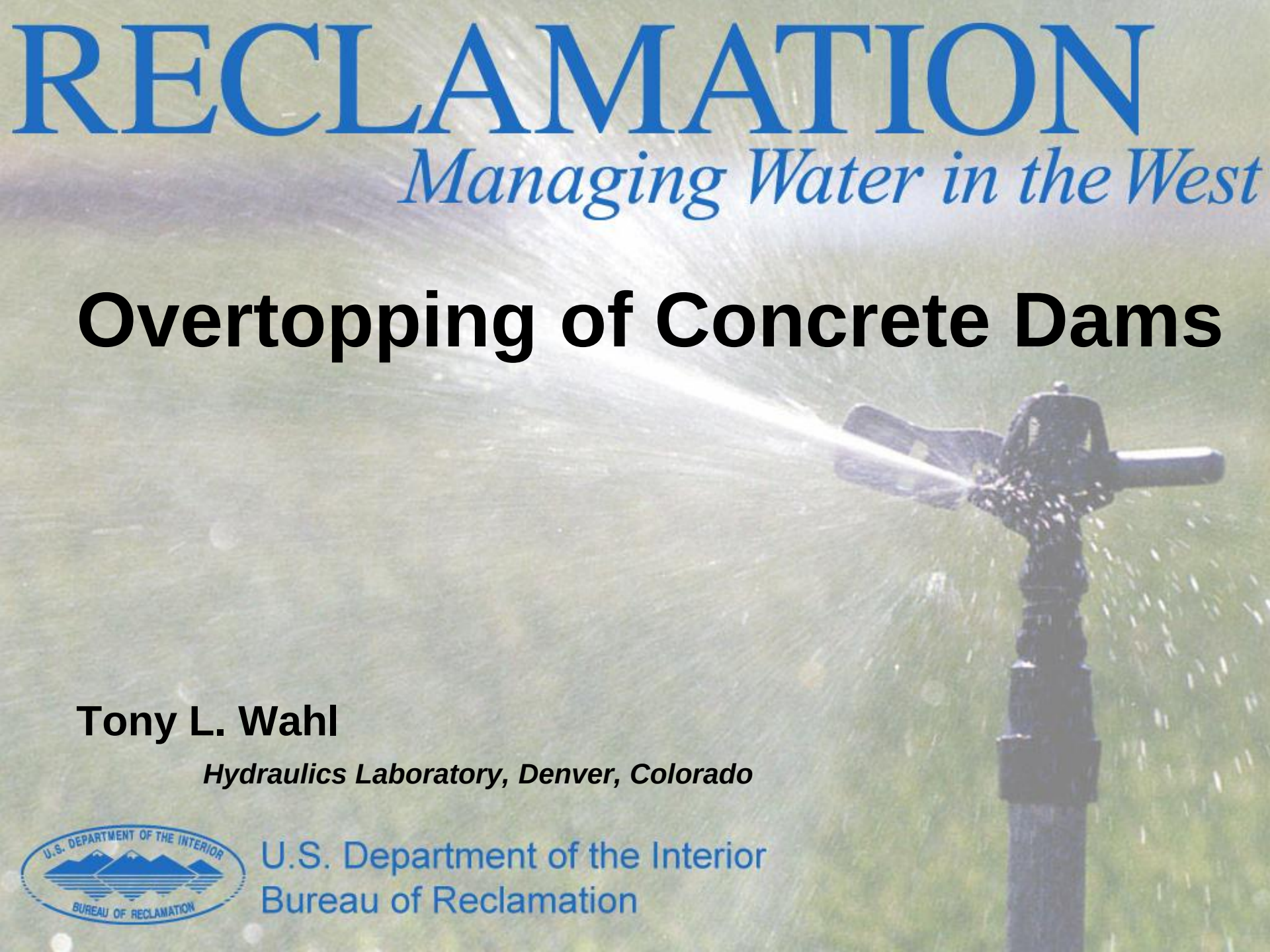
RECLAMATION

Managing Water in the West

Overtopping of Concrete Dams



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U.S. Department of the Interior
Bureau of Reclamation

Overview

- **USBR Experiences and Interest**
  - **Concrete dam overtopping event at Gibson Dam**
  - **Past studies of concrete dams with potential to be overtopped**
  - **Examples of retrofit armoring and rock-bolting**
  - **Highlight a few other sites with potential rock erosion issues in spillway channels or abutment areas**
    - **Plans for long-term monitoring of abutment/foundation changes using photogrammetry**

Gibson Dam

- June 6-8, 1964 record regional rainstorm in northern Montana
- Spillway radial gates not fully open, controls inaccessible
  - 2 gates fully open
  - 2 gates partially open
  - 2 gates closed
- 3 ft overtopping head over parapet for 20 hrs
  - Would have overtopped even with all gates open before June 1

Reference: ICOLD Bulletin 82 (1992)

