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DEERE & AULT
CONSULTANTS, INC.

March 24, 2016

Mr. Elliott Petri, P.E.
Weston Solutions, Inc.
1435 Garrison Street, Suite 100
Lakewood, Colorado 80215

Re: Red and Bonita Mine Bulkhead Closure Evaluation; D&A Job No. CG-0628.001.00

Dear Mr. Petri

This letter is in response to a request by the US Environmental Protection Agency (EPA) to comment on the Colorado Division of Reclamation, Mining, and Safety (DRMS) report "*Design Basis for Water Impounding Concrete Bulkhead, Red and Bonita Mine, San Juan County Colorado*" dated November 4, 2015. Specifically, we have been asked to comment on the potential impacts of closing the Red and Bonita Bulkhead valve (installed in September 2015) on other adits, bulkheads, and streams in the upper Cement Creek area. To aid in our evaluation, we reviewed mapping and 3D modeling conducted by DRMS and conducted a literature review of geologic maps, papers, and reports on the hydrology and the existing bulkheads. This letter is a revision of our previous report, dated February 17, 2016, and incorporates additional flow data along with text corrections.

The DRMS has done a very thorough investigation of the area including the history, geology, discharges, and mine extents. The geo-referenced 3D model of the various interconnected mine workings is particularly impressive. The DRMS also identified key structures, such as bulkheads and portals, including their elevations. The data is presented very well in their 2015 report. A summary of key structures and elevations is found on **Table 1**.

GEOLOGY

The geology in the upper Cement Creek area has been well documented in numerous reports and geologic maps (see References Section). The Gold King, Red and Bonita, and American Tunnel are all in the Burns member of the Silverton Volcanic sequence. The Burns member consists mostly of intermediate lava flows made of porphyritic dacite, rhyodacite, rhyolite, andesite, and trachyandesite. These rocks are frequently hydrothermally altered to much weaker chlorite, calcite, epidote, and albite. The Burns member is split into an upper and lower member (Burbank and Luedke, 1969) separated by a pumice rich and pebble rich welded tuff that is typically around 25 feet thick. The pebble tuff unit may be a water source or water barricade at its contact with the upper and lower Burns members. A cross-section of the geology along the American Tunnel, near the Gold King Mine, is shown below in the excerpt from Burbank and Luedke, 1969, Plate 6.

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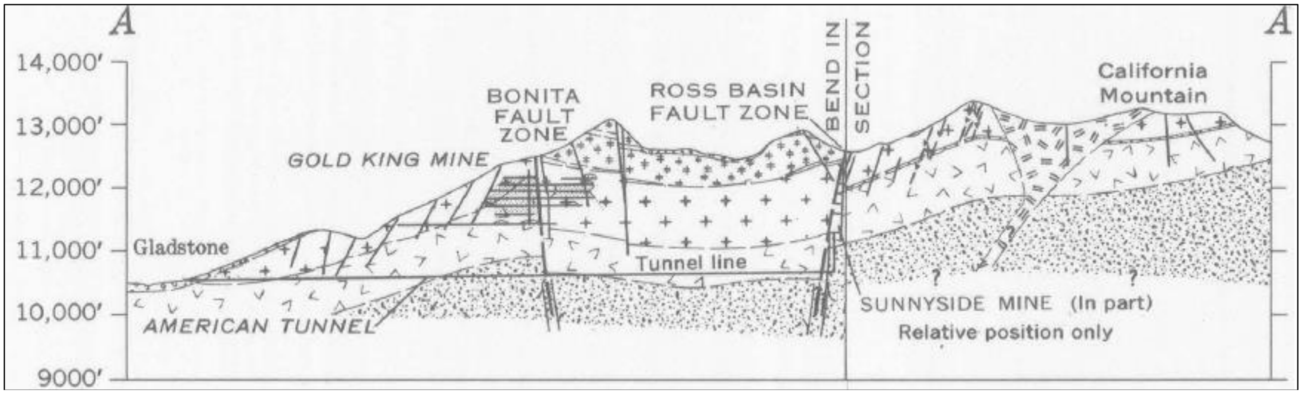
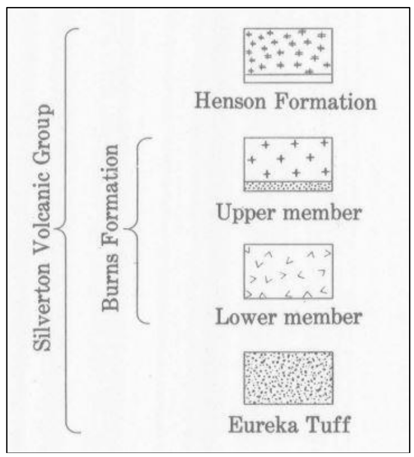




BACKGROUND

The area around the Red and Bonita Mine has been actively mined since the 1870s. Notable mines include the Sunnyside, Gold King, and Mogul. Smaller mines include the Red and Bonita, Lead Carbonate, Adams, and exploratory adits like the 268-21. These mines are shown in **Figure 1**, prepared by DRMS with additions by Deere & Ault Consultants (D&A). Elevations of these mines are included in **Table 1**.

Starting in 1900, the American Tunnel was driven 5,500 feet from Gladstone to a location 800 feet below the Gold King Mine, but to our knowledge was never connected to the Gold King workings. In 1959 through 1961, the American Tunnel was widened to 11 feet wide by 12 feet high and extended to the Sunnyside Mine workings where it became the main haulage and drainage tunnel (**Figure 2**). Hunter (1961) notes an inflow of 900 gpm at 3,000 feet from the portal, corresponding to the North Fork Cement Creek fracture zone. In 1978, Lake Emma broke into the Sunnyside Mine, exposing the upper stopes and increasing the impact of precipitation. In 1991, Sunnyside ceased production.

In 1996 the American Tunnel Bulkhead 1 was closed, sealing the lower drainage from the Sunnyside Mine. Also in 1996, the Terry Tunnel bulkhead was closed, sealing the upper drainage from the Sunnyside Mine. From 1996 to 2000, the mine pool in the Sunnyside rose from elevation 10,600 feet to 11,671 feet, where it remained steady for seven months. In 2001, the American Tunnel Bulkhead 2 was closed, sealing the wet fracture zone. Just before its closure, the water level behind Bulkhead 1 was read for the last time. In winter 2002, the American Tunnel Bulkhead 3 was closed, sealing the surface fracture inflows from the portal to Bulkhead 2. Just before its closure, the water level behind Bulkhead 2 was read for the last time.

In 2003 the Mogul bulkhead was completed. In 2009, a portal closure soil berm with drain pipe was installed at the Gold King Level 7 portal. Note that the purpose of the closure berm was to keep people out of a potentially dangerous mine, not to hold back water. It should not be equated in any way to the water controlling bulkheads installed in the other mines.

In 2011, the Red and Bonita Adit portal was excavated and re-supported, allowing water to flow out in an open channel instead of through the porous talus (URS 2012). In 2012 DRMS investigated the first 682 feet of the adit. In 2013, DRMS mapped all accessible parts of the Red and Bonita mine (Sorenson and Brown, 2015). In 2014, DRMS conducted packer testing in the Red and Bonita at the location of a proposed bulkhead. In September 2015, EPA constructed the concrete bulkhead. Its valve currently remains open.

FLOWS FROM ADITS

While data on water levels behind the various bulkheads is very limited, flow rates from various adits in the vicinity have been tracked at varying intervals. These flow rates give some indication about the groundwater elevations. For example, if no water is flowing out of an open adit, the groundwater table elevation is likely below that adit's underground workings. If the open adit is flowing, an increase in flow rates indicates a higher groundwater table elevation.

