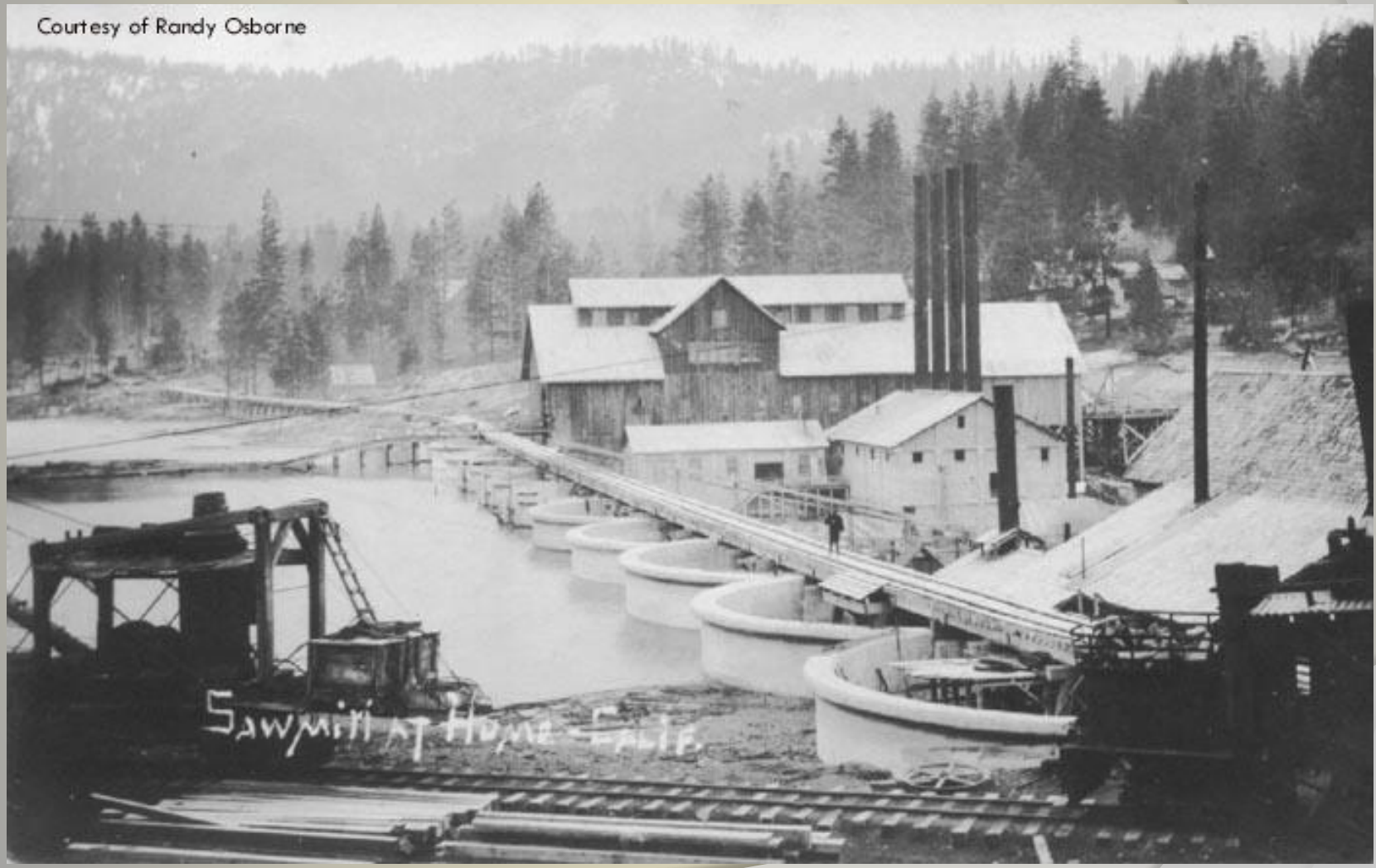
# Hume Lake Dam Preservation and Rehabilitation Project



Designed by John Eastwood and constructed in 1908 Hume Lake Dam is the first multi-arch reinforced concrete dam in the world. The dam is located in the Sierra Mountains east of Fresno, California. Its original purpose was as a log pond and water source for a 17 mile flume used to transport timber downstream.



