CESPK-ED-GP 30 JULY 2013

MEMORANDUM FOR FILE

SUBJECT: ARGONAUT TAILINGS STORAGE DAM - INITIAL INSPECTION

1. Introduction. At the request of the EPA, an inspection of Argonaut tailings storage dam was conducted on 9 July 2013, from approximately 8:00am to 12:00pm. Argonaut Dam is a concrete multiple arch dam with the purpose that "the reservoir [was] used as a stilling basin to remove the slimes from the water from the mill. Heavy tailings were deposited some distance above the dam" (Ref. 1). The dam is located in Amador County approximately 1 mile north of Jackson, CA, at the corner of Argonaut and Sutter streets. Also accompanying the inspection were Dan Shane (EPA), Christopher Abela, PE (USACE structural engineer), and Brian Milton (ENE). The dam is not included in the National Inventory of Dams (NID).

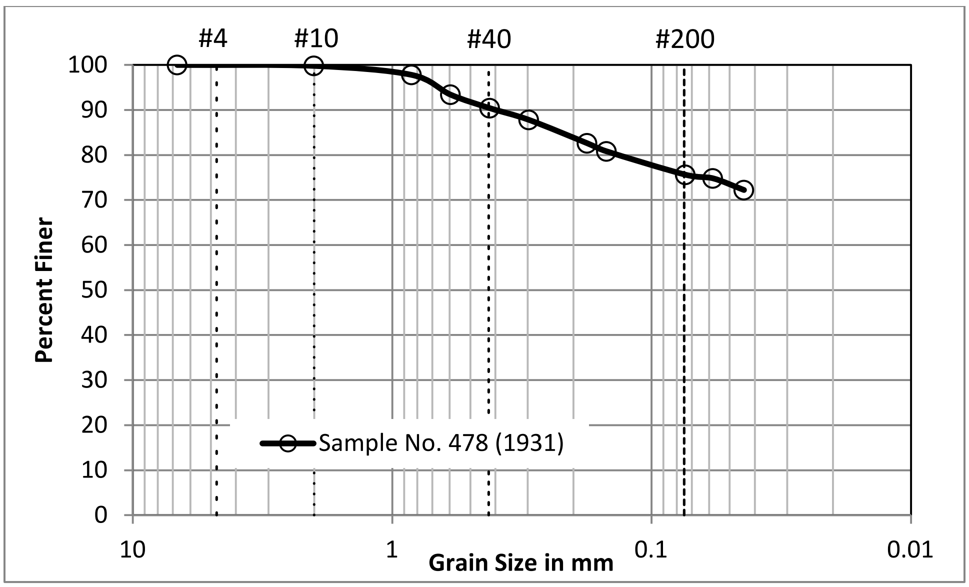
2. Background. The location of the concrete arch dam can be seen in aerial **Photo 1**, with State Plane coordinates of approximately 6,910,797 E, and 1,892,649 N (feet - NAD83). The undersigned contacted the California Division of Safety of Dams (DSOD) to review any existing documents on the dam. DSOD had pulled a file from archive storage that had some good information on the dam which included several inspection and design documents from the 1930s. The file also included a recent assessment by DSOD in 2003 that reiterated the dam was removed from state jurisdiction on 30 May 1933, "because inspection found that the reservoir storage capacity was less that 15 acre-feet due to the mine tailings deposits" (Ref. 2). State documents from 1932 indicate the dam was completed in 1916, had a height of 46 feet, a crest length of 392 feet, and a crest elevation of 1364 feet (MSL) (Refs. 3 & 4). The crest length of the dam has been reported differently in various documents.