The earliest indication of adit flow comes from a 1910 photo of the Gold King Level 7 portal area that shows significant discharge off of the side of the waste pile (Vendl, 2015), similar to today. Photos of the same area in the 1980s show no visible flows. During the enlargement and extension of the American Tunnel in 1959, Hunter (1961) noted flows of 900 gpm from the fracture zone in the existing tunnel. Simon Hydro-Search 1992 notes total flows from the completed American Tunnel reached 2500 gpm (1600 gpm coming from the extension). These facts suggest that the extended American Tunnel drained the groundwater in the Gold King area. The converse may also be true. That is, once the American Tunnel is plugged, the groundwater may return to previous levels and again discharge from the Gold King.

More frequent tracking of flow rates in the area began in the 1990s. **Figure 3** graphs the flow rates from various mines shown on **Figure 1**. In addition, it tracks flow from two abandoned mines south of the American Tunnel, the Blackhawk, and Silver Ledge (also known as Natalie/Occidental). To our knowledge, no flows have been observed or measured from the Adams Mine, Lead Carbonate Mine, or Adit 268-21. **Figure 3** also shows the annual precipitation in the area (1995 through 2015).

The data comes from the NOAA Silverton Meteorological Station. For quick reference, **Figure 3** shows the dates when various bulkheads in the area were shut.

In 1997, the summer after the American Tunnel Bulkhead 1 was closed, flows from both the Silver Ledge and Blackhawk mine increased dramatically. While this suggests some connection, it is actually unlikely given the distance from the Sunnyside Mine, the fact that the Sunnyside Mine pool elevation was lower than the Blackhawk in 1997, and that the flows from Silver Ledge decreased to pre-bulkhead rates by 2012 (average flows from 1991 to 96 were 427 gpm while average flows from 2012 to 15 were 407 gpm). Instead, both the Blackhawk and Silver Ledge Mine flows seem to be tied to precipitation and the associated surface water, not the Sunnyside mine pool.

In 1999, as the Sunnyside Mine pool reached the F Level Brenneman-Mogul bulkheads, discharge from the Mogul Mine portal greatly increased from 17 gpm in September 1998 to 141 gpm in September 1999. Flows then ranged from 100 to 249 gpm until the Mogul Bulkhead was constructed in November 2003. At that point flows decreased to an average of 22 gpm.

None of the adits showed a significant immediate response to the closing the American Tunnel Bulkheads 2 and 3. The Red and Bonita increased flows from 10 gpm in 2002 to 74 gpm in 2004, likely as a time lagged response to bulkhead closures. Between 2005 and 2015, flows from the American Tunnel and Mogul Mine remained relatively steady.

In 2005, discharges from both the Red and Bonita and Gold King Mines increased from tens of gpm to hundreds of gpm. This was likely in response to a rising groundwater elevation inside the mountain. As discussed previously, the most direct cause of the rise was the fact that the American Tunnel was no longer acting as a drain in this area. A regional contributing factor to the rise may have been the Sunnyside Mine pool at 11,671 ft (possibly higher) which acted as a vertical recharge source.

From 2005 to 2010, average flows from both the Gold King and Red and Bonita remained steady at 196 gpm and 257 gpm, respectively. Neither mine showed a reaction to the Gold King portal closure in 2009. From 2011 through July 2015, flows from the Gold King decreased while flow from the Red and Bonita increased. Interestingly, the combined flows from those two adits remained generally constant, just below 500 gpm. This suggests a strong hydrologic connection between the two mines, likely through the vein structures or mine workings on the North Cement Creek fracture zone.

After the uncontrolled release of mine water from the Gold King in August 2015, flows from the Red and Bonita dropped from 516 gpm in July to an average of 408 gpm in August and September, while flows from the Gold King increased from 69 gpm to a steady 551 gpm during the same time period. This is shown in **Figure 4**, a summer 2015 zoomed in view of **Figure 3**. The combined flow of the Gold King and Red and Bonita increased from an average of 444 gpm (2010 to 2014) to 563 gpm (June and July 2015) to 959 gpm (August and September 2015), shown in **Figure 5**. This steady flow strongly suggests a rising groundwater elevation inside the mountain, possibly in response to recharge from a return to higher and more normal levels of precipitation after a drought in 2006 through 2012 **(Figure 3)**. Note that surface drainage into the Gold King during spring run-off would be additive to this new base flow.

GROUNDWATER AND THE IMPACT OF CLOSING THE RED AND BONITA BULKHEAD

Installing bulkheads in mines essentially creates underground dams. Just as in surface dams, this necessitates a comprehensive filling plan with associated monitoring and response actions. Such a plan would include a controlled filling of the mine pool behind the bulkhead in a series of stages, say 50 to 100 feet at a time with stops at key elevations associated with nearby structures. Once the level was achieved, the valve would be partially opened to keep the water elevation constant for a given time period (several weeks), while water levels, flows, and seeps in the area are closely monitored. The valve would then be fully closed again and the mine pool raised to the next stage. The incremental filling and monitoring would be repeated until a steady pressure was achieved or a problem developed.

When installing bulkheads and raising the groundwater level, one has to consider how the increased water elevation may influence natural seeps and what potential problems ranging, from minor to severe, may develop. In the Red and Bonita area, minor problems may include additional groundwater seeps or increased flows from existing seeps, particularly along Cement Creek and the North Fork of Cement Creek (depending on their impact to Cement Creek, there might not be a problem). Moderate problems would include flows or increased flows from adjacent mines including the Adams, Adit 268-21, Gold King, and Mogul. A severe problem would be a bulkhead failure in any of the mines. Based on our evaluation of currently available information, groundwater seeps and increased flows from nearby adits are likely while a bulkhead failure is unlikely.

Figure 2 presents a cross-section along the American Tunnel, showing the ground surface, mine workings, bulkheads, and the estimated groundwater elevation. This phreatic surface is based on three points: the Sunnyside mine pool in 2001(last reading), the pressure behind Bulkhead 2 in 2002 (last reading), and the fact that water continues to flow out of the Gold King Mine (550 gpm steady flow over several months strongly suggesting a groundwater connection, not surface drainage). Water pressure behind Bulkhead 3 was, to our knowledge, never measured. The actual current groundwater table is unknown.

Prior to mining the groundwater level was likely a subdued reflection of the topography, but probably with an abrupt change in groundwater levels across the Bonita and Ross Basin Fault zones since faults act as subsurface natural dams across them, resulting in separated compartments of groundwater. With the Gold King and Sunnyside Mines perforating the Bonita and Ross Basin faults, respectively, at numerous locations and at various levels, the current and future groundwater levels in this area may be more continuous across the faults. This effect may be amplified by the primary veins being parallel to the American Tunnel, leading to greater permeability in the northwest-southeast direction (Simon Hydro-Search, 1993). Simon Hydro-Search also estimated a pre-mining and post-mining groundwater elevation 11,500 feet below the Sunnyside Basin. Given the now more continuous regional groundwater table, that elevation could reasonable be assumed post mining along much of the American Tunnel alignment. 11,500 feet would be far above the Red and Bonita portal elevation of 10,957 feet and well above the Gold King portal elevation of 11,436 feet.

One of the conclusions in the DRMS report is that the Red and Bonita Mine is strongly hydraulically connected to the American Tunnel Bulkhead 2 mine pool through a fracture zone in the American Tunnel that is expressed on the surface as the valley of North Fork Cement Creek. This conclusion is based on an evaluation of the geology, mine layout, mine exploration (particularly the wet 640 drift), design assumptions for Bulkhead 2, historical documents, and the fact that the Red and Bonita Mine started discharging water two years after the American Tunnel Bulkhead 2 was closed. This conclusion is reasonable but should be verified by field monitoring.