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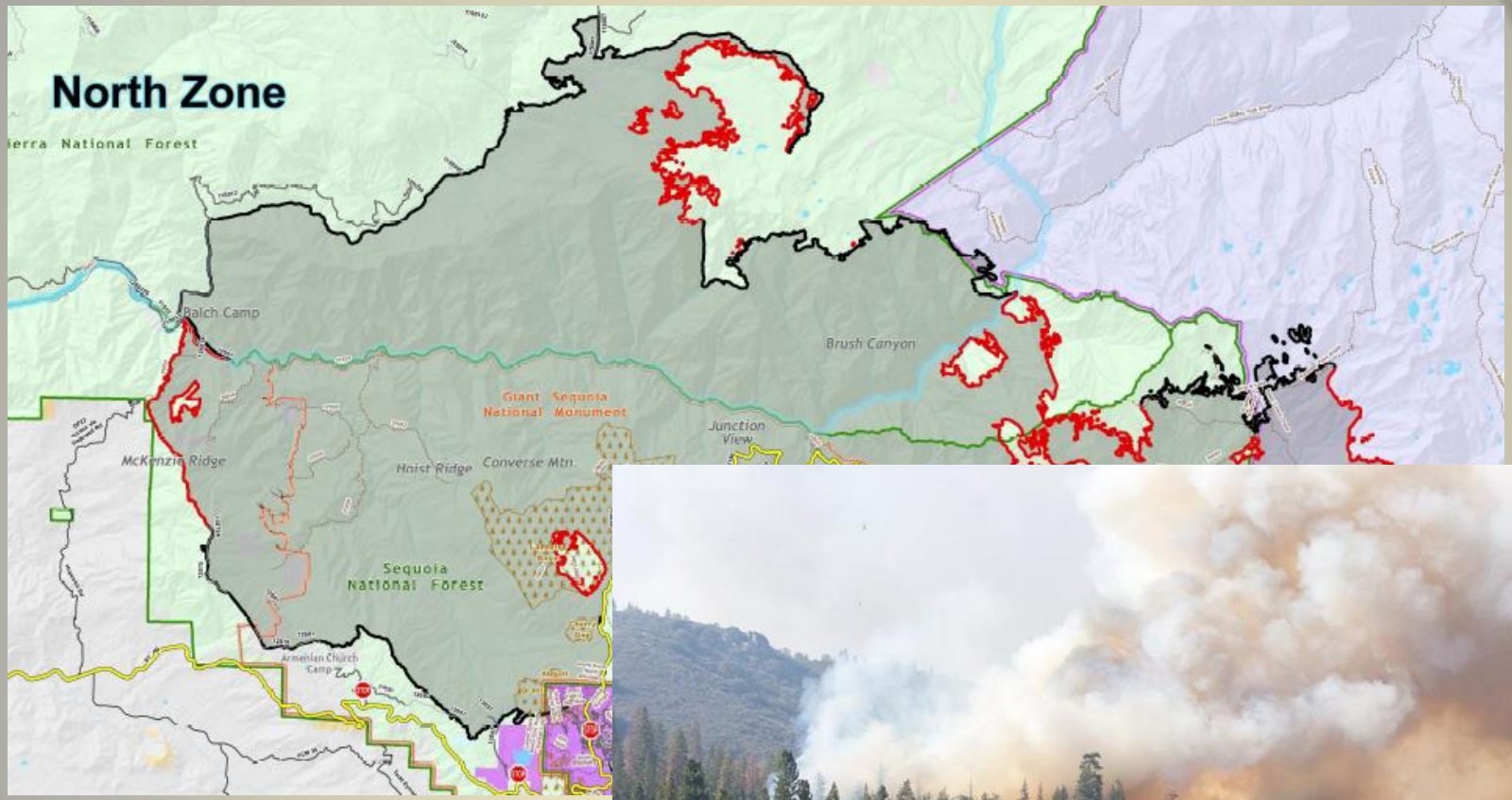
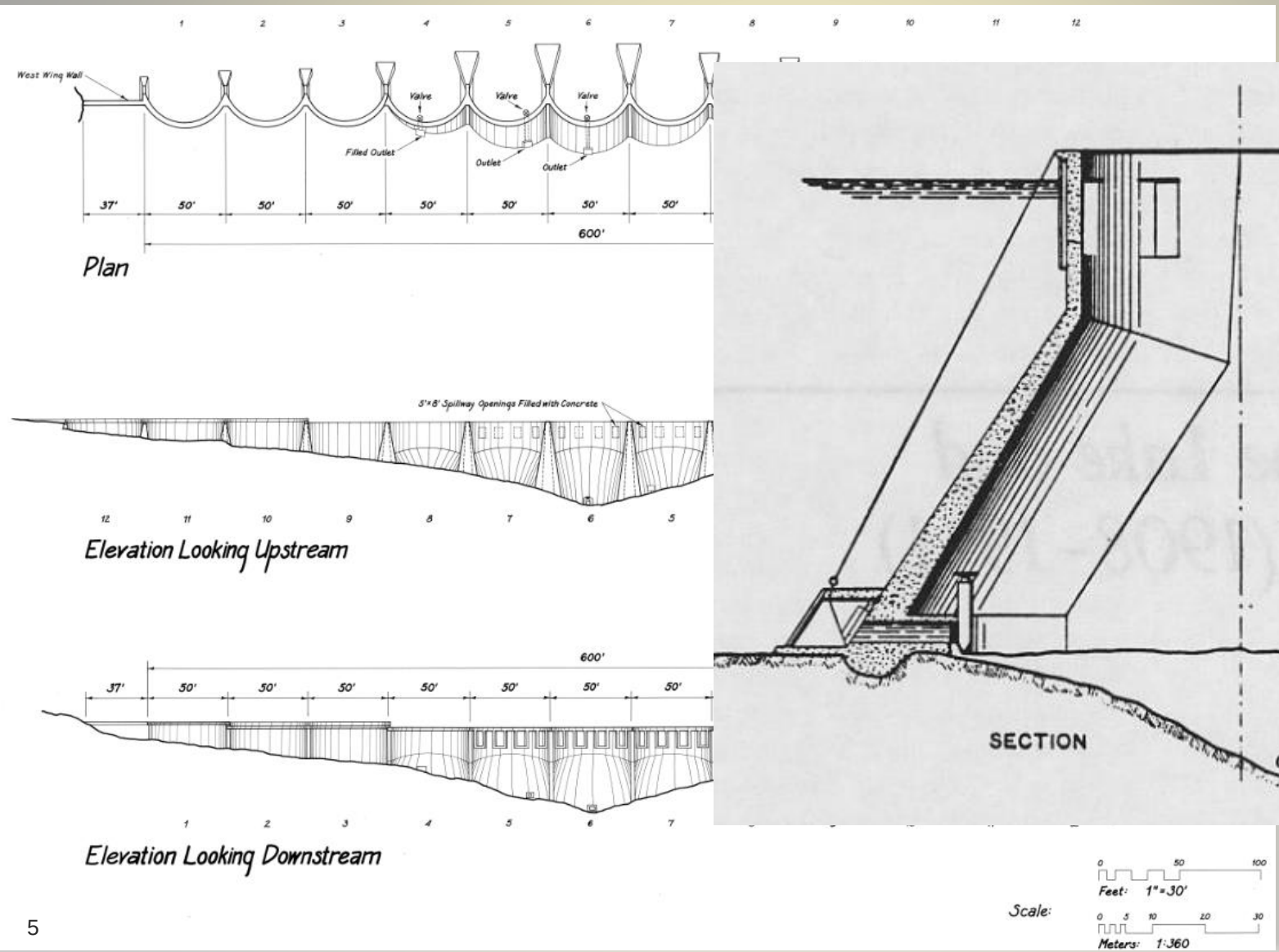
# Project delays from onset