3. Inspection. The field inspection was difficult due to the large amount of trees and vegetation covering the site, but visual assessments were made of the left and right abutments of the dam (left and right are referenced by looking downstream), a few of the arch sections at the top of the dam, and at approximately arch no. 10 at the downstream base of the dam. There are a total of 13 arches for the dam. Freeboard (from the top of tailings to the crest of the dam) was measured to be approximately 3 feet at arch no. 10, and 1.5 feet at arch no. 7. The spillway was constructed on the left side of the dam, but could not be found during this inspection. It is suspected the spillway may have been removed during the construction of Argonaut lane, or may be buried under heavy brush. A California State document from 1931 (Ref. 5) indicates that the spillway had a design capacity of 34 cfs for water at the crest of the dam. Pictures of the downstream face of the dam from 1931, showing a sluice box emanating from the spillway can be seen in **Photos 2 and 3**. Water has been seen pouring over the top of the dam on 4 April 2006 (Ref. 6). There is an outlet at the bottom of the dam that was indicated to be a 16"-diameter iron pipe, but has been reported to be "filled and no longer used" (Ref. 1).

Samples of the tailings were collected in 1931 and indicated the following (Ref. 7):

Sample No.	% Water (of dry wt)	Weight (lbs/cu ft)	Specific gravity
478-1	89.1	92.2	2.63
478-2	68,5	98.6	

A gradation test was also done on the 1931 composite sample and is shown in the chart below. It can be seen that 75% passes the No. 200 sieve and is most likely a non-plastic silt. Twenty-five percent of the sample is sand, of which 15% would be considered fine sand (passing sieve # 40), and 10% medium sand (ASTM D2487).



4. Conclusions and Recommendations. A stability assessment of the concrete multi-arch tailings storage dam could not be adequately made during this inspection. The amount of vegetation made it difficult to inspect (**Photo 4**), and just a few of the arches were visually examined. The dam has some apparent structural deficiencies that may indicate some concern. The left abutment arch and buttress (# 1) has been severely compromised and has several pieces of concrete broken off and hanging by the cable reinforcement. Also, the buttress cross braces showed significant signs of spalling and loss of section. An inspection memorandum has been prepared by Christopher Abela, P.E., of the USACE Sacramento District Structural Section, entitled: *Argonaut Multiple Arch Dam, Jackson, California,* 23 July 2013.

Tailings behind dams are typically of low unit weight and low shear strength, and can present some unusual loads on the structure. The engineering properties of tailings typically exhibit those of hydraulic fills, which are no longer recommended as dam construction materials due to their low shear strength and potential for liquefaction. The tailings behind Argonaut Dam appear to be highly erodible, of low unit weight and probably very low shear strength. Engineering properties of the tailings and the concrete materials should be determined by collecting undisturbed samples and conducting lab tests.

It appears that the dam has no spillway or functional low level outlet. Water has been seen flowing over the top or the dam in recent years, which may be a condition the dam was not designed for, and could affect the stability. There is also an earth tailings storage dam above this structure that could impact the stability of the concrete multi-arch dam if it failed, and should be inspected and analyzed. A separate cost estimate has been prepared for further inspections and investigations, and to conduct a more detailed engineering analysis. The cost estimate basically includes the following additional tasks:

1) Inspect the upper earth tailings dam and the concrete multi-arch dam once vegetation is removed.

2) Conduct Standard Penetration Test (SPT) drilling and geotechnical lab testing.

3) Obtain concrete core samples from the multiple arch dam and conduct unconfined compression testing.

4) Conduct structural stability analysis and seismic evaluation of the concrete multi-arch dam.

5) Conduct geotechnical seepage and stability analysis of the upper earth tailings dam.

/s/Kenneth R. Pattermann PE, GE
Geotechnical Engineer
U.S. Army Corps of Engineers
Sacramento District
Geotechnical Branch
Dam Safety Section

cf:
CESPK-ED-GP (Carroll, File)
CESPK-ED DS (Abela)
CESPD-PDM (McMindes)
EPA (Shane)

References.

1. Hart, S. A. "Memorandum to Mr. Hawley, Argonaut Dam No. 478," Inspected May 14 and 15, 1930.

2. Division of Safety of Dams (CA). “Argonaut Dam, No. 478 (Out of Jurisdiction)," Letter to Ms. Holt, 9 Jun 2003, Department of Water Resources, Sacramento, California.