Following from this conclusion, DRMS and the American Tunnel bulkhead 2 design assume that the North Fork Cement Creek will act as a natural over flow valve, limiting the groundwater elevation to that required to seep into the creek. While seepage into the creek is very probable, it is not clear to what level this will limit the groundwater level rise. If the inflow into the fracture zone is greater than the outflow from the creek seepage, the overall groundwater level may increase in this area and thereby affect the level further inside the mountain. In other words, closing the Red and Bonita Bulkhead will likely raise water levels in the Gold King Mine. This conclusion is supported by the flow evaluation above which showed a strong correlation between the flows from the two adits.

The most likely new source of flow once the Red and Bonita Bulkhead is closed is from the adjacent Adams Mine, 400 feet north and 200 feet above the Red and Bonita. Per mapping by DRMS (2015), the Adams Mine consists of a 300-foot long adit with a 200-foot long drift to the north and a 400-foot long drift to the south. The south drift appears to be the on the same vein as the “764 drift” inside the Red and Bonita. Currently the Adams Mine is dry, likely due to the Red and Bonita intersecting and draining flows coming north from the American Tunnel area. Once the Red and Bonita valve is closed, it will no longer drain that groundwater but allow it to build up and eventually emerge from the Adams. Note that the Adams Mine is approximately 275 lower than the Gold King Level 7 portal.

AMERICAN TUNNEL BULKHEADS

The most critical structures in this area are the bulkheads in the American Tunnel, as shown in **Figure 1** and **Figure 2**. Bulkhead 1 was designed to control the Sunnyside Mine pool. Bulkhead 2 was designed to control inflow from the wet fracture zone that manifests itself as the North Fork of Cement Creek on the surface. Bulkhead 3 was designed to impound minor flows within the first section of the tunnel. The three bulkheads work together to form a system with redundant capacity. A summary of the bulkheads is found on **Table 2**. Based on the design reports and verbal comments by others, the bulkheads were placed in specifically selected locations where the rock was of good quality and jointing was limited.

When designing or evaluating mine bulkheads, one has to consider the possible failure modes. These include hydraulic jacking of the surrounding rock mass, shear failure around the plug, structural failure of the plug, long term disintegration (chemical decomposition) of the concrete, and excessive seepage past the plug (Lang, 1999; Abel, 1988).

Hydraulic jacking occurs when the water pressure behind the bulkhead is higher than the confining pressure of the ground in the area. The hydraulic jacking causes joints in the rock mass to open up, allowing more flow through them. This can be avoided by locating the bulkhead deep underground where the confining pressure (weight of rock above and related horizontal stresses) is high enough to resist the water pressure. Bulkheads 1 and 2 are located deep in the mountain where hydraulic jacking is not a concern. Bulkhead 3 should not have a problem with jacking for its design pressure, but if water pressures were to increase to that of its re-evaluation maximum, hydraulic jacking would be possible, leading to seepage from the portal slope face.

Shear failure occurs when the bulkhead moves along the concrete/rock interface or adjacent rock due to water pressure from the mine pool. This failure can be avoided by locating the bulkhead in good ground, roughening the surface at the rock/concrete interface, and grouting the interface. Shear failures in the bulkheads are highly unlikely.

Structural failure occurs when the concrete plug itself fails due to deep beam bending or shear failure through the reinforced concrete due to water pressure or earthquake induced water hammer. It can be avoided by making the bulkhead long enough and adding rebar reinforcement at both faces. In thick, well designed and well-constructed bulkheads, structural failures would be very unlikely.

Concrete degradation occurs when the acidic mine waters chemically break down the concrete. It can be avoided by using sulfate resistant cement, pozzolans, and permeability reducing admixtures in the mix. All three bulkheads were designed with Type V highly sulfate resistant cement. The as-built reports have conflicting information about whether Type II (moderate sulfate resistance) or Type V cement was used. It is possible that the product was a Type II cement meeting Type V sulfate resistance requirements. Type F fly ash (pozzolan) was also included in the mix. Both blends of cements and fly ash should provide an acceptable level of sulfate resistance. The Construction Certification Report for Bulkhead 2 notes that pH and sulfate levels of the water behind the bulkhead were monitored and that "*The pH and sulfate levels remained well below the severity exposure that the concrete mix was designed for*." Current water quality data is not available. Note that the Red and Bonita Bulkhead was also designed with type V cement.

The most likely failure mode of a bulkhead is seepage and piping. Excessive seepage past the plug occurs when the higher upstream head finds fractures in the downstream rock mass or concrete-rock interface and bypasses the bulkhead. The worst case would be where the gradient and seepage is high enough to wash out material in joints, leading to a piping failure. Seepage and piping can be avoided by placing the bulkhead in good ground, contact grouting the concrete-rock interface, and ring grouting the rock mass prior to installing the bulkhead. If seepage is excessive, it can often be reduced by pressure grouting the affected joints. Seepage and piping is a direct function of the pressure gradient across the bulkhead.

The design of all three bulkheads is based on relationships developed by Garrett and Campbell-Pitt (1961) and adapted by Chekan (1985). The relationships came from full scale testing in South Africa where an experimental bulkhead was constructed in quartzite inside the deep West Driefontein Mine. The researchers installed an un-grouted bulkhead and pressurized the space behind it until water leakage around the bulkhead became excessive. They repeated the experiment each time after grouting the contact between the concrete and rock, grouting the rock mass, and chemical grouting the rock mass. They then calculated the pressure gradient (pressure at leakage/length of bulkhead) for each case. Finally, they recommended applying a Factor of Safety between 4 and 10 to these gradients. Their results are summarized on the table below.

Allowable Pressure Gradient (psi/ft of Bulkhead Length) per Garrett and Campbell-Pitt

Bulkhead Grouting	Factor of Safety		
	1	4	10
None	10	2.5	1
Contact Grouting Only	***228***	***57***	***23***
Rock Mass Grouting	400	100	40
RM Chemical Grouting	887	222	89

The three American Tunnel Bulkheads were designed and constructed with contact grouting only, leading to an allowable pressure gradient of 228 psi/ft. Design pressure gradients and associated factors of safety are summarized below. These pressure gradients are comparable with other mine bulkheads listed in the South African study whose pressure gradients ranged from 21.2 psi/ft to 43.5 psi/ft.

American Tunnel

Bulkhead	Length (ft)	Pressure (psi)	Pressure Gradient (psi/ft)	Factor of Safety
1	25	670	27	8.5
2	10	277	28	8.2
3	11	450	41	5.6

Based on our review of the as-built reports, we are somewhat concerned about the contact grouting carried out for the American Tunnel bulkheads. It is standard practice in civil engineering for high pressure hydraulic structures to grout contacts to a pressure somewhat higher than the design head of the structure. That way the bulkhead and surrounding rock have been treated to a pressure in excess of design pressure, and leaks developed under that pressure have been sealed with grout. Garrett and Campbell-Pitt recommend grouting to 2.5 times the design static water pressure. In the West Driefontein Mine experiment, the concrete-rock interface was grouted to 3000 psi. Garrett and Campbell-Pitt also recommend grouting a zone around the plug to a depth of at least 20 feet and even greater depth in bad ground.

For Bulkhead 1, the design pressure is 670 psi. The construction certification report by Sunnyside Gold is missing some pages that may discuss the contact grouting. The construction observation report by Abel, included in the certification report, notes that "*Only contact grouting of the bulkhead/rock interface, at the specified 100psi to 500psi pressure, needs to be completed*." Based on Abel 1988, the grouting was probably limited to the crown and did not penetrate the rock mass to any significant depth.