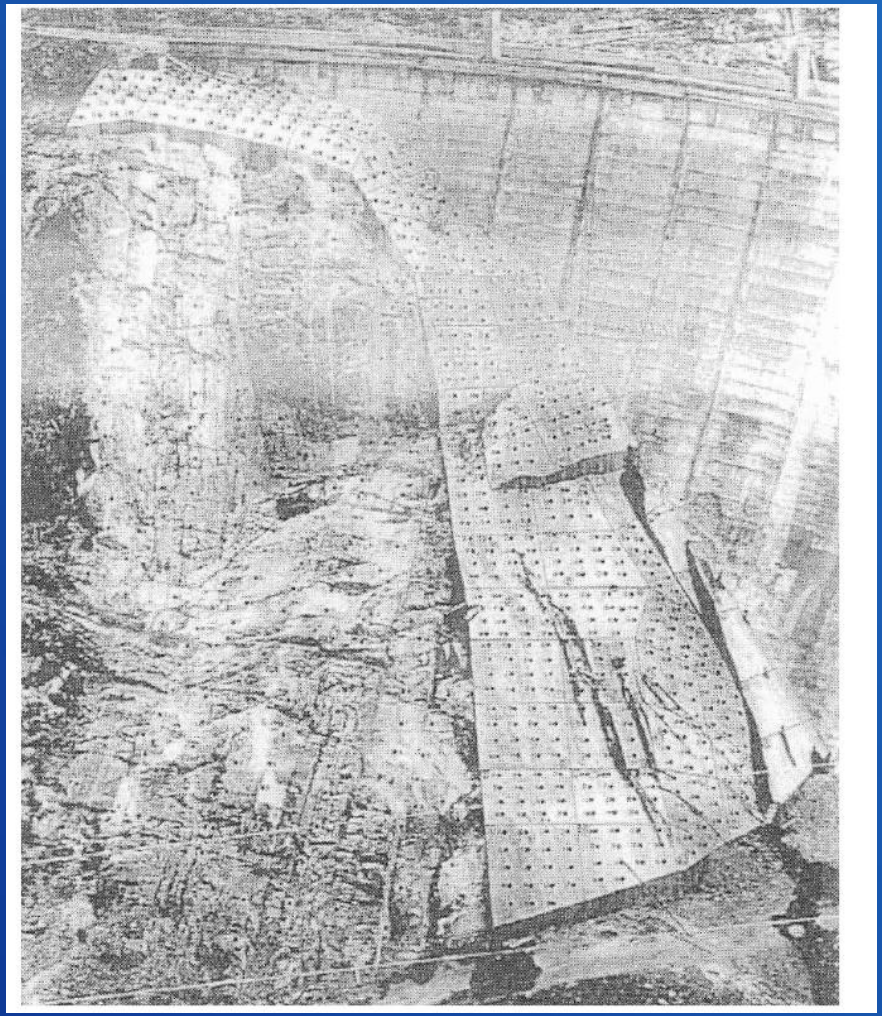
Gibson Dam, 1964

Gibson Dam modifications

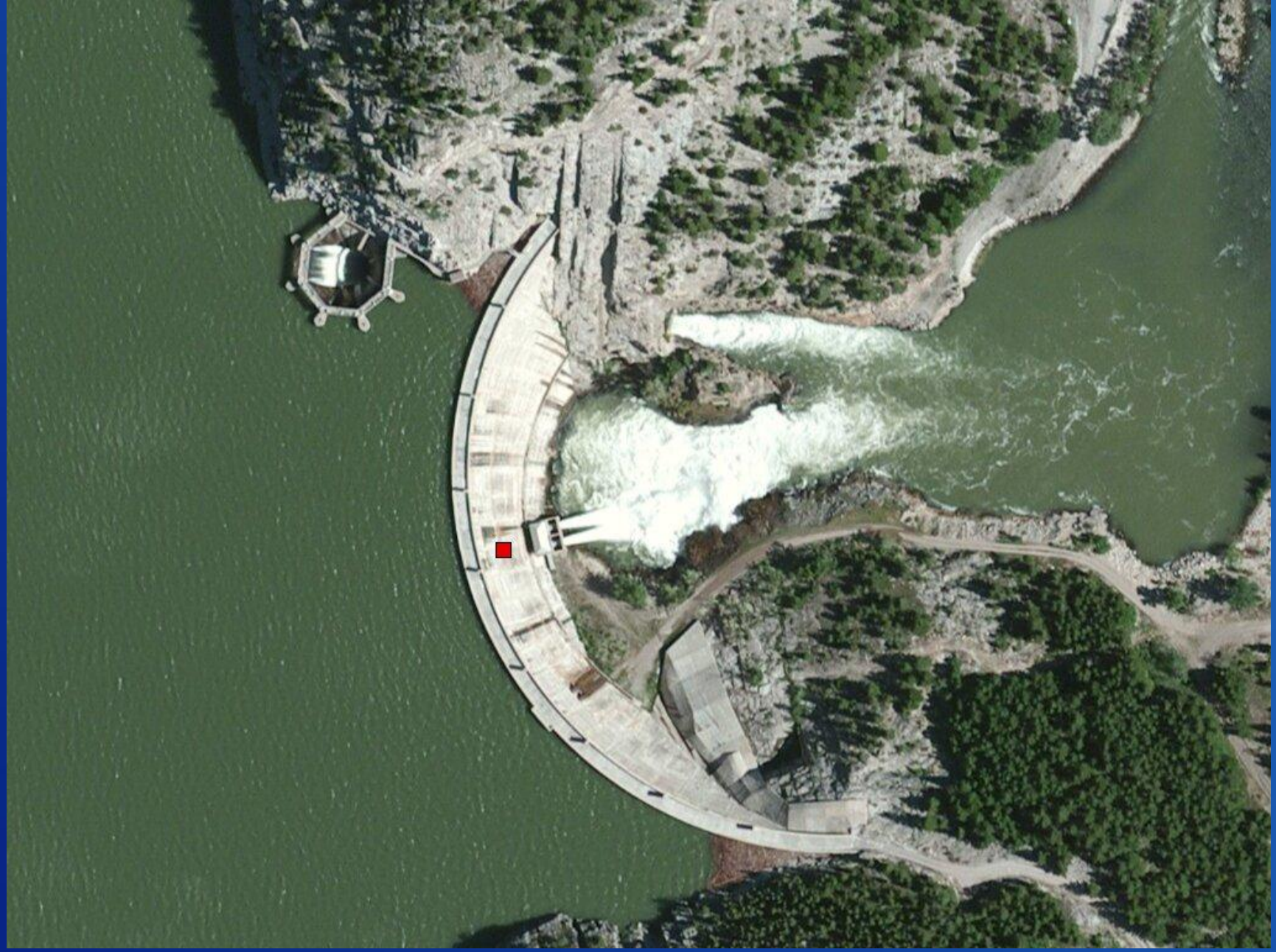
- 1981, modified for up to 12 ft of overtopping
- Excavation of unstable rock on both sides
- Rock bolting, concrete overlays
  - extensive on right side
- Splitter piers on crest for nappe aeration

Gibson Dam

- Right abutment rock bolts and concrete overlay
- Left abutment
  - Less extensive
  - Concrete to fill a couple of significant joints