3. Division of Water Resources. “Resume of Investigations Leading to Approval of the Dam," 3 Jun 1932, Department of Public Works, State of California.

4. Division of Water Resources. “Arch Dam Analysis," 26 Feb 1931, Department of Public Works, State of California.

5. Division of Water Resources. “Analysis of Spillway," 4 Mar 1931, Department of Public Works, State of California.

6. Amador County Public Works. "Argonaut Mine Tailings Dam, Jackson, California," Tami Trearse, Engineering Geologist, 30 September 2010.

7. Goodall, G., E. "Memorandum to Mr. Hawley, Argonaut Dam No. 478 and Kennedy Dam No 477," 14 May 1931.

Photo 1. Aerial View of Argonaut Dam (~2012).

Photo 2. View from Downstream Right Abutment Looking Towards Left Abutment (1931).

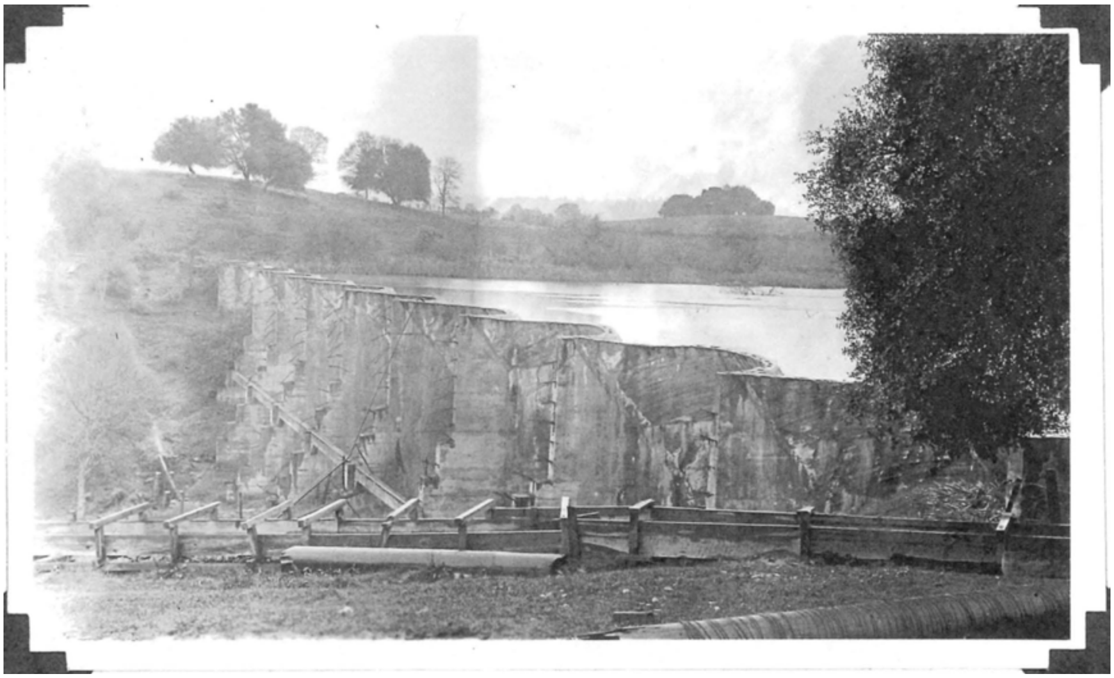


Photo 3. View from Downstream Left Abutment Looking Towards Right Abutment. Spillway Sluice Box in Foreground. Concrete-Box Spillway Not Shown. (1931).

Photo 4. View at Downstream Base of Dam Showing Excessive Vegetation Growth.

