US Army Corps of Engineers

Sacramento District

Heavy Rainfall Inspection Monitoring Report 2015

Argonaut Mine Dam Inspection and Site Support
Amador County, California

EPA / USACE Superfund Program
Work Authorization Assignment No.04
WA Revision No. 05 11-18-2014

Report Date: 1-20-2016

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1. Introduction

On December 31, 2015, an inspection of the Argonaut multiple arch dam was performed, to investigate the condition of the dam holistically with special interest given to the concrete arches, buttress walls, and struts. The inspection team included Chris Abela PE (USACE Structural Engineer), Dan Shane (EPA), and representatives of the city of Jackson and the Department of Toxic Substance Control (DTSC). This inspection was performed due to recent storm events in which a substantial amount of rainfall had occurred over a short period of time. The weather during the inspection was clear with the temperature in the mid to high 50s. References in this memo to right and left are made from an orientation facing in 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 32ft o.c., which were reinforced with a 1” or 1 1/8” diameter steel wire rope that passed through arches and buttress walls. Historical documents provided an inspection history of the dam from 1930 to 1933. Water overtopping the dam appears to be a common occurrence given the erosion on the tops of the arches and photos of water overtopping the dam as recently as 2006. The dam sits approximately a quarter mile from businesses within the Jackson community on private property owned by Ms. Van Horn. Current access to the dam is being coordinated with Mr. Ken Foley, the property owner’s lawyer.

3. Seismicity of Argonaut Dam

According to the USGS 2008 Hazard Map (PGA, 2% in 50 years) Amador County is located in a moderate to low seismic region.

4. Site Conditions and Access

Compared to previous inspections, the site condition and access was significantly improved. The arches were easier to inspect and a close up hands on inspection can be performed for the majority of the arches.

4.1. Concrete Features and Condition

Appendix B provides an upstream elevation view of the dam with the arches, buttresses, and struts all numbered and locations identified.

4.1.1. Arches and Buttress Condition Assessment

As noted in the previous inspection reports, the top surfaces of all the concrete arches showed signs of erosion possibly due to water running over the dam and/or possibly due to freeze thaw cycles. All downstream faces of the arches have signs of efflorescence, staining from corrosion of the embedded wire ropes, and algae build up indicating that the dam has consistently seen water during its service life, see Figures 2 and 3. It is postulated that the areas of the efflorescence, rust staining, and algae/sediment build up coincide with locations of the wire rope. The wire ropes, due to improper concrete cover, may have corroded causing cracks in the concrete, which lead to efflorescence, rust stains, and water to leach out. Many of the arches also were observed to have large piles of soil between the buttresses. It is unclear if the soil piles were put their intentionally during the construction of the dam (due to leftover formwork), or if it was deposited over time during overflow events.

The following describes the conditions of each arch noted in the field (Appendix A contains the field notes):

- *Arch #1*: Found to be partially demolished from road construction and remnants possibly buried. The right buttress wall is severely damaged with several large pieces of concrete hanging away from the buttress and held in place by only the embed cable.

Figure 1 Condition of Arch #1

Figure 2 Condition of Right Buttress Wall of Arch #1

- *Arch #2*: Found to have several large cracks through the arch with active seepage. The right buttress wall has delaminated sections of concrete. Appendix A illustrates the locations of some of the large cracks within the arch. These cracks do not appear to be new due to the large accumulation of algae and sediment build up suggesting that water leakage thru the cracks has occurred consistently over the years. See Figure below.

Figure 3 Condition of Arch #2

- *Arch #3:* Observed to have similar cracks in the arch as Arch #2. The top edge of the arch in multiple locations was also noted to have small concrete spalls. Other locations on the right buttress were also observed to have concrete spalls that have exposed the embed cables. See Figure below.