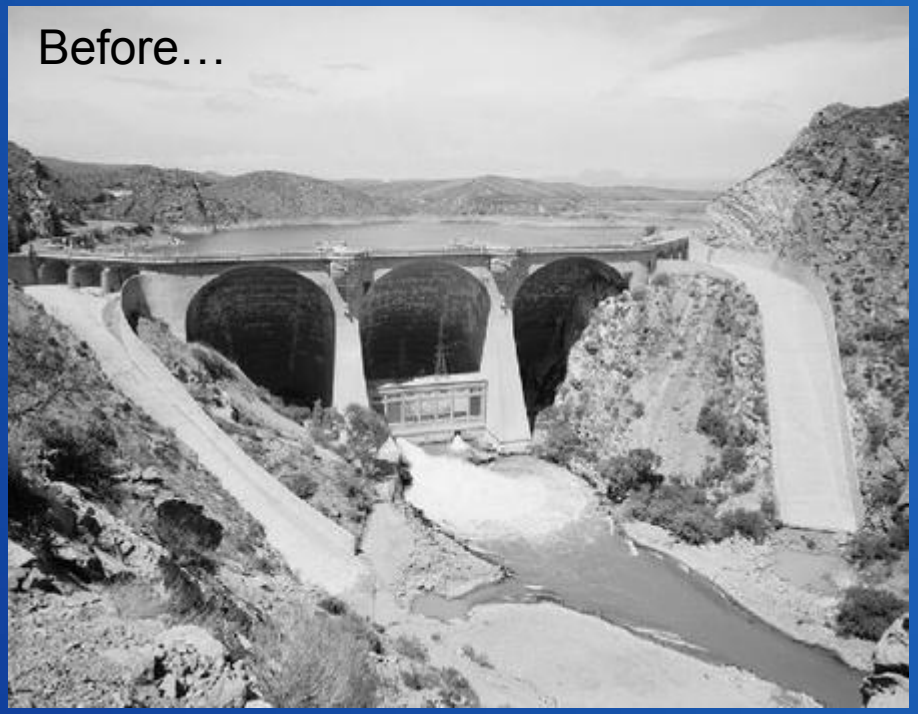
Gibson Dam with 1981 modifications

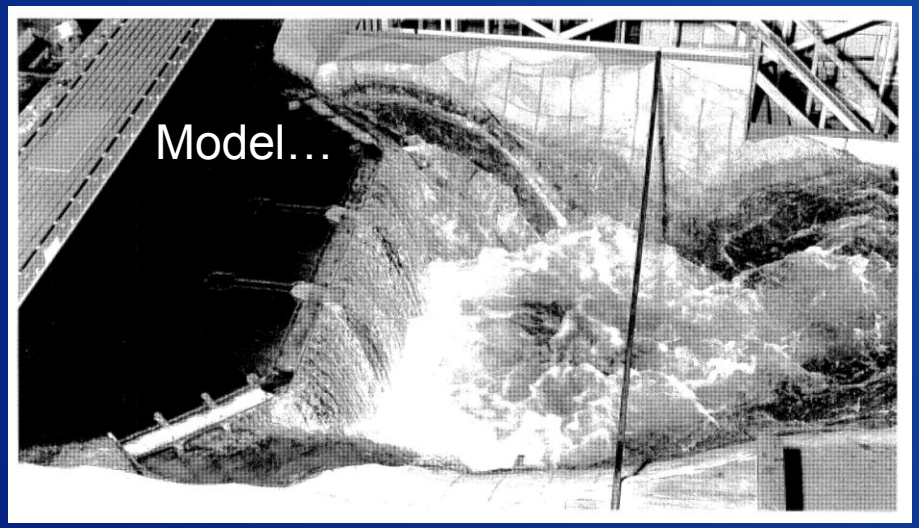


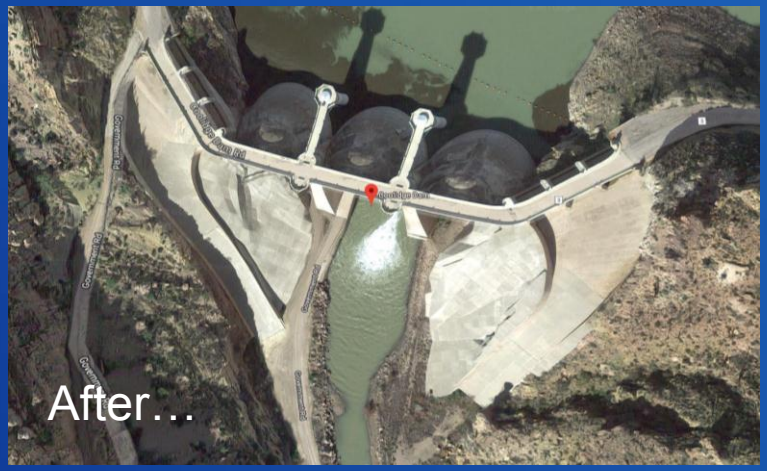
Investigations – Physical Models

- Coolidge – BIA (Bureau of Indian Affairs)
  - 1996 physical model (1:55), modified to pass PMF
  - 300,000 cfs over dam, 160,000 cfs through spillways
  - Extensive concrete blanketing of abutments
  - Spillways also modified with aeration ramps to mitigate potential for cavitation damage

Coolidge







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Investigations - Analytical

- **Annandale's scour threshold method**
  - **Estimate impinging jet properties, stream power intensity at impact with abutments or in plunge pools**
  - **Estimate K_h headcut erodibility index values**
- **Kathy Frizell**
  - **Gibson (2006)**
  - **Owyhee (2006)**
  - **Arrowrock (2007)**
  - **Yellowtail (2009)**

Owyhee Dam
Oregon

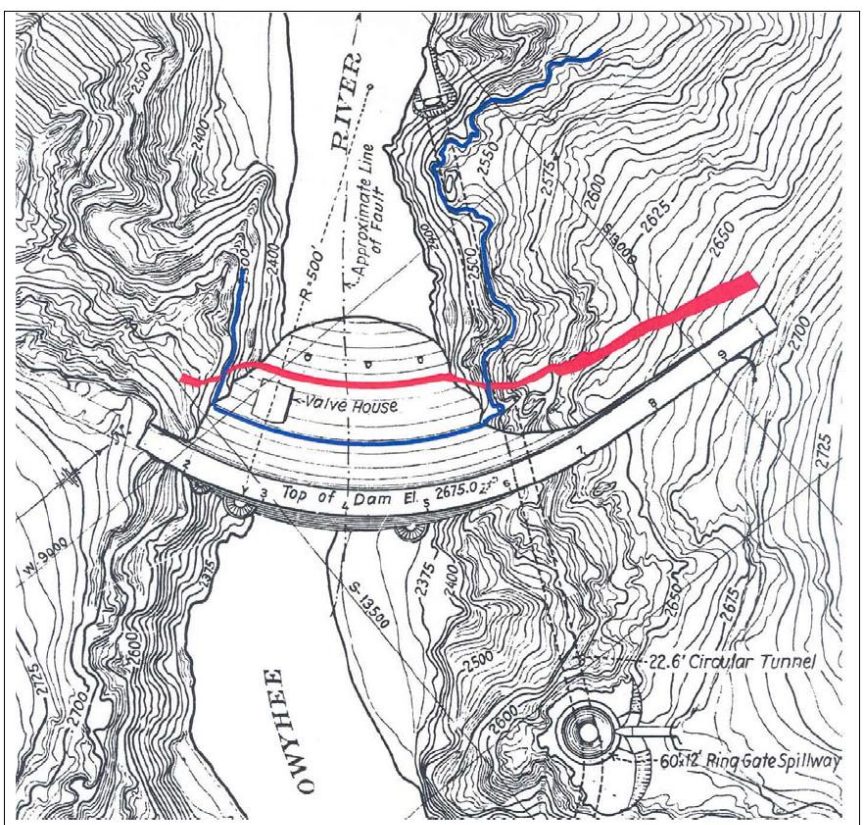
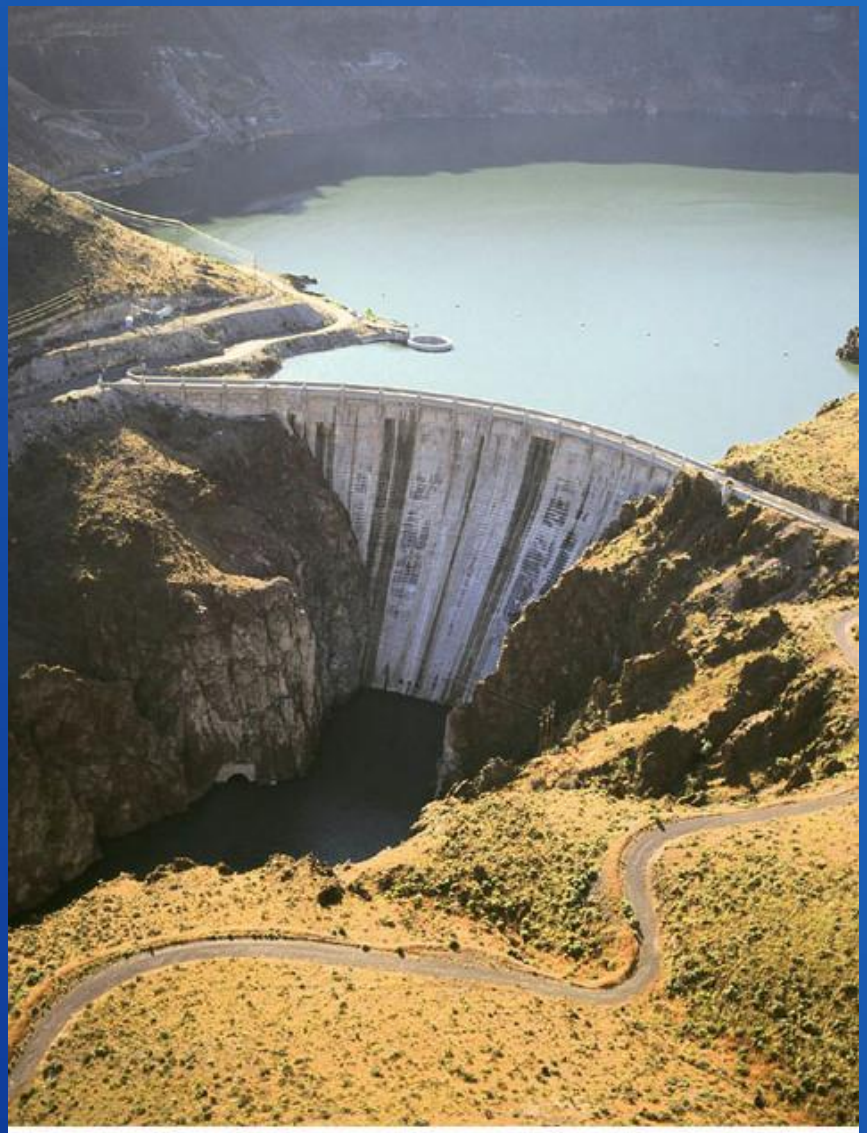