MEMORANDUM FOR: Dam Safety Section (ATTN: K. Pattermann)

SUBJECT: Argonaut Multiple Arch Dam, Jackson, California

1. Introduction

On July 9, 2013, an inspection of the Argonaut multiple arch dam was performed. The inspection team included Chris Abela PE (USACE Structural Engineer), Ken Pattermann GE (USACE Geotechnical Engineer), Dan Shane (EPA), and three members of the US Coast Guard Strike Force team. For this memo unless stated otherwise the orientation of right and left is based on facing the downstream direction.

2. Background

The Argonaut dam is a multiple arch concrete dam that was constructed around 1916 for the purpose of storing mining tailings. The dam, from historic documents, was stated to be 420ft long and 46ft tall at its highest point and ranging in thickness from 30” at the base to 12” at the top. In addition, the dam consists of 13 arches, which were reinforced with a 1” or 1 1/8” diameter hoisting cable that passed through arches and buttress walls. Historical documents provided an inspection history of the dam from 1930 to 1933. The dam is believed to be under the jurisdiction of Amador County.

3. Site Conditions and Inspection

Dense vegetation obstructed the team’s ability to visually inspect the dam. Only 3 arches, presumed to be arches 9, 10, and 11, were accessible for inspection from the top of the dam, and 3 arches presumed to be arches 1, 9, and 10 were accessible for inspection from the base of the dam, see Figures 1 & 2.

3.1. Concrete Features and Condition

3.1.1. Arches

The top surfaces of the concrete arches showed signs of wear possibly due to water running over the dam and or possibly due to freeze thaw cycles, see Figure 3. The downstream end of arches 9, 10, and 11 had signs of efflorescence staining and algae build up, indicating that the dam has been consistently leaking over time, see Figure 4. A crack was noticed at the upper left corner of arches 9 and 10 (facing downstream), which may be consistent with observations made from the inspection in February 1933, where G.F. Engle, a previous inspector, noted a crack at the right end (facing upstream) of arch 9, see Figure 5. In addition, at the base of the dam rust staining was visible on the downstream face of arch 9 where the cable had little or no concrete cover, see Figure 6.

3.1.2. Buttress Braces

The concrete braces extending between buttresses showed signs of significant spalling. The spalling was most likely due to the corrosion of the embedded cable, which over time caused the concrete to crack and eventually spall, see Figure 7. Although significant spalling was only observed on the braces associated with arches 9 and 10, it is speculated that all buttress braces are in a similar condition. The brace for arch 11 was not visible due to vegetation overgrowth. The buttress brace dimension was determined to be 12”x 22”.

3.1.3. Buttresses

The buttresses were sounded with a geologic hammer and no hollow spots were audible. The concrete surface although stained with efflorescence and algae growth appeared to be in satisfactory condition given the age of the dam. A crack was noted in the buttress wall that extended from the base towards the top of the buttress, see Figure 8. Exposed aggregate on the buttress surface was also noted in various areas, see Figure 9. The upper portion of Buttress 1 was found to have completely cracked off and hanging from its cables, see Figure 10.

3.1.4. Abutments

The right abutment was covered in moss and algae, but what was visible appeared intact and in satisfactory condition, see Figure 11. In contrast the left abutment was missing and presumed to have been destroyed during the construction of a road. Cables protruding from the ground provided some evidence of where the right abutment could have rested, see Figure 12. In addition, it was observed that a portion of an arch that connected Buttress 1 and the left abutment was also destroyed during the road construction, see Figure 13.