For Bulkhead 2, the design pressure is 277 psi. According to its construction certification report, it was grouted to *200+ psi with very little grout take* on August 30, 2001. The bulkhead valve was closed the next day. *On September 15, 2001 additional low pressure grouting was successfully completed, minimizing seepage that increased under pressure along the contact area*.

For Bulkhead 3, the revised design pressure is 450 psi. The construction certification report states that one ring of nine holes was drilled to intersect the rock contact along the perimeter at the midpoint of the bulkhead. It goes on to state that *"Each hole was pressured to 200 psi with very little grout take although one series of holes appeared to take grout into the formation. These holes were drilled on successive days and grouted until refusal."* No information is provided about which holes took and how much. The report continues with "*The construction pipe was permanently closed on December 3 2002 and additional formation grouting was done downstream of the bulkhead for the remainder of the week. Very little grout was accepted during this process*." No information is provided regarding grout locations, drill hole depths, quantities, and effectiveness in reducing flows. The report also does not state why the formation grouting was carried out (visible joints, dripping water, grout return from the bulkhead, etc.). We do not suggest that the construction was done improperly, we simply do not know enough to comment. This concern would be mitigated if the downstream side of the bulkhead and tunnel could be visually inspected.

The limitation of the West Driefontein Mine seepage experiment and calculations is that they only consider leakage through the bulkhead, concrete-rock contact, and immediate rock mass. They do not consider seepage or piping through joints or shears parallel to the tunnel, across the plug. The as built documentation does not discuss ground conditions in the vicinity of the bulkheads other than stating that the location was "dry and apparently impermeable rock" (Abel, 2001). Since no ring grouting of the rock formation was carried out, there exists the possibility of seepage or piping though a geologic feature around the bulkhead. The only formation grouting mentioned was downstream of Bulkhead 3, as discussed above. We do know that flow measurements at the American Tunnel portal have averaged near 110 gpm since 2005 with no significant trends up or down during that time period (**Figure 3**). The source of this water is not known. The fact that the flows have remained relatively steady is a good sign. A significant increase or decrease in flows would suggest a seepage/piping problem or blockage between the portal and Bulkhead 3, respectively.

We have reviewed the design and as-built reports for all three American Tunnel bulkheads and generally concur with their stated capacities. The controlling analysis in the design of all three bulkheads was the deep beam bending stress (i.e., avoiding a structural failure). While this analysis produced the lowest factor of safety, it was also based on very conservative assumptions within the ACI 318 code which contains its own factors of safety. In our opinion, the critical design issue is not the structural capacity of the bulkhead, but the seepage around it.

A critical point to consider is that bulkheads, including those in the American Tunnel, were designed to resist a differential pressure across them. On the upstream side the design head is the anticipated mine pool. On the downstream side the design head is 0 (free air). If the head on the downstream side increases, the head on the upstream side can increase by the same amount without affecting the loading on the bulkhead. For example, if one were to construct a bulkhead out of a plastic sheet, its design head would be very low. However, if the head on both sides of the sheet was nearly equal, it could be submerged in hundreds of feet. In the American Tunnel, Bulkheads 1 and 2 have water on both sides, increasing their capacity to resist the head from the upstream mine pools. This is shown in **Figure 2** as the design head and maximum head based on the design head of the downstream bulkhead. The actual head capacity will be between these values.

The cross-section in **Figure 2** shows that the bulkheads were designed with adequate capacity for the anticipated water heads. The problem is that there is no monitoring in-place to check actual groundwater heads and confirm that they are within the design limits. In order to check current groundwater levels, measure the impact of closing the Red and Bonita Bulkhead, and monitor the pressure on American Tunnel Bulkhead 2, a vibrating wire piezometer could be installed in the fracture zone along the North Fork of Cement Creek, near the Gold King waste pile.

The most critical American Tunnel bulkhead in terms of a major discharge is number three, located 375 feet from the portal and the only one to have water on just one side. After its re-evaluation to better as-built conditions, its design capacity was increased to 1,037 feet of head (elevation 11,632, nearly that of the Sunnyside mine pool in 2001). To monitor the pressure on the American Tunnel Bulkhead 3, an option would be to drill and install a monitoring well on the hill above the portal. The well could be installed in the bedrock near the tunnel to measure the surrounding groundwater level or drilled into the tunnel to measure the head directly. The second option would be more accurate, but more expensive since it would require more precise surveyed drilling to hit a specific target. The well would also require a valve and blow out prevention measures in the event of artesian conditions.

The primary concern we have with the American Tunnel is with Bulkhead 3. This concern is based on an unknown head on the bulkhead and the unknown condition of the bulkhead and downstream area. As with the other bulkheads, the most plausible failure mode would be by seepage or piping. The difference is that a piping failure from bulkhead 3 could lead to a dangerous blow out. This concern would remain even if the Red and Bonita Bulkhead were left open.

For high hazard structures such as dams, annual inspections and thorough monitoring are standard practice. In the case of a high pressure underground bulkhead where the consequences of failure would be great, it would be prudent to be able to perform annual visual inspections of the structure. Currently, American Bulkhead 3 is not accessible because the tunnel was backfilled with muck.

Whether or not the Red and Bonita valve is closed, we recommend reestablishing access to Bulkhead 3 by mucking out the American Tunnel from the portal to the bulkhead and installing ground support as needed. Then annual inspections, much like for high hazard dams, could be carried out to look for signs of seepage past or through the bulkhead. If problems were discovered then or in the future, the area could be formation grouted and the bulkhead extended. Clearing out the American Tunnel and surveying it would also aid in establishing the drilling location for tunnel monitoring behind Bulkhead 3.

CONCLUSIONS AND RECOMMENDATIONS

Based on our review and evaluation, we present the following conclusions and recommendations.

Red and Bonita

- The Red and Bonita bulkhead valve should be left open until a comprehensive filling and monitoring program is in place and can be carried out. The valve can be closed and the water pressure brought to 50 feet of head once the following actions are taken:

  - Installing a vibrating wire piezometer in the fracture zone (North Fork Cement Creek) upstream of American Tunnel Bulkhead 2
  - Reading the existing pressure gauge at Mogul Mine Bulkhead (determine if it is still functional and replace if needed)
  - Reading pressure gauges at Red and Bonita Mine Bulkhead
  - Monitoring flow at Red and Bonita, American Tunnel, Gold King, Mogul, Adams Mine, and Adit 268-21
  - Observing and documenting seeps along Cement Creek and its North Fork
  - Preparing Gold King Level 7 Adit and portal area for higher flows (contractor's construction dewatering system must be capable of effectively transferring flow to permanent piping system)

- The Red and Bonita bulkhead can be pressurized above 50 feet of head once the following additional tasks are complete:

  - Installing the flow control structure and instrumentation at the Gold King Portal
  - Installing a monitoring well into the American Tunnel (possibly with pressure gauge) upstream of Bulkhead 3
  - Establishing access to American Bulkhead 3

- Additional support should be installed inside the Red and Bonita Mine, particularly near the portal, to allow long term reliable and safe access to the bulkhead valve and pressure gauge and allow for annual inspections.

- The existing vibrating wire piezometer inside the Red and Bonita bulkhead with its associated data logger, should be calibrated to the pressure gauge at to allow real time tracking of the mine pool and follow the filling plan. Calibration should be checked on a monthly basis.

- After the evaluation, if the decision is made to leave the Red and Bonita bulkhead valve open, the bulkhead will still act as a flow control device, allowing water flows to be limited when needed and mitigating the impact of surges from the mine.

American Tunnel

- Based on their design pressures, the American Tunnel Bulkheads are unlikely to fail in a catastrophic manner. If water pressures were higher than expected, the most likely consequence would be increased seepage past the bulkheads and through the rock mass.