Figure 9. - Footprint of the trajectory with no spread of the jet for the PMF overtopping at Owyhee Dam. Note the location of the footprint does impact on the rock over the location of the spillway tunnel above the PMF tailwater shown in blue at El. 2531.



C48-100-700 Aerial view of Owyhee Dam, 11 mi. SW of Adrian, Or. Constructed in 1932. Owyhee Project, ID. FACL/Storage Dam.
Reclamation Photo by Dave Walsh. June 22, 2005.

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Arrowrock Dam

Idaho

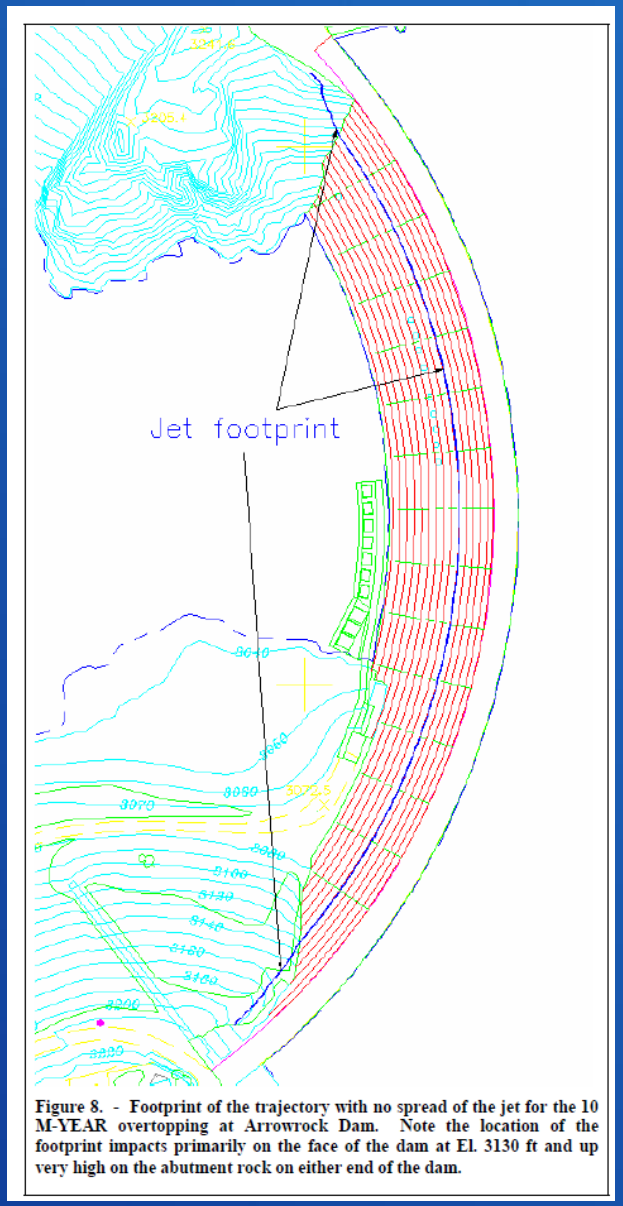

Figure 8. - Footprint of the trajectory with no spread of the jet for the 10 M-YEAR overtopping at Arrowrock Dam. Note the location of the footprint impacts primarily on the face of the dam at El. 3130 ft and up very high on the abutment rock on either end of the dam.

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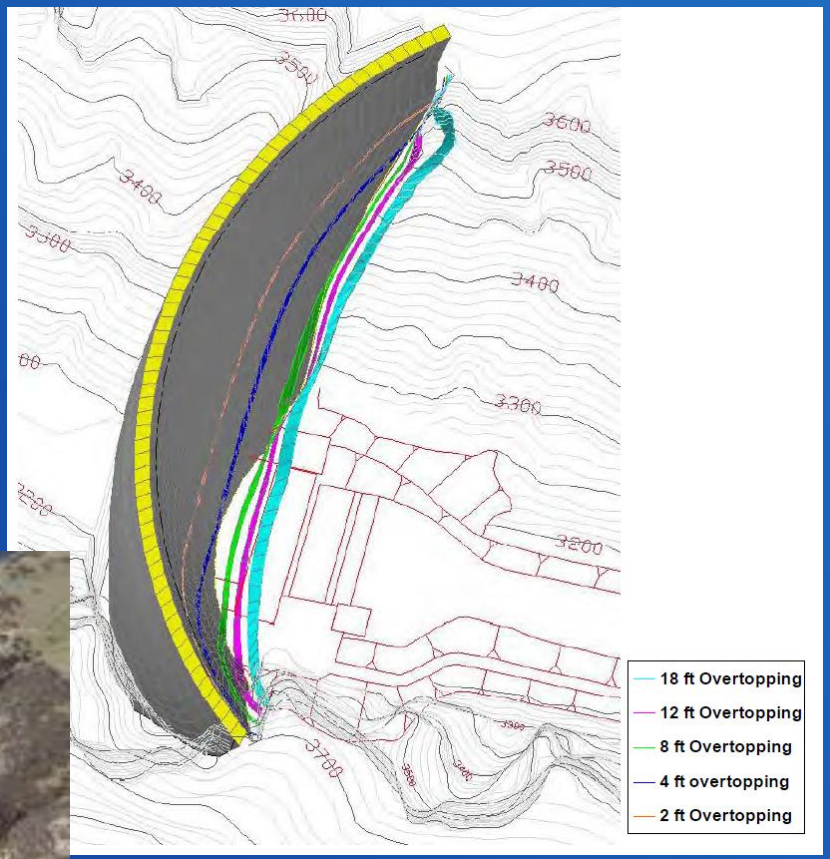
Yellowtail Dam