# General Details

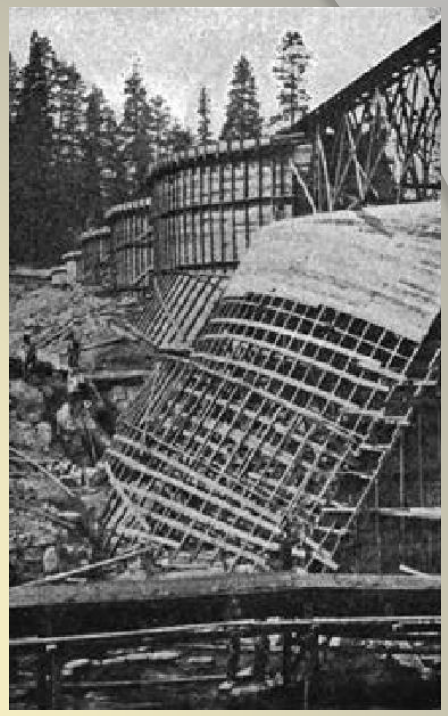
- Maximum height is 50.4 feet
- 12 Bays each of which is 50 feet in diameter
- Reinforcement is reported as vertical rail steel with cable horizontals. Spacing is uncertain.
- Concrete was batched onsite



# HUME LAKE DAM TIMELINE

## 1908-09

Dam construction began August 18, 1908, and took 111 days to complete. Hume Lake was filled to its 1411-acre capacity in June 1909. Upon completion it was the first reinforced multi-arch concrete dam built in the world.