Figure 1 Dense Vegetation Obstructing View of Arches

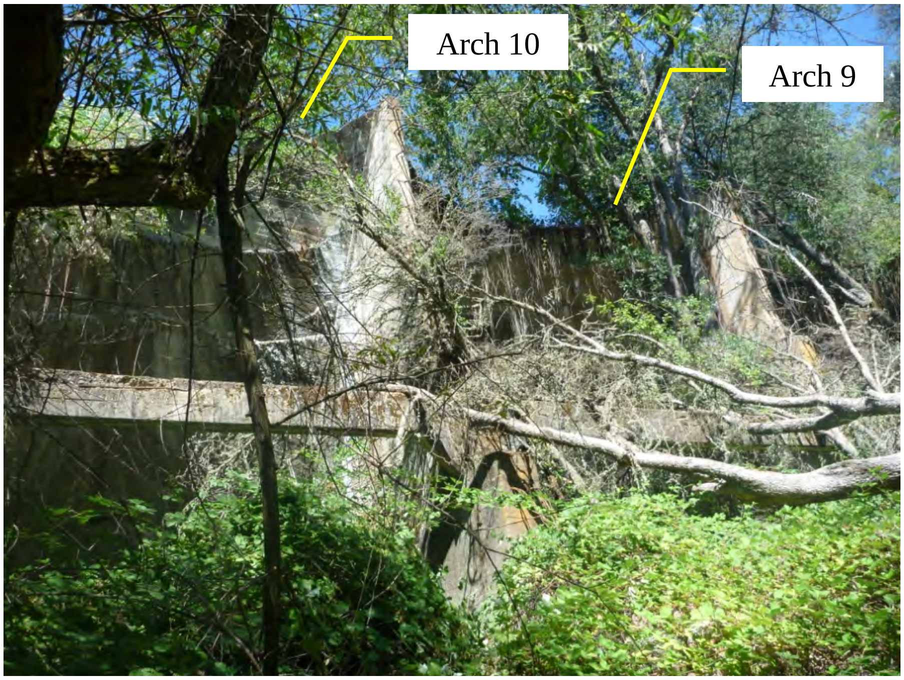


Figure 2 Arches 9 and 10

Figure 3 Worn Surface of Concrete (Typical)

Figure 4 Typical Efflorescence on Arches and Buttress Walls

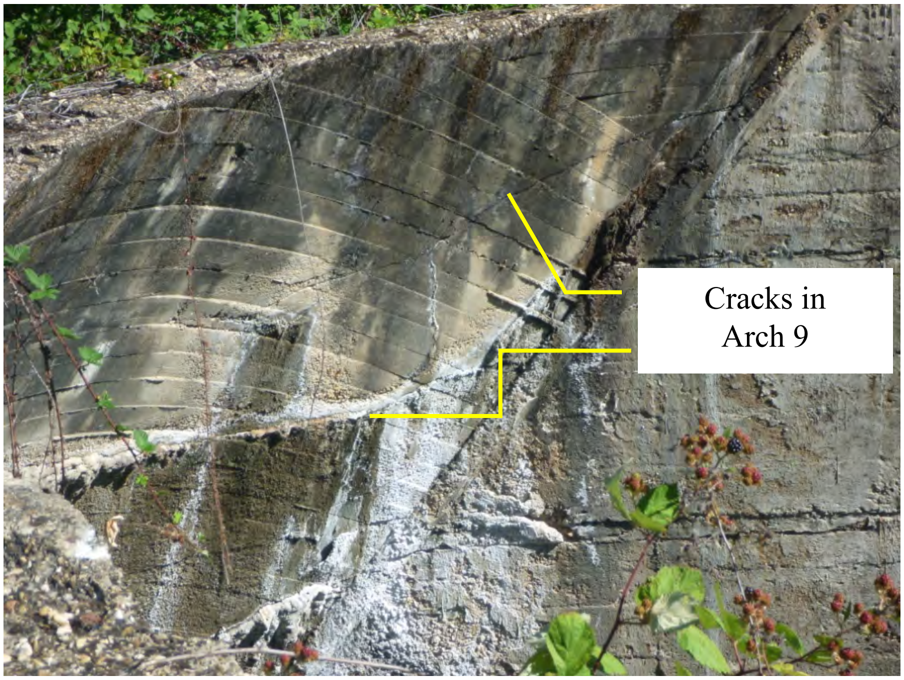


Figure 5 Crack in Arch 9 (Typical)