Montana



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Recent Analytical Investigations

- **2015, Thief Valley Dam - Oregon**

Examples of Jet Analysis

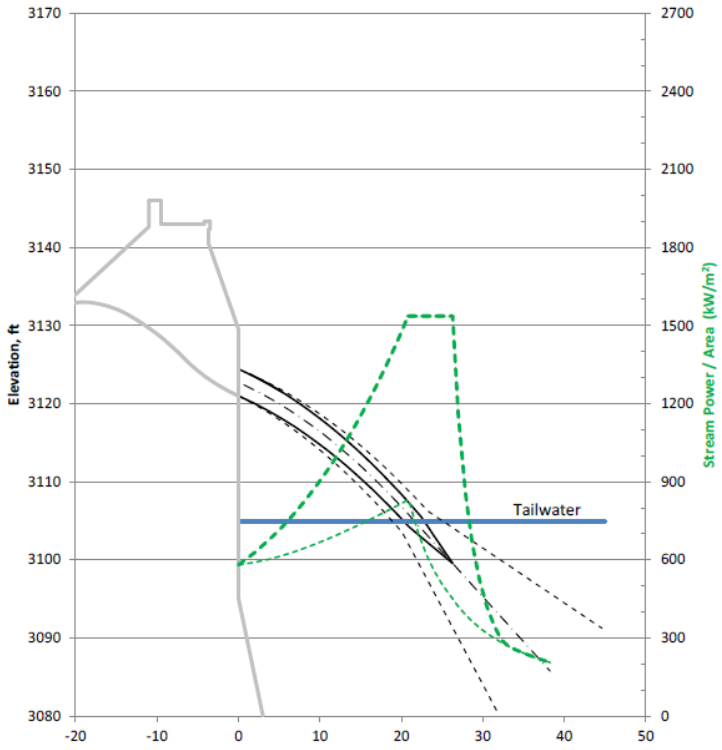

Figure A - 7. — Jet trajectory and stream power intensity for peak spillway flow during the 100,000,000-yr frequency flood, Thief Valley Dam, Oregon. Heavy, dashed green lines show the stream power intensity. The jet is expected to have an intact core when it reaches the tailwater surface.

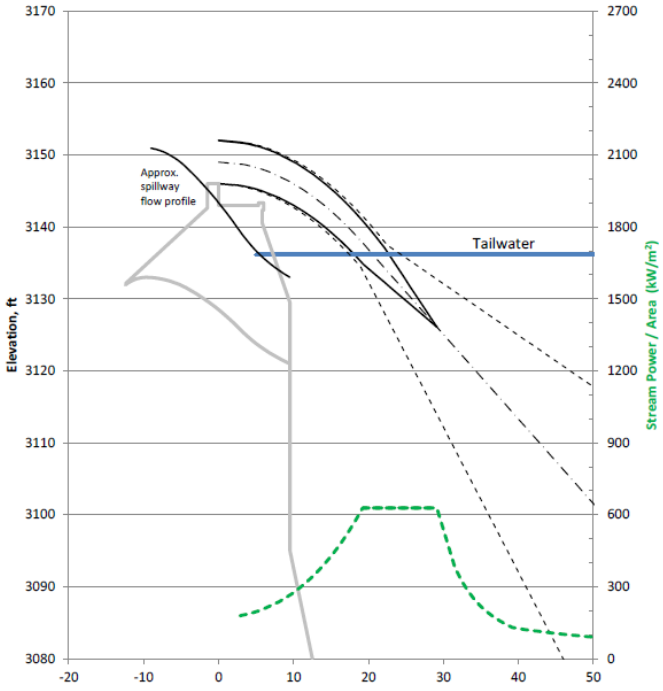

Figure A - 8. — Jet trajectory and stream power intensity for peak dam overtopping flow during the November PMF event, Thief Valley Dam, Oregon. Discharge overtopping the dam is 16,900 ft^3/s, and discharge through the spillway is 120,000 ft^3/s. Heavy, dashed green lines show the stream power intensity. The spillway crest is at elevation 3133.0 ft, so the tailwater is above the crest, but is probably not sufficient to reduce flow through the spillway. A sketch of the spillway flow profile is also shown for illustration, but stream power intensities are not calculated for the spillway flow, since the spillway lip is submerged. Note that at the dam and spillway crests there is significant drawdown of the water surface from the reservoir elevation of 3159.99 ft.

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Friant Dam

- **Recent risk study considered erosion due to flow in groin areas during overtopping**

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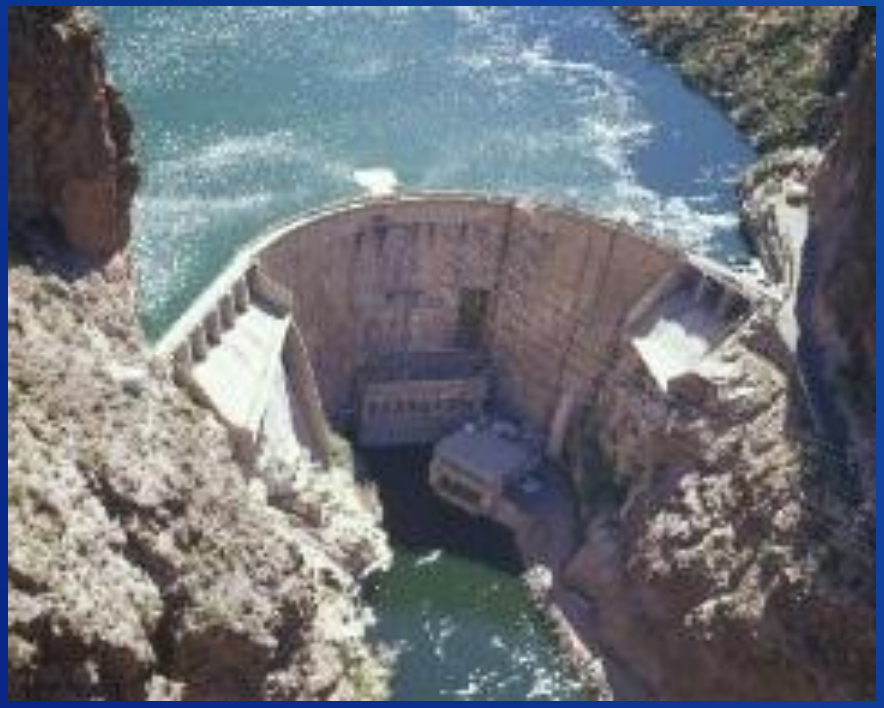
Spillway Rock Erosion