- It is unlikely that the American Tunnel Bulkhead 3 will be directly affected by closing the Red and Bonita Bulkhead. Bulkhead 3 may be affected more generally by the overall increase in groundwater levels in the mountain. This condition can be monitored by installing the monitoring wells described above.

- The American Tunnel Bulkhead 3 has the highest hazard and consequence of failure. The most plausible failure mode would be seepage or piping past the bulkhead, possibly through joints or shears in the rock mass. This risk can be mitigated by re-establishing access to the bulkhead from the portal and conducting annual visual inspections.

- The American Tunnel should be mucked out, if needed, from the portal to Bulkhead 3 (375 feet) with support installed as needed for long term access. The condition of the bulkhead and area downstream should then be closely evaluated and then monitored on at least an annual basis. This action should be taken whether the Red and Bonita valve is closed or not.

- The Red and Bonita should not be pressurized above 50 feet without establishing access to Bulkhead 3.

- Re-establishing access to the bulkhead will also allow better placement of the upstream tunnel piezometer and will reduce the possibility of a blowout due to blockage between the portal and bulkhead.

- If access to Bulkhead 3 cannot be established in the short term but the tunnel piezometer behind Bulkhead 3 is installed and shows low water levels, it may be possible to raise the pressure on the Red and Bonita temporarily above 50 feet. This will require careful and frequent monitoring.

General

- The existing groundwater table in this area is unknown. Based on increased flows since 2005, it appears likely that the elevations have increased since the last mine pool reading in 2001. Piezometers should be installed to establish the current groundwater levels at key locations upstream of American Tunnel Bulkheads 2 and 3 and monitor them for changes, particularly once the Red and Bonita valve is closed. Installing a piezometer in the Sunnyside Mine pool should be considered to measure the current elevation and gain a better understanding of the pool's potential regional impact.

- While the Gold King Mine does not appear to be directly connected to Red and Bonita, the flow correlation indicates that the two mines are hydrologically connected. Raising the overall groundwater table by closing the Red and Bonita valve will likely increase flows in the Gold King. Hence, the Red and Bonita valve should not be pressurized to more than 50 feet of head until the Gold King flow control structure or a permanent bulkhead is in-place. Even with the low pressure closure, the Gold King Adit contractor and treatment plant operator must be prepared to deal with significantly higher flows.

- Developing a better understanding of the hydrogeologic relationship between the Red and Bonita mine and the Gold King mine could be accomplished by using the low pressure flow control structure and pressure sensors in the Gold King Mine Level 7 Adit to monitor changes in flows at the Gold King as a function of rising water levels behind the bulkhead in the Red and Bonita mine.

- Seepage and increased flows from other mines and surface features are likely once the Red and Bonita Bulkhead is closed. This is particularly true for the Adams Mine.

- Access should be established to the Adams Mine and Adit 268-21. Flow measurement instrumentation should be installed in both and monitored for changes. If possible, perform an inspection of the Adams Mine and document seeps.

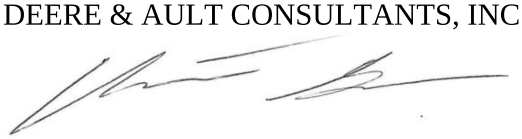
- Flow monitoring should be conducted at the nearby but higher Lead Carbonate Mine to establish a baseline measurement. Initially this could simply be a visual documentation of no flows. If flows start, a small flume could be installed.

Please note that the recommendations in this report are based on investigations, designs, and construction by others, as shown in the attached reference section. Also note that the effect of a rising water table on the groundwater chemistry and environmental impacts from flows and seeps has not been considered in this evaluation.

Thank you for the opportunity to continue working with you on this project. Please call with any questions or comments you may have. We look forward to discussing the results with you and your team.

Sincerely,

DEERE & AULT CONSULTANTS, INC.



Christoph Goss PhD, P.E.
Mining Engineer, Principal

CG:cg

Attachments

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Table 1: Upper Cement Creek Area Features and Elevations

Name	Elevation	Date	Design Pressure (ft head)	Source	Notes
Bonita Peak	13231			Google Earth	
Gold Prince	12400			Simon Hydro 1993	
Gold King Paul Level	12288				
Lake Emma Bottom	12270			Google Earth	Regraded after 1978 collapse
Design Pressure Sunnyside F & B Level Bulkheads	12218		630	Abel 1993	
Design Pressure Red & Bonita Bulkhead	12213		1253	DRMS 2015	
Lake Emma Outlet Ditch	12210			DRMS 2015	
Design Pressure AT Bulkhead 1	12210	1996		Abel 1995	
Design Pressure Terry Tunnel 1 Bulkhead	12205		650	Abel 1993	
Sampson Level 1	12192				
Gold King Level 1	12160				
Sunnyside B Level Secondary	12148	1994	70	DRMS 2015	Prevent discharge to Mogul, 3' thick
Sunnyside B Level Primary	12148	1994	70	DRMS 2015	Prevent discharge to Mogul, 3' thick
Gold King Level 2	12072				
Gold King Level 3	12034				
Gold King Level 4	11909				
Lead Carbonate Mine	11875			Google Earth	
Gold King Level 5	11785				
Sunnyside Mine Pool	11671	2001		DRMS 2015	Final pressure reading at AT Bulkhead 1, May 2001
Gold King Level 6	11662				
Design Pressure Mogul Bulkhead	11640	2003		Abel 2003	
As-built Allowable Pressure AT Bulkhead 3	11632	2002		Abel 2001	773 ft head design increase 34.2% per Abel for as-built dimensions
Blackhawk Mine	11600			Runkel 2015	Mine adit 1.1 miles southeast of Red and Bonita portal
Sunnyside F Level Secondary Bulkhead	11592	1994	630	DRMS 2015	Prevent discharge to Mogul, 8' thick
Sunnyside F Level Primary Bulkhead	11588	1994	630	DRMS 2015	Prevent discharge to Mogul, 8' thick
Terry Tunnel Bulkhead 1	11555	1996	650	DRMS 2015, Abel 1993	3810' from portal, control Sunnyside Pool
Terry Tunnel Bulkhead 2	11521	2000		DRMS 2015	305' from portal
Terry Tunnel Portal	11520	1986		MLRB 1986	Drains Sunnyside levels F and higher
Sunnyside Mine Pool 1959	11500	1959		DRMS 2015	Before American Tunnel reached Sunnyside, Hydro Search assumed pre-mining levels and 10 year post closure
Gold King Level 7	11480				
Mogul Mine Pool Behind Bulkhead	11470	2003		Fearn 2003	30 psi (70' head above portal elevation) measured 6 weeks after closing
Gold King Level 7 Portal	11436			ITC Survey	2015 Rehab, 11440 used by DRMS
Mogul Mine Bulkhead	11422			Abel 2003	241' from portal, 9' thick, 218' design head
Mogul Mine Portal	11400			DRMS 2015	
Design Pressure AT Bulkhead 3	11368			Abel 2001	773 ft head design increase 34.2% per Abel for as-built dimensions
Anticipated AT 2 Head to Leak into NF Cement Creek	11310			DRMS 2015	
Calculated Hydraulic Jacking at R&B Bulkhead	11269			DRMS 2015	
Design Pressure AT Bulkhead 2	11252			DRMS 2015	
North Fork Cement Creek at AT Cross	11250			DRMS 2015	
Adit 268-21	11170			DRMS 2015	
Adams Mine Portal	11160			DRMS 2015	Same vein as R&B 764 drift
Water behind AT Bulkhead 2	11015			DRMS 2015	Final pressure reading at AT Bulkhead 2 August 2002
Silver Ledge Mine	10960			Runkel 2015	Mine adit 1.4 miles south of Red and Bonita portal
Red & Bonita Bulkhead	10960	2015	1253	DRMS 2015	*15' thick, 6x8*
Red & Bonita Portal	10957			DRMS 2015	
American Tunnel Bulkhead 1	10660	1996	1550	DRMS 2015	7950' from portal, control Sunnyside Mine Pool, 25' thick
American Tunnel Bulkhead 2	10612	2001	640	DRMS 2015	2000' from portal, control fracture zone under NF Cement Crk, 10' thick, 17' tall vs 14' design
American Tunnel Bulkhead 3	10595	2002	1037	DRMS 2015, SGC 2003	375' from portal, control minor seeps, as-built 34.2% higher capacity, no pressure measured, 11' thick, 13' high vs 15' design
American Tunnel Portal	10589			Hunter 1961	
Gladstone	10560			Google Earth	