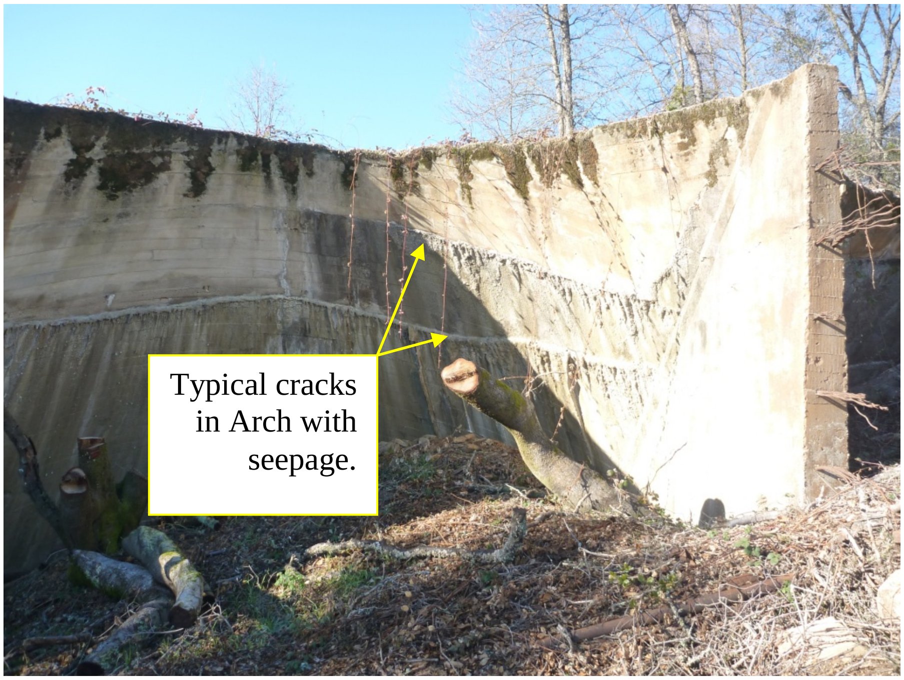

Figure 4 Condition of Arch #3

- *Arch #4:* Observed to have similar cracks in the arch as discussed previously for Arches #2 and #3. Large cracks were observed along the upper portion of the buttress walls and minor spalling also was found along the arch edge. These conditions do not appear to be new. See Figure below.

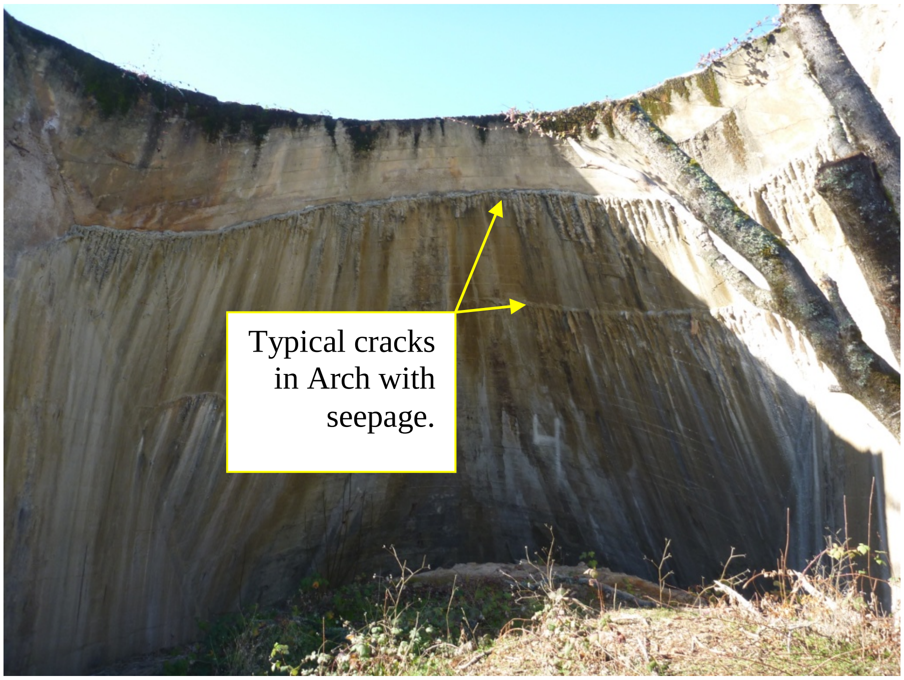

Figure 5 Condition of Arch #4

- *Arch #5:* Typical cracking and active seepage of the arch was again observed. However, a large diagonal crack in the right buttress wall was found, which was not found to be typical among the previously inspected arches. This crack should be monitored closely with the use of crack gauges. The type of crack gauges to be used and the location to position the gauge is discussed in the recommendation section. The figure below illustrates the crack, which was found to disappear possibly into the foundation 13'-6" from the visible arch, see Appendix A. The surface of the right buttress was found to be flaky possibly due to years of freeze thaw damage. The tie beam connecting the two buttress walls was found to be in poor condition. As noted in the previous inspection reports and the Phase I and Phase II inspection reports, the left support of the tie beam has cracked completely through and only the embed cables appear to be holding the tie beam in place. Severe cracking with extensive spalling, which exposes much of the embed cables to the elements was observed along the length of the tie beam. Freeze thaw damage was also observed on the buttress steps. The figures below illustrate some of the observations made for this arch.