## 1935-1937

Forest Service acquired the Hume Bennett Lumber Company property. Prior to acquisition of the property regional FS engineers required removal of debris around the dam, removal of old trestle, removal of "unsightly buildings around the lake", and hydrologic/hydraulic analysis of outfall and watershed. The remnant Hume Community was salvaged and cleaned up by CCC Forest Service workers. This area is the present-day Hume Lake Campground.

1942

USFS infilled the 12 original 5x8' spillway gates (also known windows) in arches 5, 6, & 7. Primary spillway is now the outlet works. Auxiliary spillway is the dam crest.

1954-55

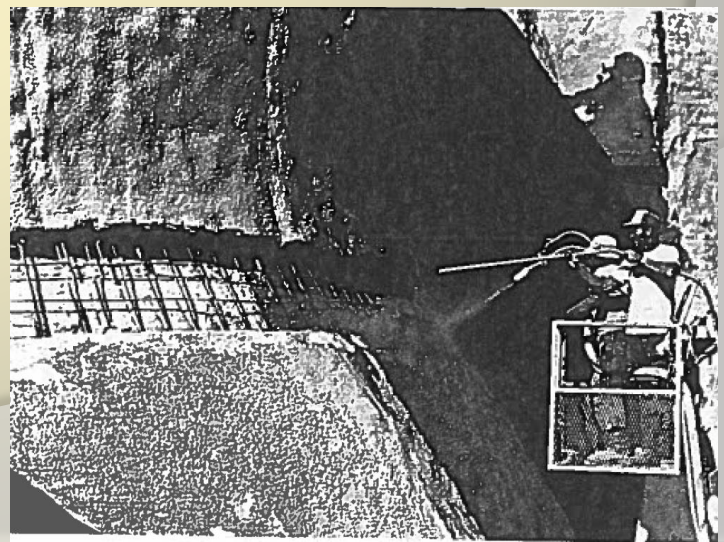
Gunnite and steel reinforcing was applied to the upstream side of the dam; Two parapet walls were placed on arches 1, 10, 11, & 12 to concentrate higher flows over the central arches where competent bedrock exist downstream. Foundation grouting program was conducted on east side of the dam; Valves were replaced with new and larger valves including a 24 inch valve on primary spillway.

1978-85

The dam was studied extensively which included a structural analysis, seismic analysis, hydrologic/hydraulic evaluation, safety evaluation, and historic evaluation. The dam was reclassified as a "high hazard".

1983-85

USFS placed 6" of shotcrete with rebar reinforcement on the entire dam. A Crystalline 'waterproof' membrane was applied to the upstream face. Foundation grouting on east side of the dam. New outlet works was installed including 36" ball valve and 12" gate valve.



## 2010 – 2016

The latest effort began in 2010 when the primary outlet works was upgraded.

Then in 2014/2015 inspections revealed a substantial increase in foundation seepage and corrosion of the internal reinforcement in the West side of the dam. It was felt that changed lake conditions caused by the ongoing drought may be contributing to observed deficiencies.

Worried about the long term viability of the dam the Forest Service proceeded with a $3 million upgrade to the dam structure that was intended to significantly reduce seepage through and under the dam which included,

1. Installation of a waterproof membrane on the upstream face of the dam
2. A substantial foundation grouting program on the west side
3. Installation of a cathodic corrosion protection system on the outlet works to extend its service life

The work on items 1 and 2 was completed in March of 2016 and appears to have accomplished the intended remedial objective. Work on item 3 will be completed in the Fall of 2016.

The work also involved the structural evaluation of the entire dam and safety upgrades to include,

- installation of satellite based remote sensing,
- infrared void detection,
- echo impact/pulse velocity concrete competency testing and coring,
- and a terrestrial Lidar stress/strain deformation analysis.