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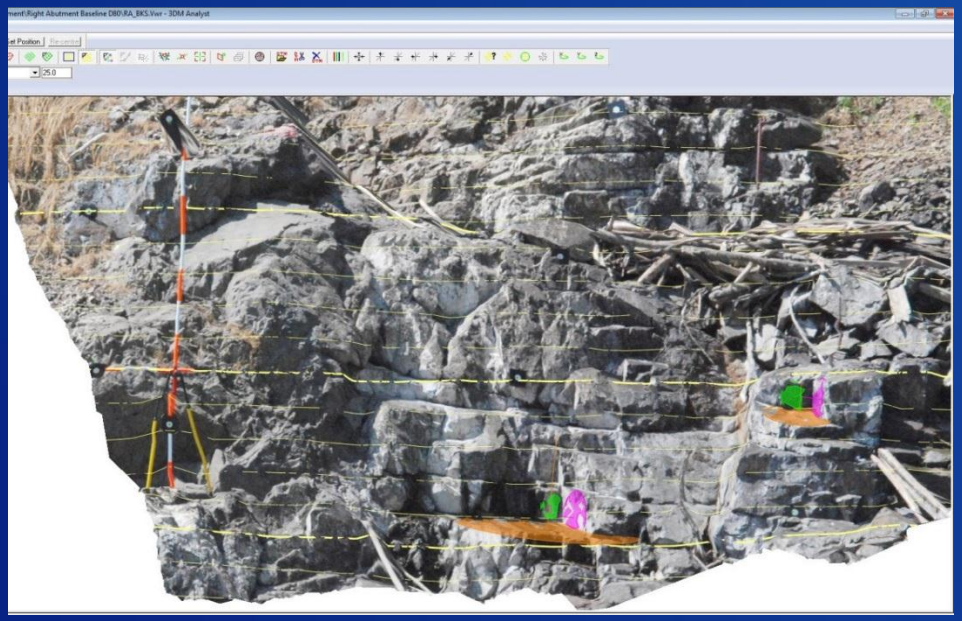
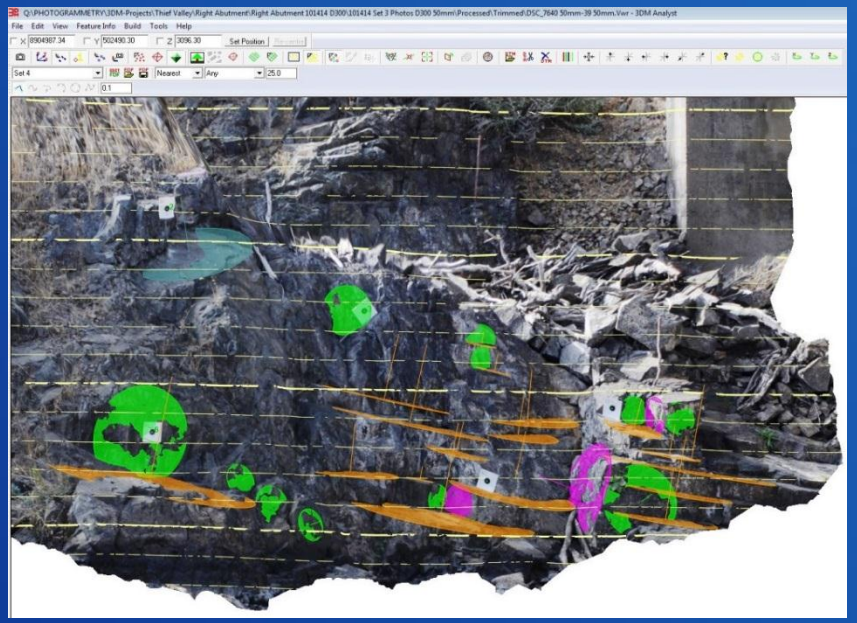
Photogrammetry for Long-Term Monitoring

- Beginning to use photogrammetry to map 3D surfaces and joints to determine changes over time due to flow events





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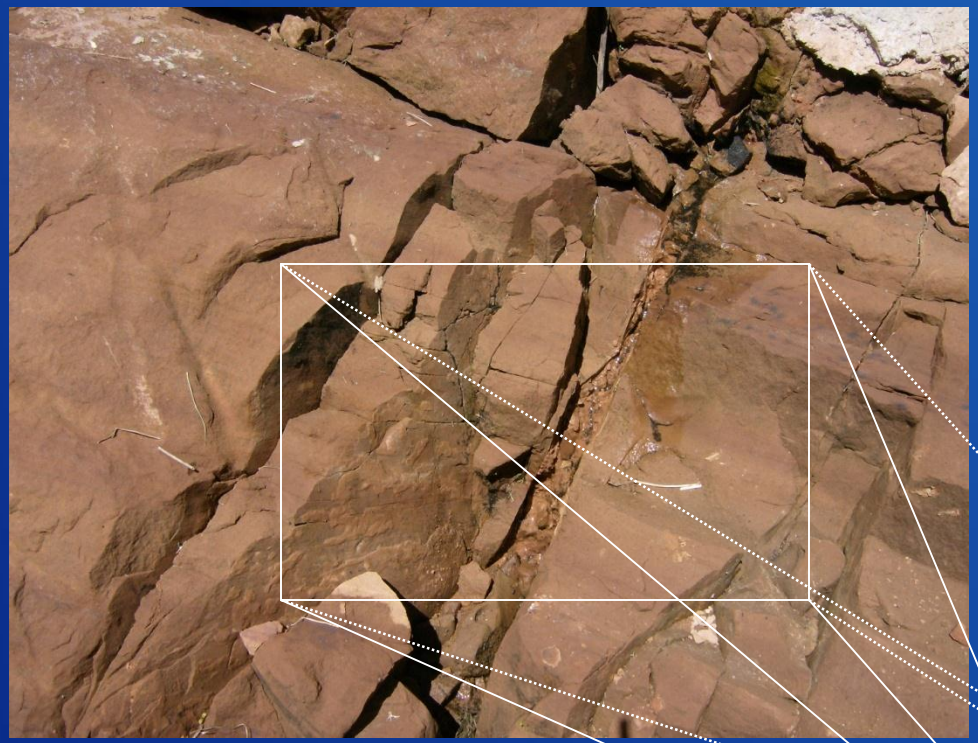