Figure 6 Condition of Arch #5

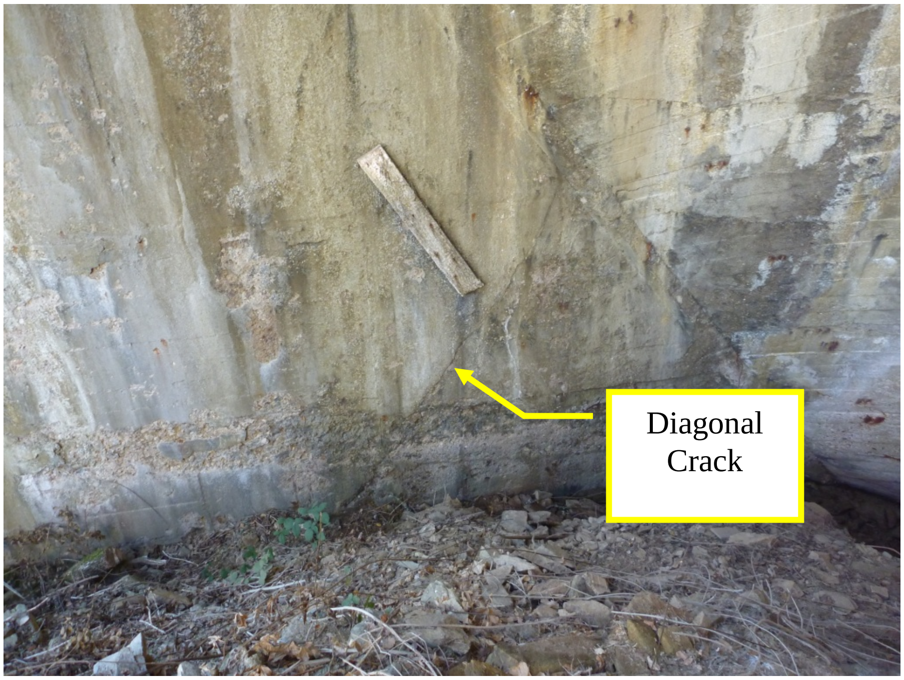

Figure 7 Right Buttress Wall of Arch #5 with Diagonal Crack

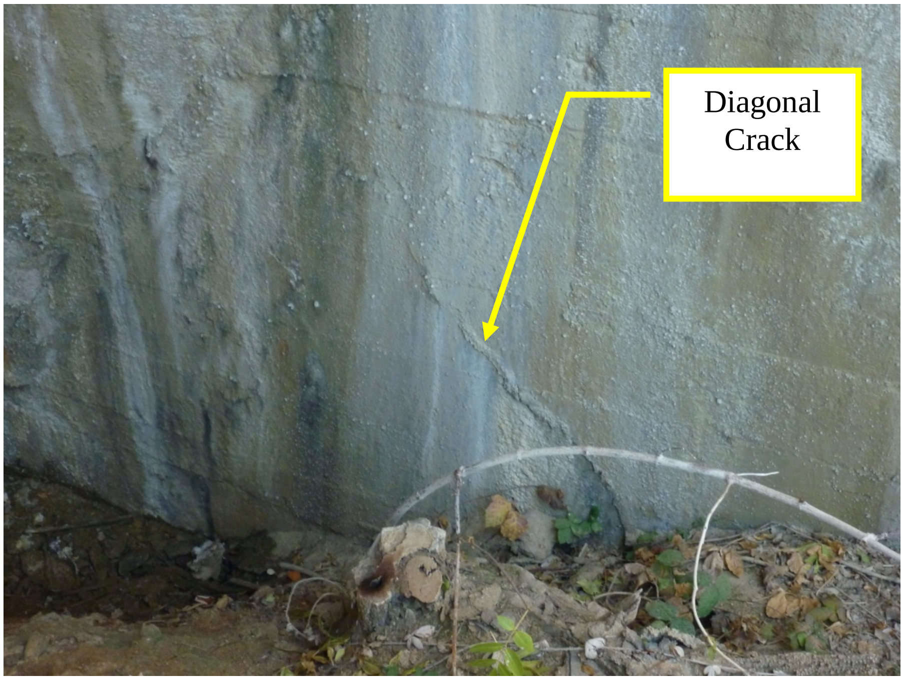

Figure 8 Left Buttress Wall of Arch #5 with Diagonal Crack

Figure 9 Right Buttress Wall of Arch #5 showing signs of Freeze Thaw Damage

Figure 10 Failed Tie Beam extending between Buttresses of Arch #5

Figure 11 Crack between Arch and Buttress Shared by Arches 5 and 6

- *Arch #6:* The diagonal crack observed in the right buttress of Arch #5 was found to extend through the entire thickness of the buttress wall shared between Arch #5 and Arch #6. This is concerning as there is little to no modern reinforcement within the buttress to maintain structural integrity across this crack. It is likely that the embed cables do cross the crack and provide some level of stability, but nonetheless this crack should be closely monitored for changes and movement. Further recommendations regarding this crack will be discussed later. The buttress shared by arches 5 and 6 appeared to have a very slight bow