Table 2: American Tunnel Bulkhead Summary

Bulkhead	Length (ft)	Design Head		Maximum Head		Design Parameter & Failure Mode	Design Factor of Safety	Estimated Probability of Failure	Consequence
		(ft)	Elevation (ft)	(ft)	Elevation (ft)				
1	25	1550	12210	2190	12850	Hydro-jacking	6.96	Negligible	Leakage past bulkhead
						Perimeter Shear Failure	1.26	Very Low	Severe leakage
						Structural - Bending	1.01	Very Low	Severe leakage
						Structural - Shear	N/A	Very Low	Severe leakage
						Earthquake	1.26	Very Low	Severe leakage
						Concrete Degradation	N/A	Very Low	Leakage through bulkhead
						Seepage/Piping	8.50	Low	Leakage past bulkhead
2	10	640	11252	1413	12025	Hydro-jacking	6.63	Negligible	Leakage past bulkhead
						Perimeter Shear Failure	1.16	Very Low	Severe leakage
						Structural - Bending	1.03	Very Low	Severe leakage
						Structural - Shear	1.48	Very Low	Severe leakage
						Earthquake	1.12	Very Low	Severe leakage
						Concrete Degradation	N/A	Very Low	Leakage through bulkhead
						Seepage/Piping	8.20	Low	Leakage past bulkhead
3	11	773	11368	1037	11632	Hydro-jacking	1.15	low for design head	Leakage into portal slope face
						Perimeter Shear Failure	1.08	Very Low	Severe leakage
						Structural - Bending	1.02	Very Low	Severe leakage
						Structural - Shear	1.51	Very Low	Severe leakage
						Earthquake	1.24	Very Low	Severe leakage
						Concrete Degradation	N/A	Very Low	Blowout
						Seepage/Piping	5.6	Low	Blowout

Bulkhead 1 and 2 Maximum Head based on maximum downstream head
Bulkhead 3 Maximum Head updated to re-evaluation per as-builts - Abel 2003

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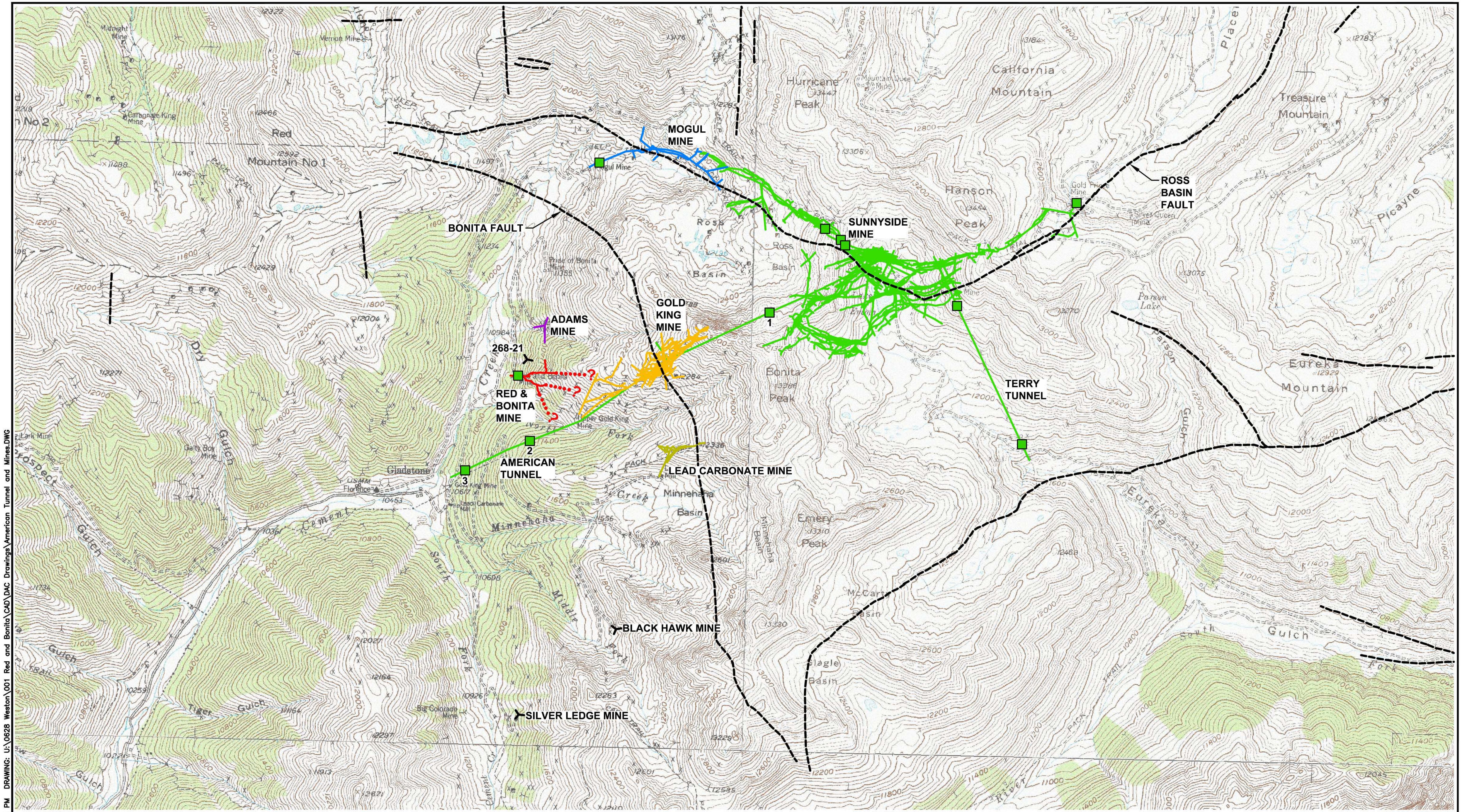

LEGEND:

- BULKHEADS
- USGS MAPPED FAULTS - PP1651
- MOGUL AND GRAND MOGUL
- RED AND BONITA
- GOLD KING
- SUNNYSIDE
- ADAMS MINE
- LEAD CARBONATE MINE

0 1000' 2000'
SCALE: 1" = 2000'

NOTES:

1. BASEMAP BY USGS.
2. MINE SHAPEFILES PROVIDED BY CDRMS.

JOB NO. 0628.001.00

AMERICAN TUNNEL AND MINES

Plan

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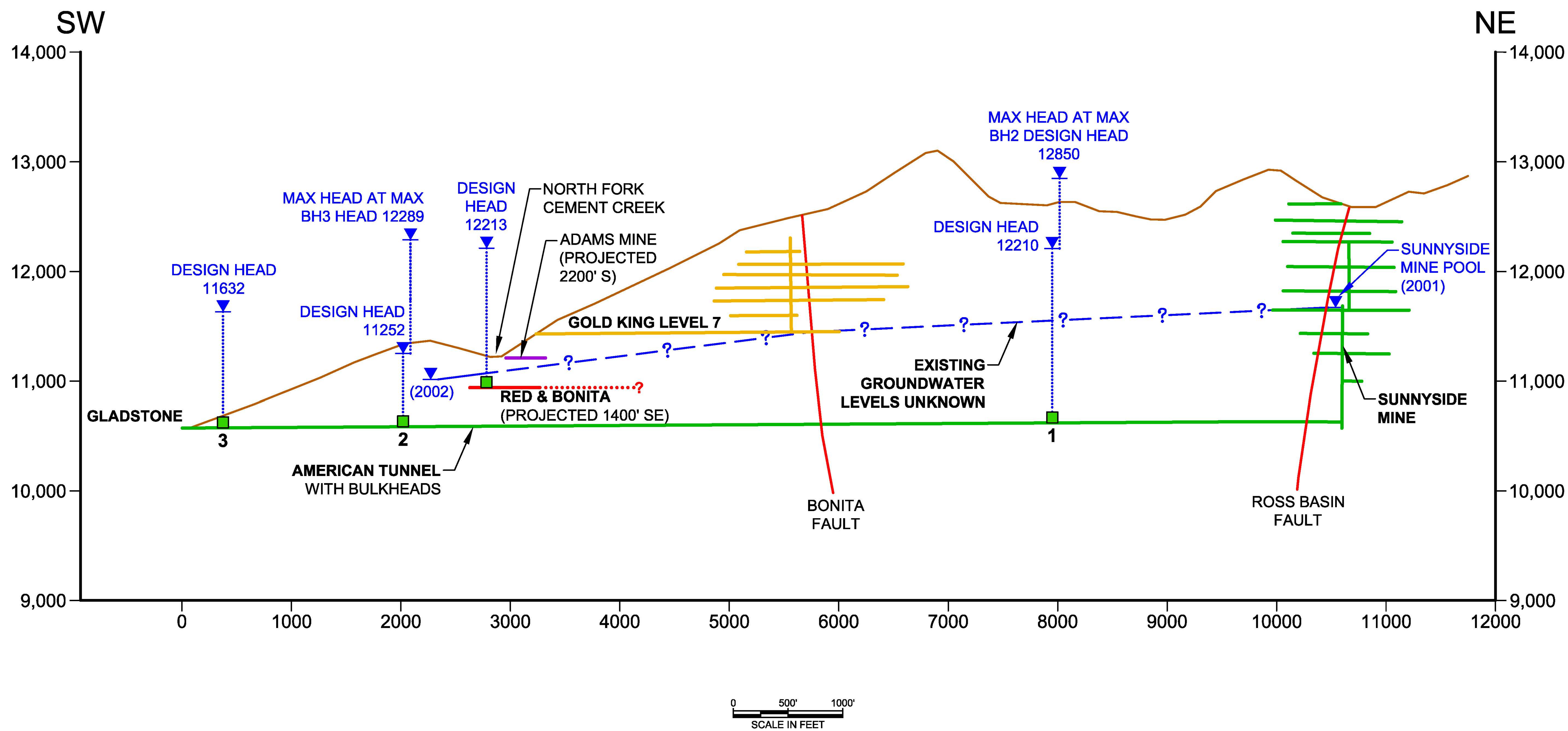
FIGURE NO. 1

DATE: 3-24-16

SCALE: AS NOTED



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AMERICAN TUNNEL AND MINES

Profile

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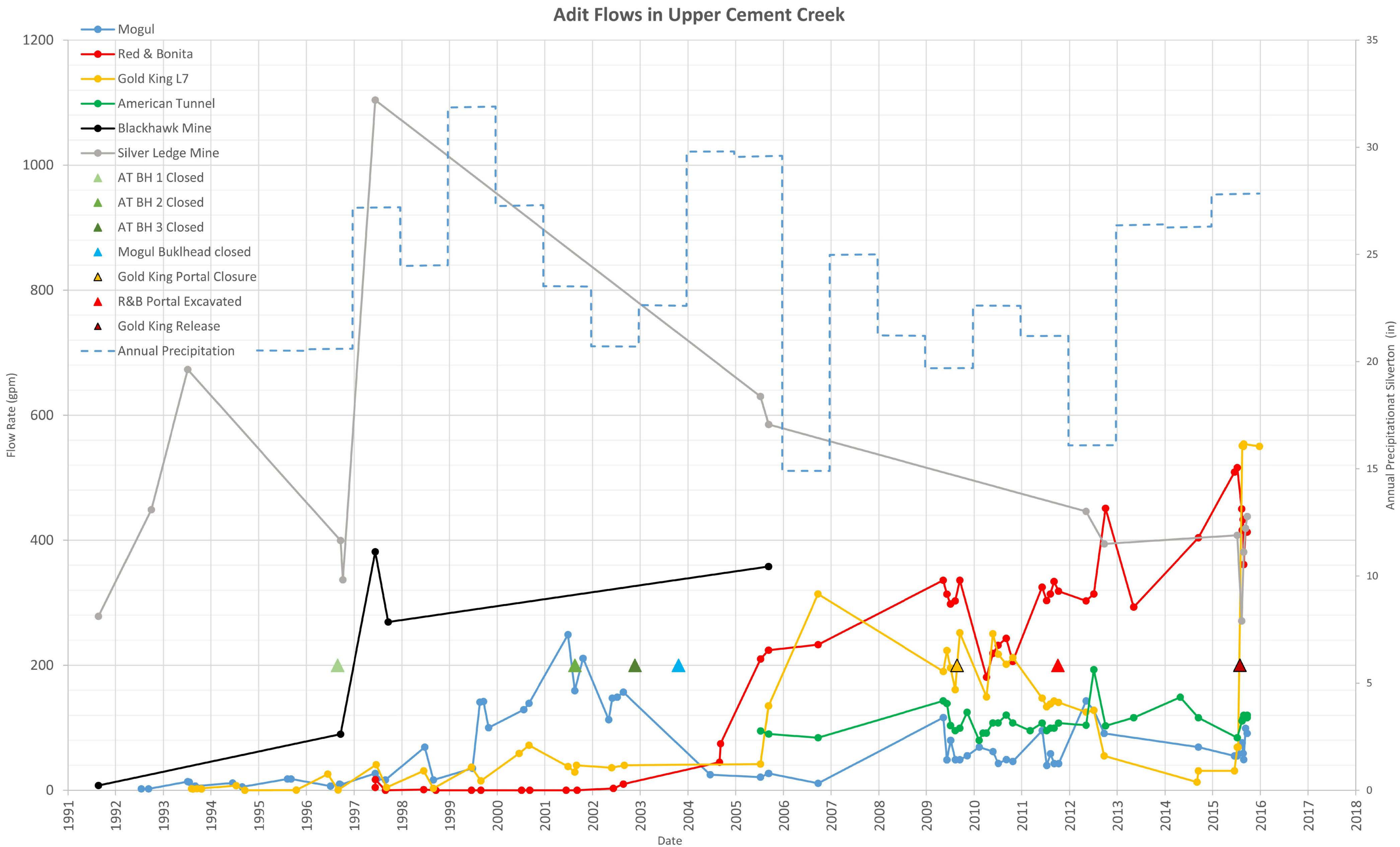
FIGURE NO.	2		
DATE:	3-24-16	SCALE:	AS NOTED



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Adit Flows in Upper Cement Creek