2010

Outlet works was upgraded with new controls and the installation of an isolation valve upstream of the existing 36 inch ball valve.

Engineering: US Forest Service

Contractor: JB Travis Construction

Controls: Mcjunkin Redman


# 2015/16 CONSTRUCTION PICTURES

After 4+ years of drought more than 20 inches of precipitation fell on the project during construction significantly complicating construction.

Prime Contractor – MCS Construction prepping the inflow bypass. Approximately 7 feet of sediments were deposited since the last major project in 1984. Total depth of sediments is approximately 15 feet which included material from a coffer dam failure in 1984.

MCS Construction

Carpi USA subcontractor

Construction of the liner on the upstream face – January 2016. The liner consist of a 100 mil PVC membrane over a geonet drain. Four holes were cored through the dam to drain the geonet.

Ground Engineering Contractors (GEC)

| Depth | 3p3 | 3p2 | 3p1 | 3s1 | 4p3 | 4p2 | 4t2 | 4s1 | 4t1 | 4p1 | 5s2 | 5p2 | 5s1 | 5p1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5-Feb | Blue | Green | Red | Green | Red | Green | Green | Green | Green | Red | Blue | Blue | Blue | Green |
| 10-May | Blue | Red | Red | Green | Red | Red | Red | Green | Green | Green | Blue | Blue | Blue | Green |
| 15-Oct | Blue | Green | Green | Green | Red | Green | Green | Red | Green | Green | Blue | Blue | Blue | Green |
| 15-18 | | | | | Green | Green | | | | | | | | |

Green represents grout takes that are below threshold for any additional work

Red represents grout takes that are above threshold for recommending additional work or variances from expected

Blue represents water testing complete but no grout data at the time of analysis

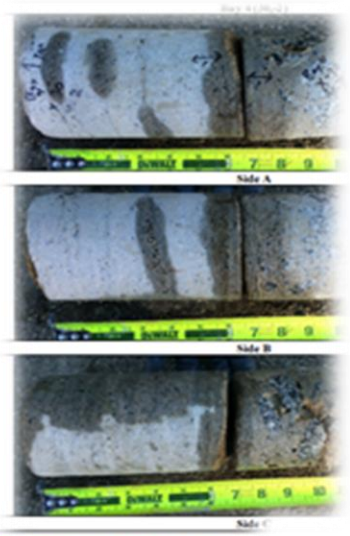
Note: Green secondary holes between red primary holes are indicative of proper closure.