to it based on a visual observation of the tie beam line extending across the dam. However, this bow may also be a result of construction and not necessarily dam movement. The tie beam showed extensive cracking and was found to be in poor condition. The figures below illustrate the various conditions found at Arch #6.

Figure 12 Condition of Arch #6

Figure 13 Possible Freeze Thaw Damage on Buttress Wall

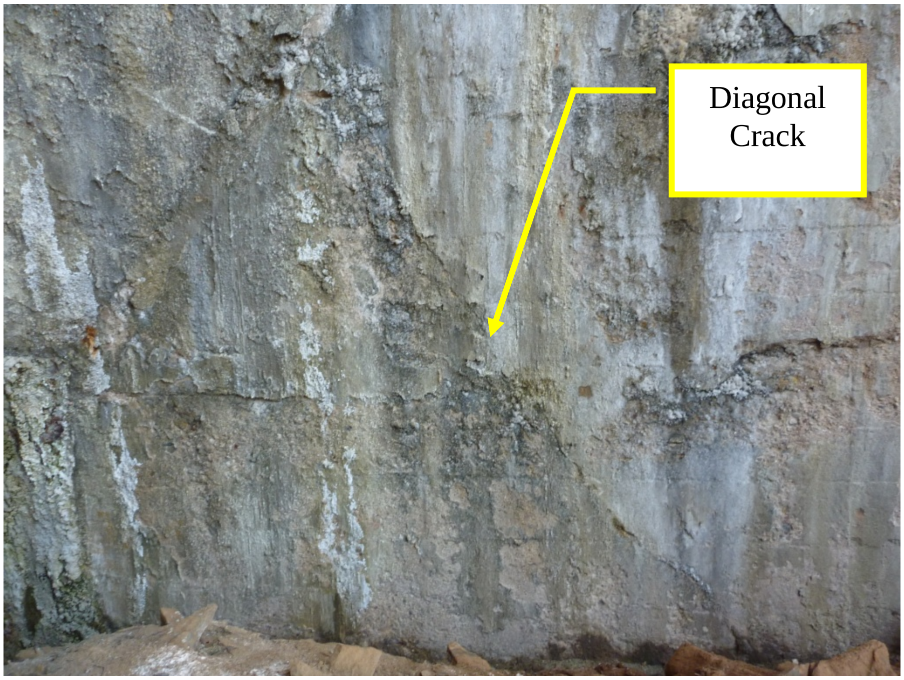

Figure 14 Diagonal Crack Identified on Right Buttress Wall of Arch #5 Extended through the entire Buttress Wall and into Left Buttress of Arch #6

Figure 15 Seepage Coming through possible Diagonal Crack on Right Buttress Wall of Arch #6

- *Arch #7:* Due to extensive blackberry overgrowth this arch could not be inspected as well as the other arches. The arch was found to have the typical cracking with active seepage dripping through the arch cracks. The tie beam was found to have extensive spalls delamination and cracks with the cables in some locations exposed. The figures below illustrate the condition of Arch #7.