Figure 6 Rust Staining from Embedded Cable

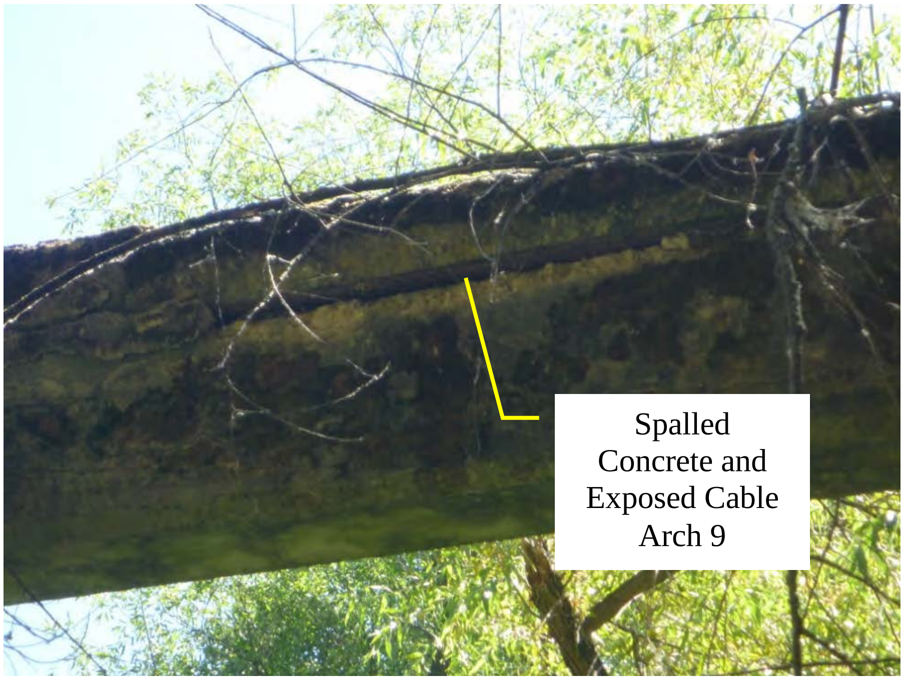


Figure 7 Buttress Brace with Spalled Concrete and Exposed Cable

Figure 8 Crack in Buttress Wall of Arches 9 & 10

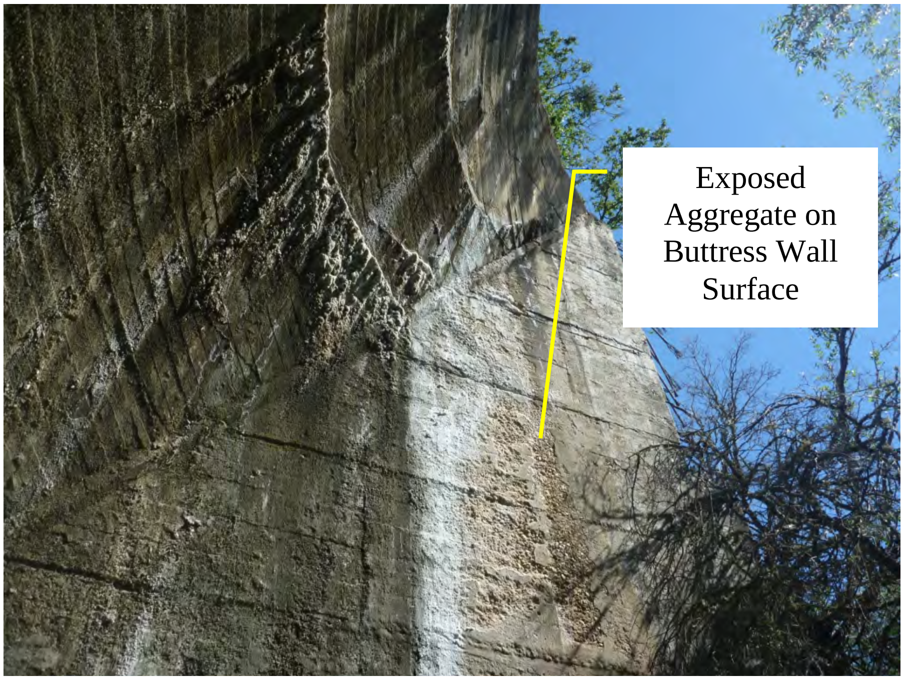


Figure 9 Exposed Aggregate of Buttress Wall

Figure 10 Upper Portion or Remains of Buttress 1

Figure 11 Right Abutment

Figure 12 Possible Remains of Left Abutment

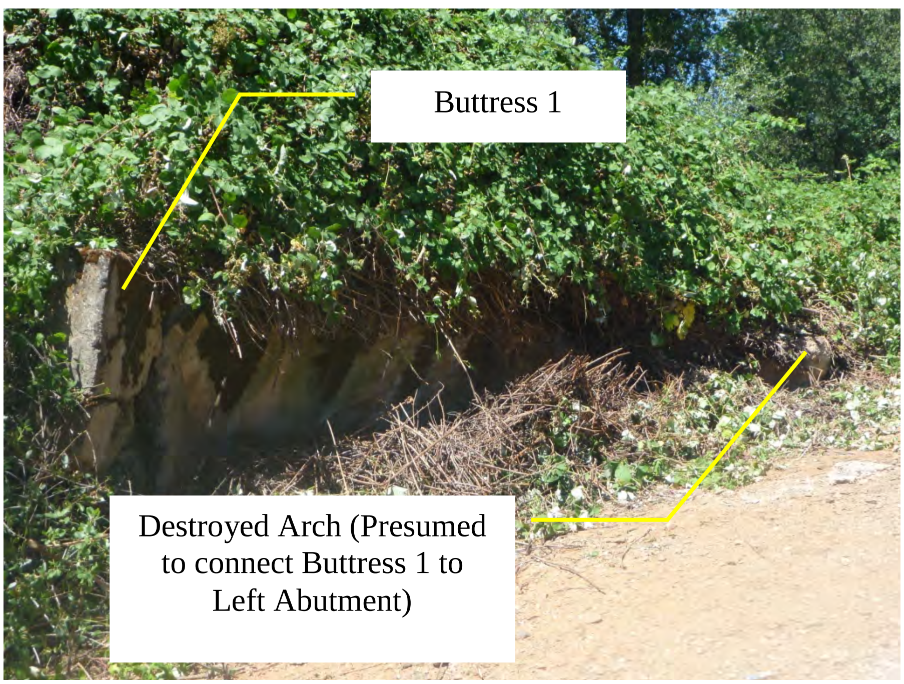


Figure 13 Arch Connecting Buttress 1 to Left Abutment

4. Historic Performance of Arch Dams

According to the Federal Energy Regulatory Commission (FERC) of 600 dam incidents (including failures) only 2 have involved multiple arch dams. These two multiple arch dam failures included: Gleno Dam in Italy, which was completed in 1923 and failed only 30 days after filling, and Leguaseca Dam in Spain, which was completed in 1958 and failed in 1987 due to deterioration from aging and freeze thaw cycles.

According to (FERC, 1999) from a seismic perspective arch dams have an excellent record of performance with respect to earthquake motion. No failure has occurred in an arch dam as a result of an earthquake. However, it should be noted that very few MCE earthquake have occurred closed enough to arch dams to truly test their performance and durability. In addition, (FERC 1997) also noted that buttresses, like those used in multiple arch dams, when unreinforced or unbraced, are susceptible to damage from lateral earthquake loading. This statement is especially concerning in regards to the Argonaut dam whose buttresses are essentially unreinforced and whose lateral braces were found to be deteriorating. It is important to note that for a buttress to be considered reinforced the reinforcement pattern should offer confinement and allow the buttress to fail during a seismic event in a ductile manner. The existing cables embedded within the Argonaut dam do not offer any confinement and it is probable that during a significant seismic event a brittle failure mode could develop within the buttresses.