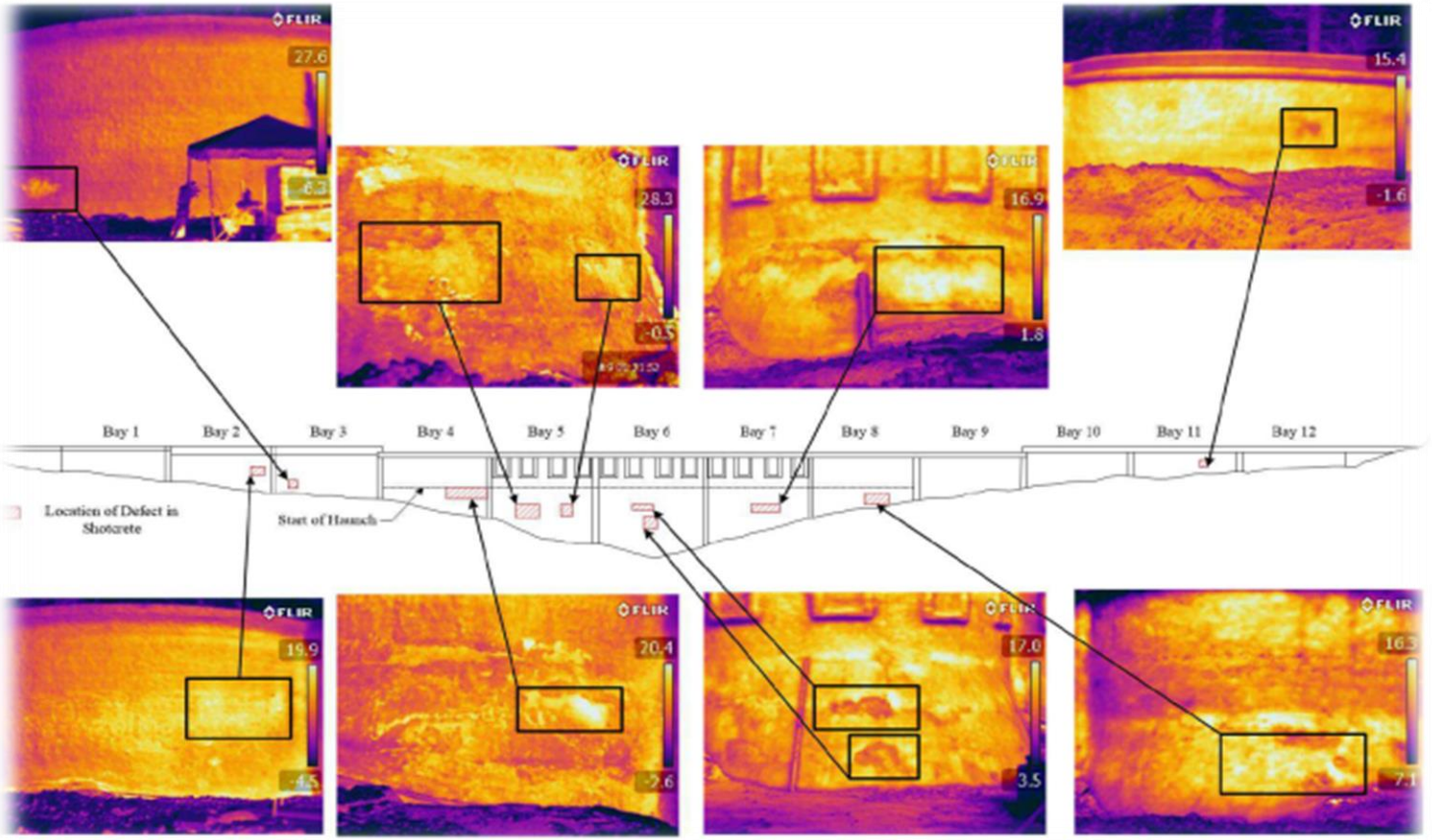
Foundation grouting program grout take analysis from December 2015

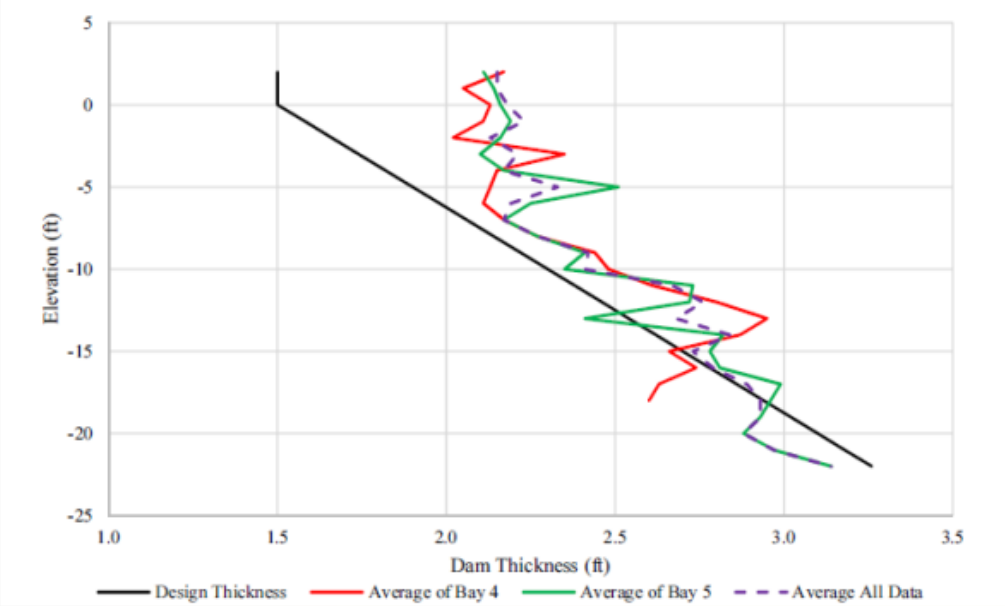
Cementitious grouting with some sodium silicate on occasion. Rotary drilling – no percussion.

Infrared imaging to detect areas of shotcrete delamination for liner installation.