Figure 16 Condition of Arch #7

- *Arch #8:* The tallest of all the arches was found to have a very similar diagonal crack through its left buttress wall as what was observed in the buttress wall shared by Arches #5 and #6. The crack width was found to vary between 1/8" to 3/16". This crack is again very concerning given that this arch is the tallest of the all of the arches and is required to hold back the largest amount of soil and water pressure. The crack requires very close monitoring and further actions are discussed in the recommendations section. The right buttress wall was also noted to have a very similar diagonal crack. Other observations made of Arch #8 included typical cracking within the arch downstream face and freeze thaw damage along the exposed faces of the buttress walls. Large spalls, exposed cables, and extensive cracking were also seen along the tie beam. The figure below illustrates some of the observed conditions.

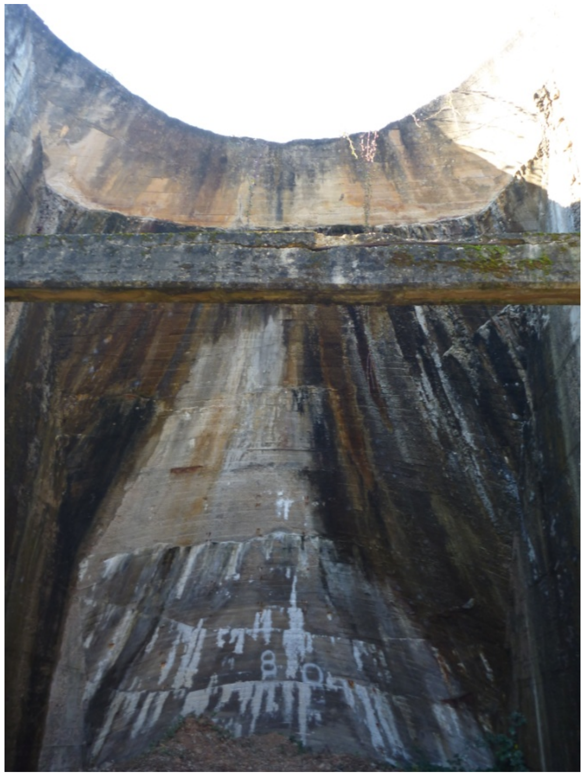

Figure 17 Condition of Arch #8

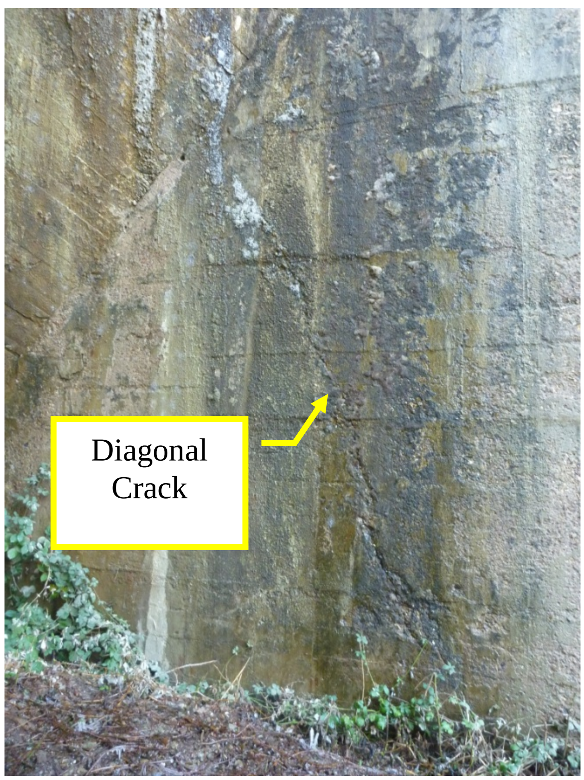

Figure 18 Large Diagonal Crack along Left Buttress of Arch #8

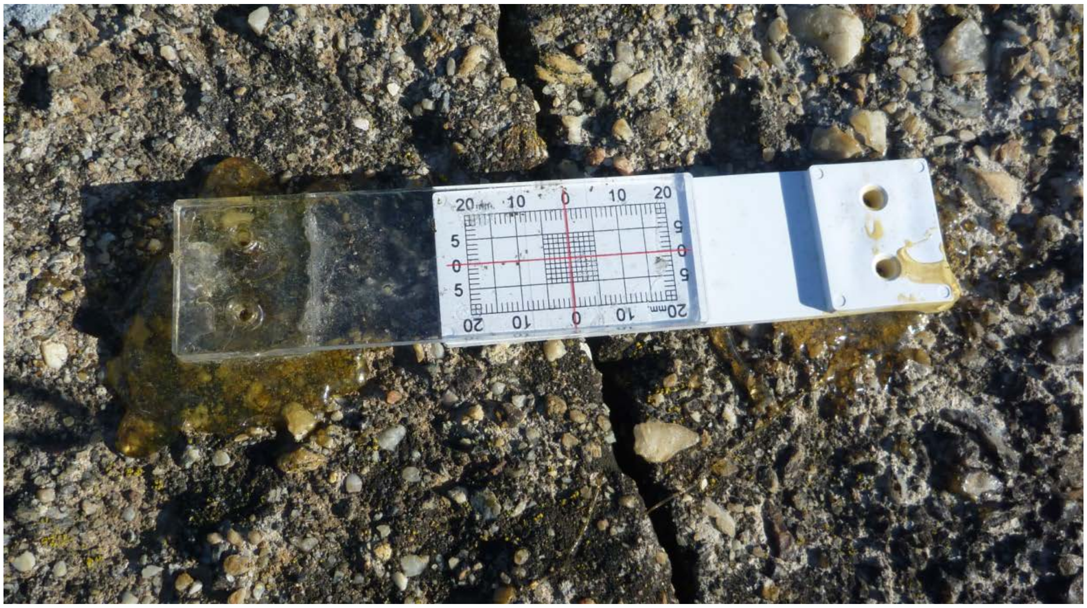

Figure 19 Crack between Arch and Buttress Shared by Arches 8 and 9

Figure 20 Crack between Arch and Buttress Shared by Arches 7 and 8

- *Arch #9:* Typical cracks with active seepage were observed within the arch along with typical freeze thaw damage along the faces of the buttresses. See figures below.

Figure 21 Condition of Arch #9

- *Arch #10:* Typical cracks with active seepage were observed within the arch along with typical freeze thaw damage along the faces of the buttresses. See figures below.

Figure 22 Condition of Arch #10