5. Recommendations

From observations made during the site visit and given the close proximity of buildings and other structures downstream of the dam, the following are the structural recommendations for Argonaut dam:

a) The dam should undergo a preliminary seismic evaluation in accordance with USACE standards.

b) Vegetation downstream of the dam should be cleared and removed exposing the remaining condition of the arches, buttress braces, and buttress walls.

c) A second site visit after the vegetation has been cleared should be performed by a structural engineer to investigate the condition of the remaining 10 arches that could not be previously inspected.

d) If the seismic study is funded, several concrete core samples should be taken to determine the compressive strength of the existing concrete. Sampling of the concrete cores should be performed under the guidance of the appropriate ACI codes and ASTM standards.

6. Cost Estimate

Preliminary Seismic Study:

a) Perform hand calculations, construct 3D FEM model, perform analysis, and provide assessment report: $15, 921.60 (160hrs)

b) QC review of calculations, FEM model, and report: $5,168.80 (40hrs)

c) Final approval and review: $1, 335.90 (10hrs)

d) Follow up site visit: $995.10 (10hrs)

Final Cost Estimate: **$23,421.40**

7. References

1. Federal Energy Regulatory Commission, (1997) “Chapter 10 Other Dams” Engineering Guidelines for the Evaluation of Hydropower Projects.

2. Federal Energy Regulatory Commission, (1999) “Chapter 11 Arch Dams” Engineering Guidelines for the Evaluation of Hydropower Projects.

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Inspection and Engineering Analyses of Argonaut Tailings Storage Dams

Updated 07/30/2013

Engineering Division Personnel	Hourly Labor Rate $	Project Coordination / Meetings hrs	Field & Drilling Inspection hrs	Engineering Analyses hrs	Report Writing hrs	Report Review / Correction hrs	Subtotals $
Engineer 1 (KP) - Geotechnical (L2L0710)	132	16	24	80	40	8	22176
Engineer 2 (KH) - Geotechnical (L2L)	105	8	24	60	32	8	13860
Geologist (TK) - (L2L0710)	143	8	24	32	24	8	13728
Engineer 3 (JC) - Supervising (L2L0710)	166	2	4	7	4	2	3154
Vehicle							105
	Subtotal hrs>>	34	76	179	100	26	415
	Subtotal $>>	3284	6352	18022	9304	2228	$ 53,023
						Overhead>>	$ 7,953
						subtotal>>	$ 60,976

Geotechnical Field Investigations:	
SPT Drilling and Undisturbed Sampling (2 boreholes to 80 feet each, and 2 to 60 feet ea.)	28000
ASTM Lab Testing [gradation + hydrometer (16), plasticity (16), triaxial (4)]	10000
Concrete Core Sampling (4 - 6"x12")	4000
Concrete Cores UCS Lab Testing (4) - ASTM C39	400
Subtotal	$ 42,400

Structural Engineering Estimate*	$ 24,000
subtotal	$ 127,376
Contingency (30%)	$ 38,213
Grand Total	**$ 165,589**

Purpose: Inspection and Engineering Analysis for EPA as to the safety condition of the dams. The site contains a concrete multiple arch tailings storage dam, that is filled to the crest with mine tailings, and an upstream earth tailings dam. An initial site visit of the concrete dam was conducted on 9 July 2013 and a memo prepared. Access to the site for the concrete dam was difficult due to trees and bushes. Next Site Inspection scheduled for week of 12 August 2013.

USACE Major Tasks: Participate in conference calls, review project documents, conduct field inspections and drilling, conduct slope stability and seepage analyses of earth tailings and concrete dam. Write a letter report that includes field investigation findings, geology assessment, and engineering analyses. Geotechnical field investigations and testing of materials will be separate task orders processed through Geology section and Materials unit, which will have to prepare more detailed estimates once approval to proceed is obtained.