Provided by Vector Corrosion Services








Echo impact/pulse velocity results Bay 4 and 5. The loading response and coring suggest results were skewed by shotcrete overlay. However, future investigations and/or treatments could use results as a guide. Targeted structural grouting may benefit from such non-destructive techniques.

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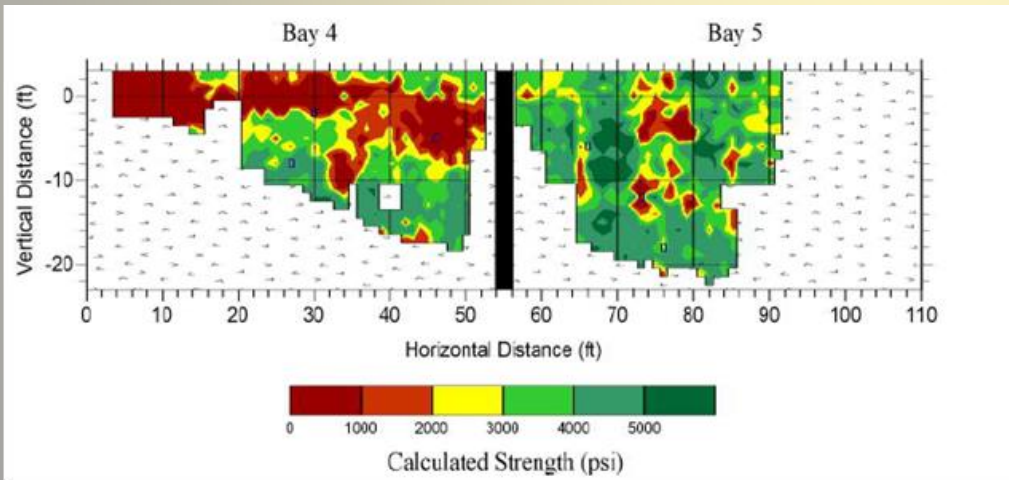





Terrestrial Lidar and Survey – point cloud sample of upstream and downstream dam face. Preliminary result appears to indicate the dam crest rotates in an upstream direction during loading – counter to the assumed direction. Also, movement in buttress 8 was two to three times greater than the rest of the buttresses surveyed.

Finite element modeling is underway to determine conditions that would produce the result.

Joint effort – University California Los Angeles and US Forest Service survey crews

US Forest Service Survey Crews established controls on the face and crest of the dam

UCLA did the lidar scan

Low permeability control density fill on upstream toe – March 2016.

| **Control Density Fill Mix Design** | **Mix 1** |
|---|---|
| ***Cement Content, lbs*** | 50 |
| ***Fly Ash, Class F, lbs*** | 600 |
| ***Coarse Aggregate (3/8 inch minus), lbs*** | none |
| ***Fine aggregate (sand), lbs*** | 2500 |
| ***Water Content, lbs/cuyd*** | 460 to 540 |

1. 12 inch slump
2. Must be able to pump
3. May use plasticizers
4. Set time shall be less than 1 hour after placement.
5. Add accelerant at site

Panoramic view of Hume Lake Dam after the completion of foundation grouting and membrane installation – March 2016

# 2016 POST CONSTRUCTION OPERATION INSPECTION PICTURES

Upstream side of Hume Lake Dam 2015. Reservoir at 4.5 feet below sill with .25 to .5 cfs seepage in Bay 4


Upstream side of Hume Lake Dam 2016. Reservoir at 4 feet below sill with 0 cfs seepage in Bay 4.

Bay 4 foundation seepage has essentially been eliminated. Seepage through the dam structure has been eliminated. Preconstruction pictures are on the left.

Downstream face 2015. Significantly increased seepage on the West side (right side of picture) has encouraged plant growth.

Post Construction 2016 - seepage through the entire dam has been in effect eliminated. Seepage in the West side dam foundation has been significantly reduced or eliminated.

Seepage in Bay 5 has been reduced from 5 to 10 cfs to level that is difficult to measure. Stained rocks are the previous seepage path. Preconstruction are pictures on left. Post construction on right.

Note ponds and majority of foundation seepage have been eliminated. Preconstruction is on the left. Note also that wet spots on face no longer exist indicating seepage through the dam has been eliminated.

Seepage through dam face in Bay 6 has been eliminated. Preconstruction is on the left.

Bay 2 is still impacted by a spring discovered during construction activities. No welling or other indications of head driven seepage from the reservoir are evident.