Building 3D models with simple photographs

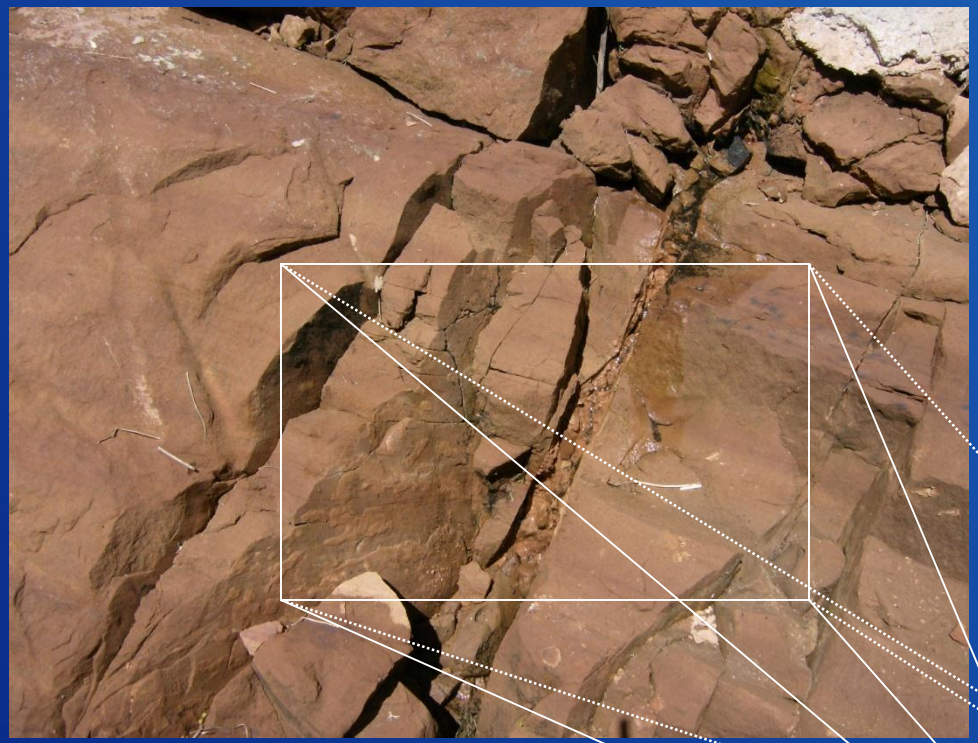
"Off-the-shelf" Eye Balls

3D Data

Brain

Left eyeball

Right eyeball



Building 3D models with simple photographs

"Off-the-shelf"
Nikon D700 Camera

3D Data

Computer

Left camera

Right camera

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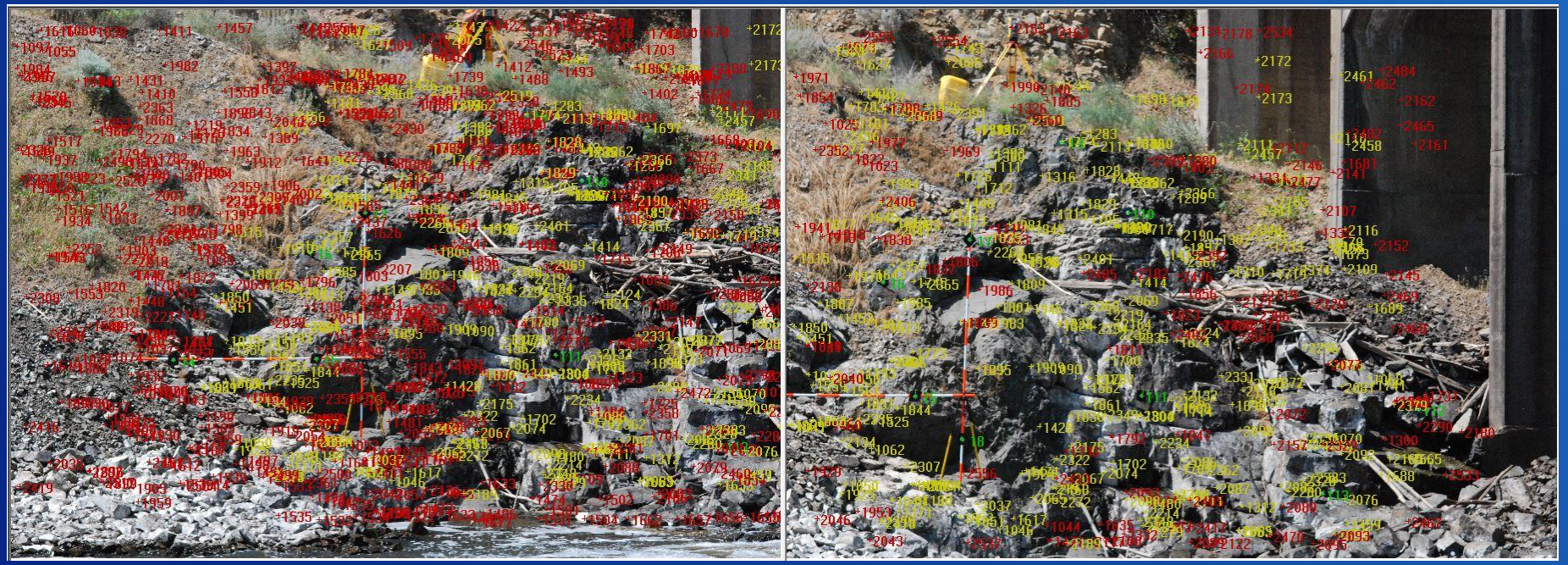
AdamTech processing of common points in photo image pairs



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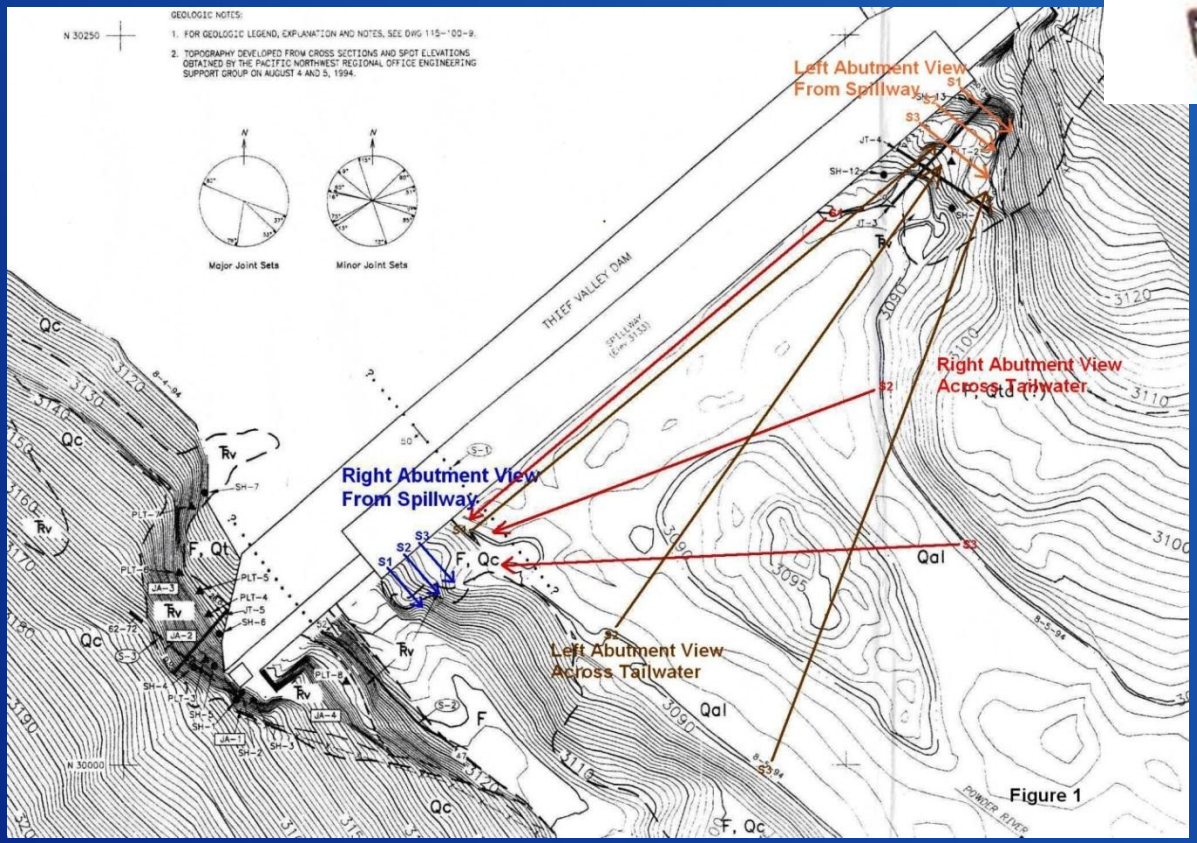
Thief Valley Dam, Field Events