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FIGURE NO. 3

DATE: 3-24-16

SCALE: AS NOTED

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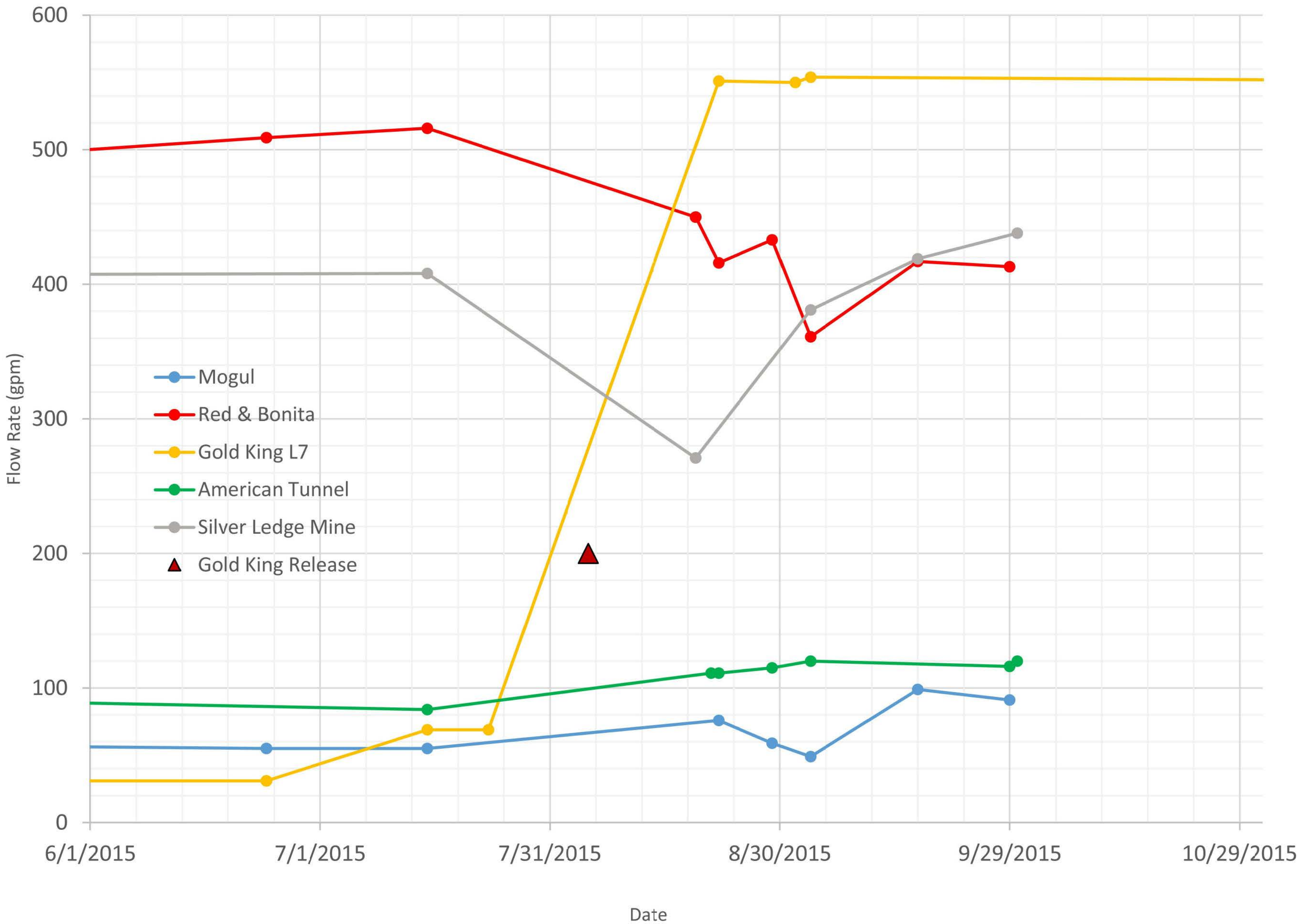

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Adit Flows in Upper Cement Creek Summer 2015

JOB NO.	**0628.001.00**	**SCALE:**	**AS NOTED**	**FIGURE NO. 4**

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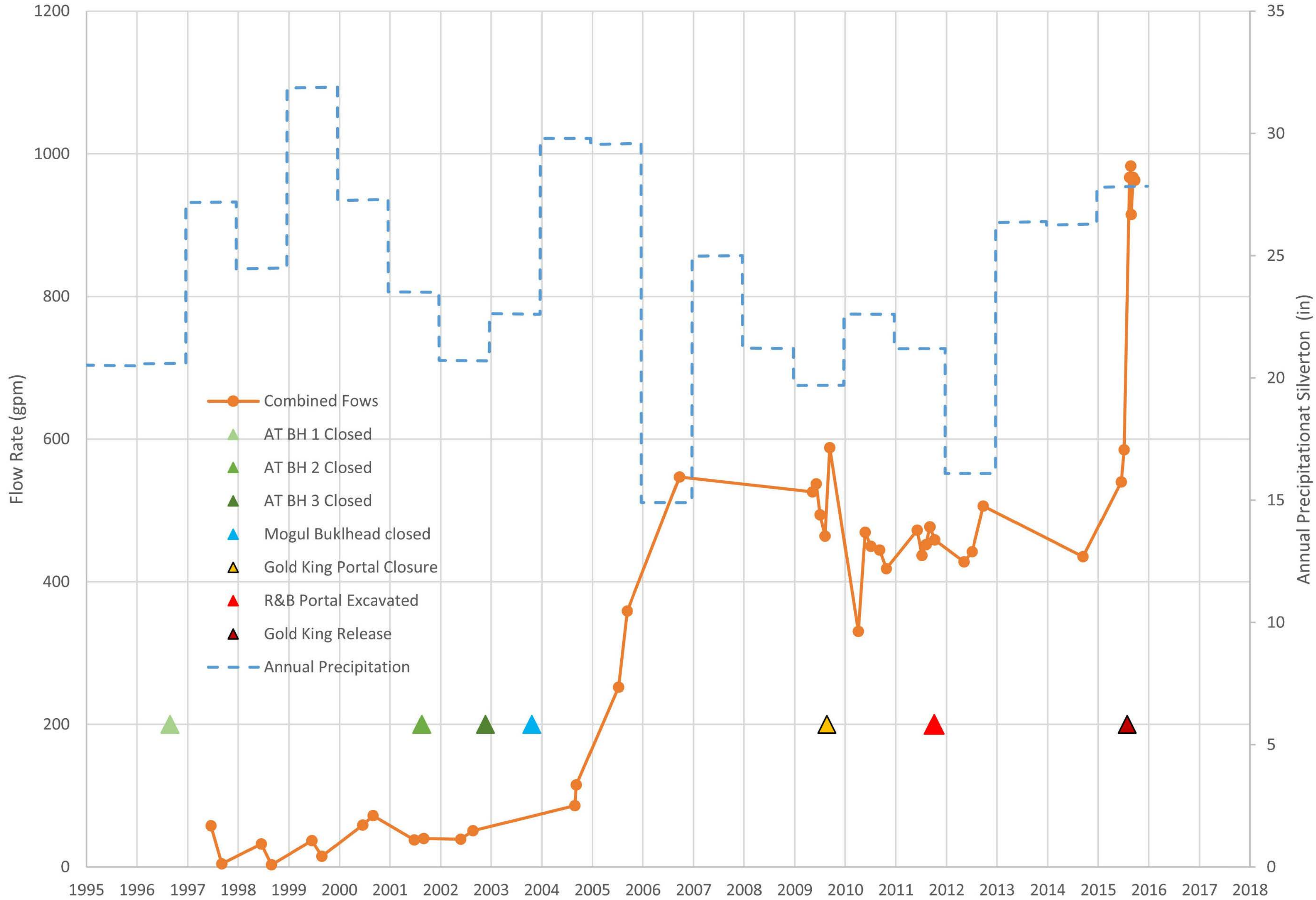

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Red & Bonita and Gold King Combined Flows

JOB NO.	0628.001.00	SCALE:	AS NOTED	FIGURE NO. 5