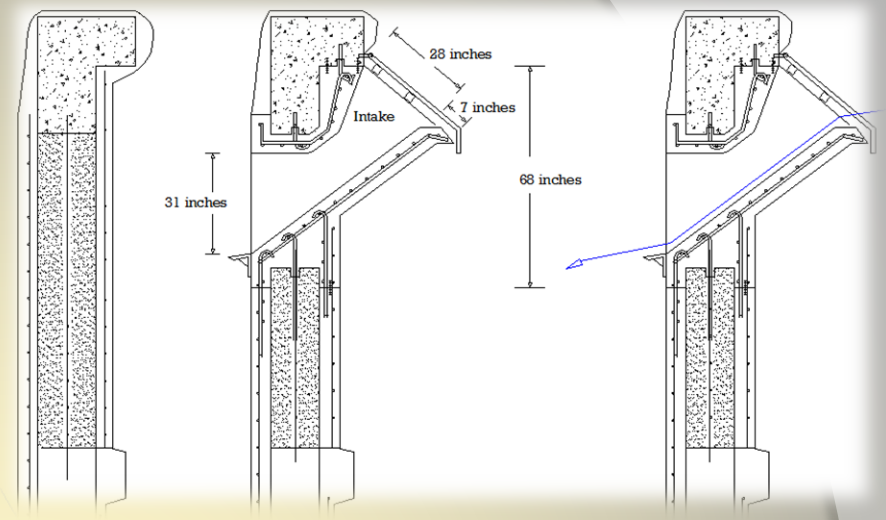
Foundation seepage in Bay 3 has been eliminated – picture on right.

PLANNED FUTURE WORK

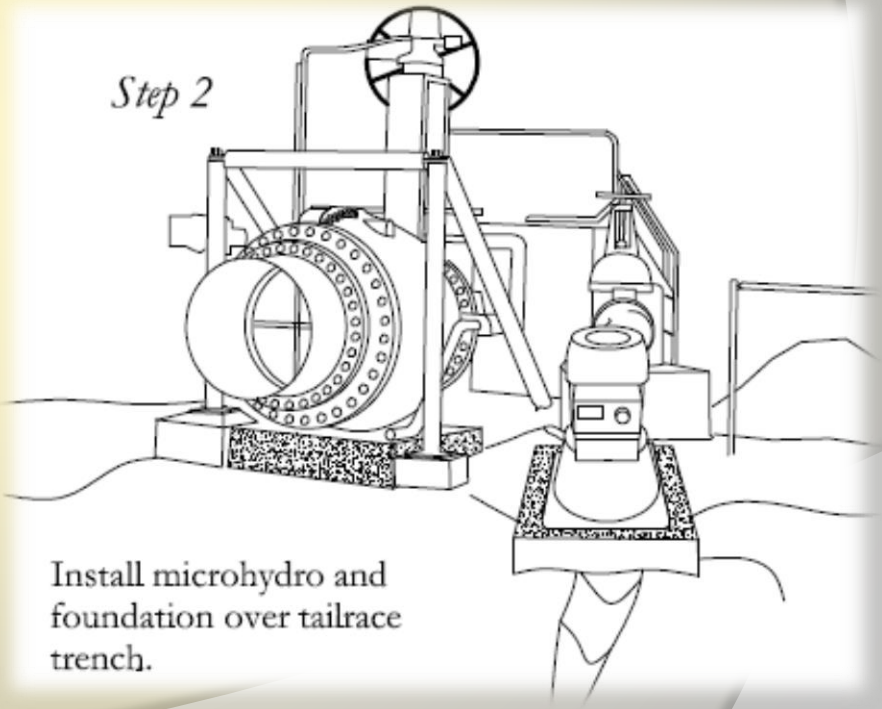
New SCADA system

New micro-hydro unit to power valves and nearby fire station is in the works

Re-establish passive spillways







# Hume Lake Dam Rehabilitation/Preservation Project Team

United States Forest Service Engineering - civil engineering and project management

United States Forest Service Surveying – controls for deformation study

MCS Construction – Prime Contractor

Carpi USA – Geomembrane

Ground Engineering Contractors – Foundation Grouting

Vector Corrosion Services – Non Destructive Testing

University of California Los Angeles – Lidar

Mcjunkin Redman – Valve Controls

# Any Questions?