Time 1 – June 2009

For Each Abutment

- Set up targets
- Survey Target Locations
- Take photogrammetric photographs



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Thief Valley Dam, Field Events

Time 1 – June 2009

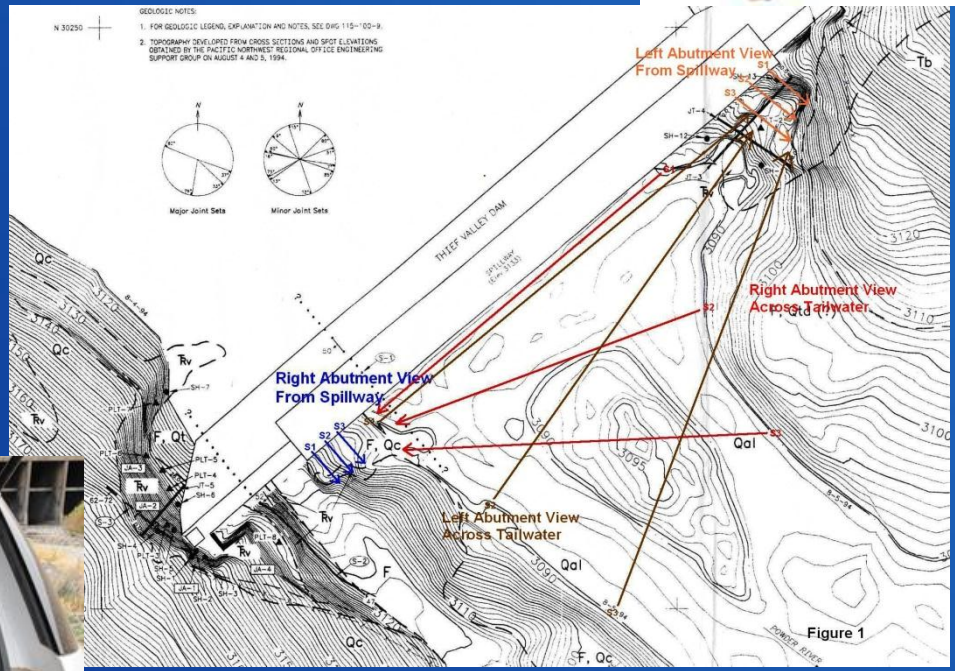
Time 2 – October 2014

RECLAMATION

Thief Valley Dam, Field Events

Time 2 – Oct 2014

For Each Abutment
Set up targets
Survey Target Locations
Take photogrammetric photographs
Field Mapping on photographs of exposed joints



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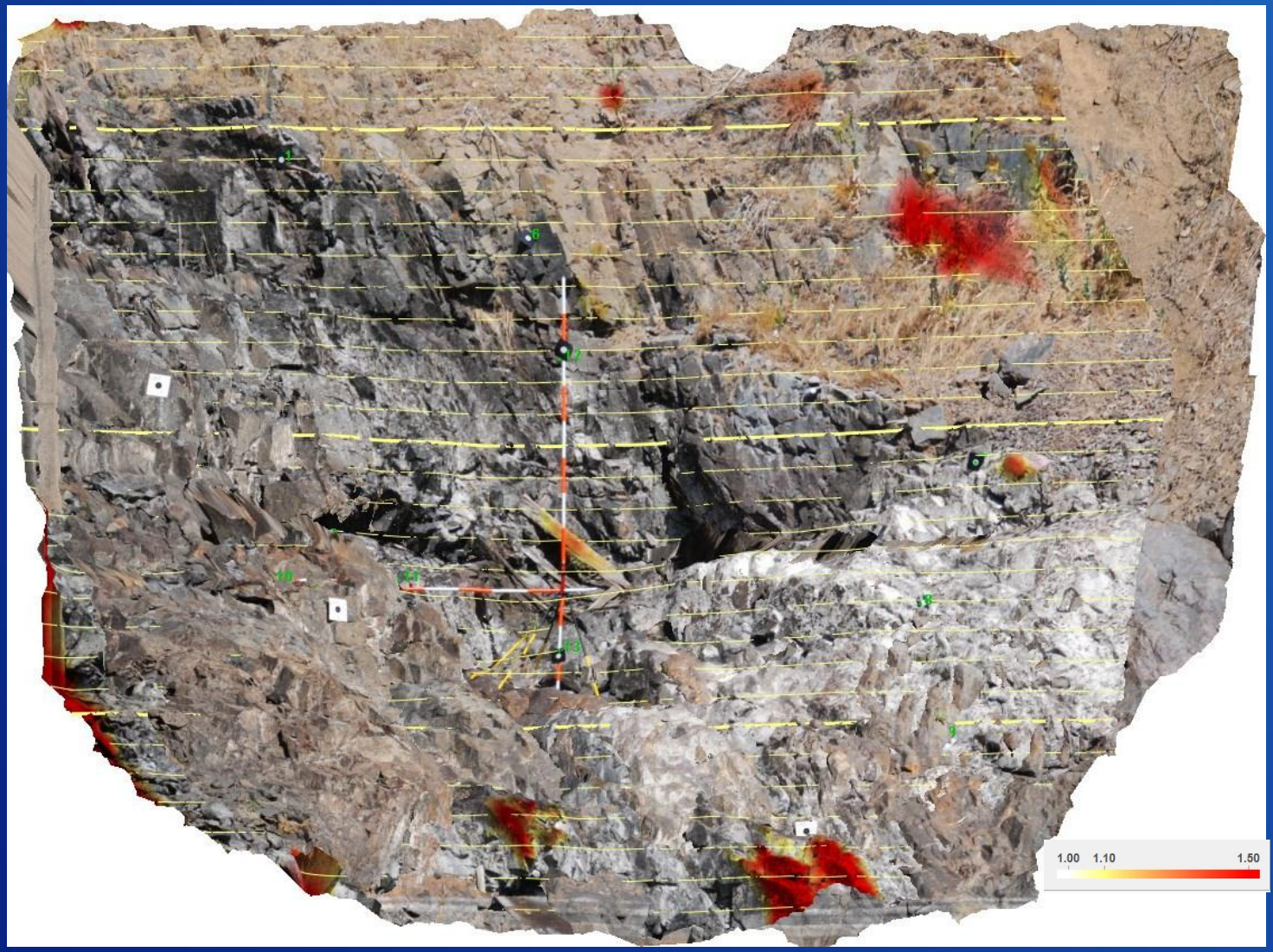
Thief Valley Dam - Left Abutment
Photogrammetric Model Difference Model



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Research Interests

- Monitoring
  - Photogrammetric mapping
  - Have base-condition maps for several sites
  - Awaiting spill events. Hoping to use UAVs in future.
- Modeling / Prediction
  - Going beyond stream power threshold analysis
  - Dynamic pressures in plunge pool, interaction with joints / fissures
  - Estimating rates of rock removal