- *Arch #11:* Observed to have a hole through its right side, which does not appear to be a recent development due to the buildup of material beneath it. The hole diameter was approximately seven inches. This was noted in the previous inspection reports. During the inspection water was found to be actively draining through it. The arch also contained typical cracking seen in the other arches along with active seepage, see Figures below.

Figure 23 Condition of Arch #11

- *Arch #12:* Typical cracks with active seepage were observed within the arch along with typical freeze thaw damage along the faces of the buttresses. See figures below.

Figure 24 Condition of Arch #12

Figure 25 Right Buttress of Arch #12

- *Arch #13: Buried and could not be inspected.*

4.2. Survey Results

Appendix B contains the results of the baseline survey performed on October 20, 2015 and subsequent survey conducted on January 4, 2016 as part of the heavy rainfall inspection. Due to safety concerns caused by heavy rains (extremely muddy and slippery), the survey team could not perform the vertical survey.

Details of the survey equipment and methods including tolerances, are provided in the original survey report, Structural Monitoring Surveys, Argonaut Mine Dam Inspection and Site Support, dated November 19, 2015.

In order to make a more definitive observation on whether or not the dam has moved, more survey data is needed. The dam should continue to be monitored and survey data collected following heavy rain events (typically in the winter) and the summer, which will provide survey data during the cold and hot seasons. This data will help determine what seasonal and or water differential movements the dam experiences.

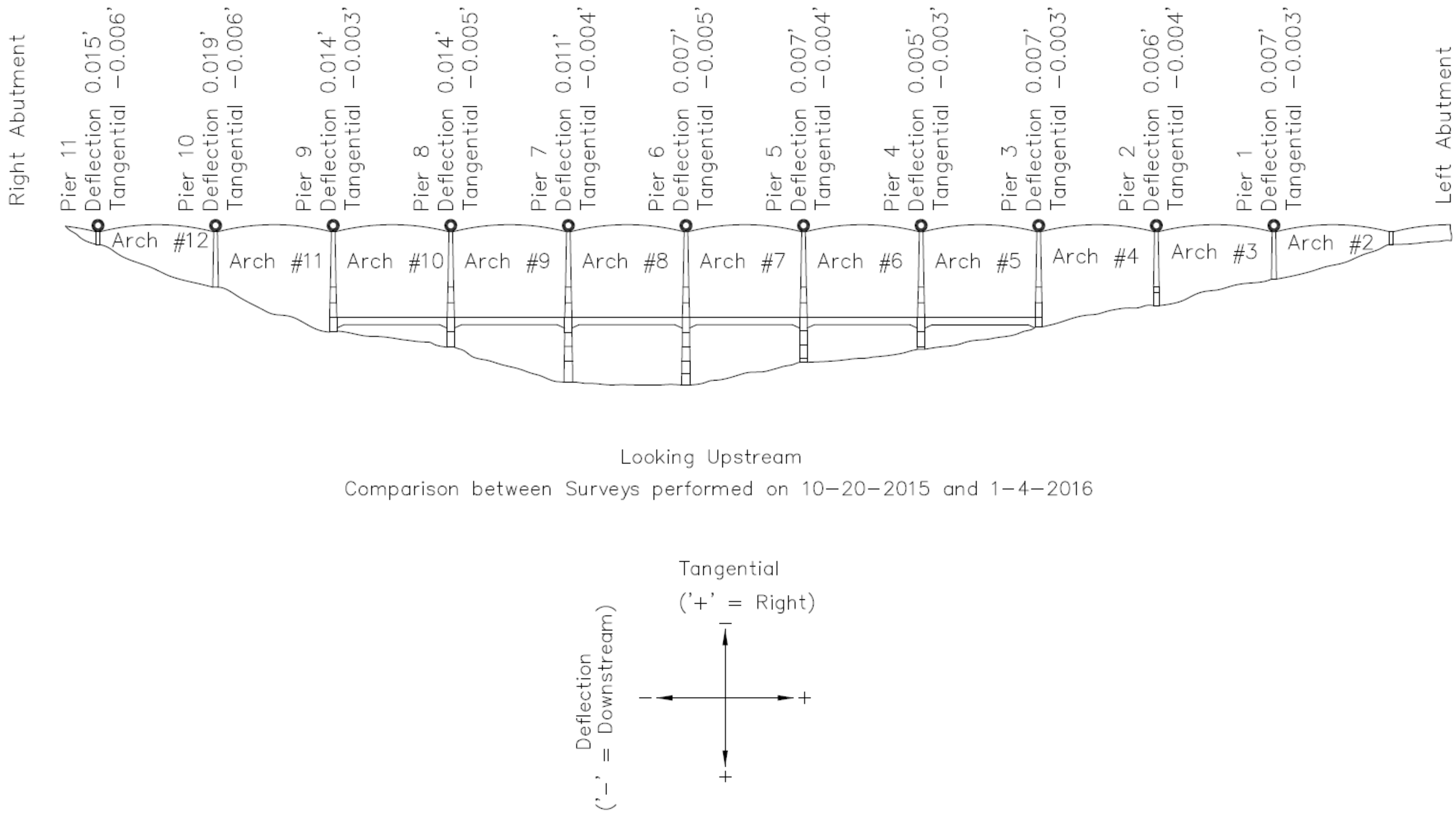

Figure 26 Survey Data for Various Pier

5. Conclusions

Given the relatively close proximity of the dam to businesses, condition of the existing struts, and the fact that the dam is unreinforced, continued monitoring of the dam's overall stability is warranted. As detailed in the Phase I and Phase II stability evaluation reports the dams overall stability should be improved to within acceptable safety factor values based on USACE guidance. Until this recommendation can be completed, close monitoring of the dam during long heavy rain events is recommended along with an annual condition assessment inspection of the dam. This translates to at a minimum one annual inspection and at least one special inspection during heavy rain events possibly more. It is recommended that the inspections be schedules during different times of the year to gather data and assess the dam's movement. The next annual inspection should be performed in July-August time frame. Special inspections will most likely be held during the winter months of December and January when rainfall is likely to be the heaviest.

6. Recommendations

The following are recommendations on how to begin evaluating the Argonaut dam's stability:

a) Install crack gauges (Humboldt H-2936A or equal) on the buttress piers at the designated locations below. Install crack gauges in pairs (one primary and one redundant) following manufacturer installation recommendations especially in regards to if screws or epoxy should be used. See figures below.

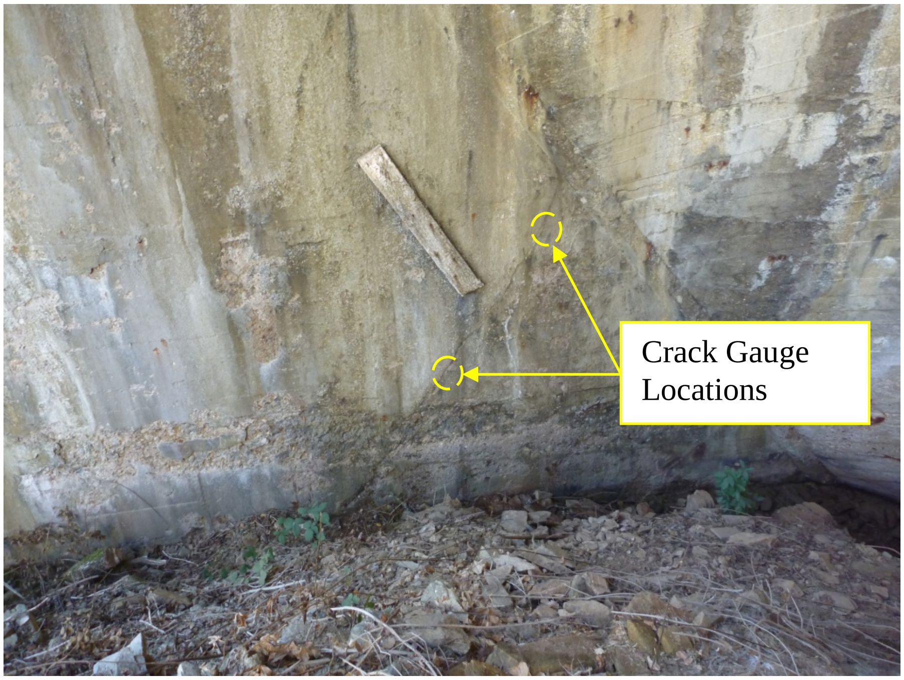

Figure 27 Pier Shared by Arches 5 and 6

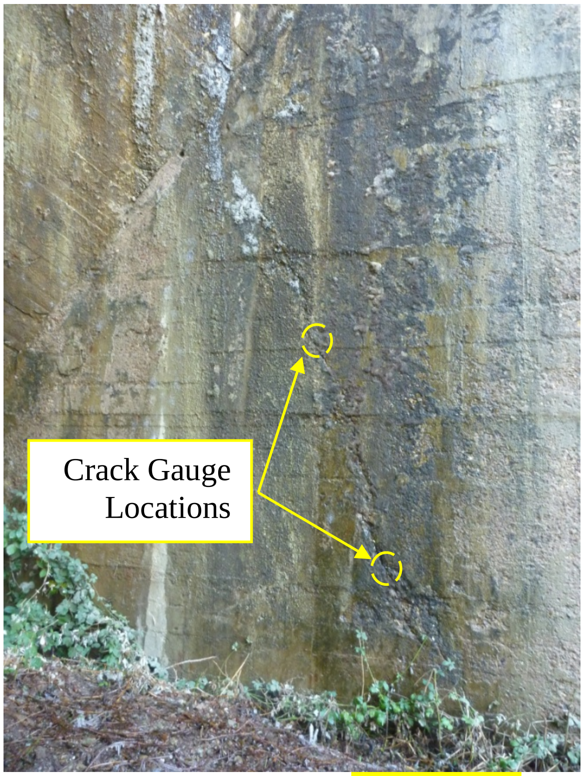

Figure 28 Pier Shared by Arches 7 and 8

b) Clear vegetation at Arch #7 to allow for inspection of both buttress walls and arch face. See figure below.

Figure 29 Vegetation overgrowth at Arch #7

7. References

1. ER 1110-2-1156, (2011). Engineering Regulation *Engineering and Design -Safety of Dams - Policy and Procedures*, United States Army Corps of Engineers, Washington, DC.
2. EM 1110-2-2100, (2005). Engineering Manual *Stability Analysis of Concrete Structures*, United States Army Corps of Engineers, Washington, DC.

3. USACE (2013) "Argonaut Tailings Storage Dam – Initial Inspection", United States Army Corps of Engineers Memorandum, July 30, 2013.

4. USACE (2013) "Argonaut Tailings Storage Dam – Second Inspection", United States Army Corps of Engineers Memorandum, November 15, 2013.

Appendix A

Appendix B