Preliminary Design Report
Mill Level Tunnel Bulkhead

Idarado Mining Company
Telluride, Colorado
April 18, 2018

Prepared For:
Idarado Mining Company
Telluride, Colorado

Prepared By:

MES Mining
P.O. Box 1511
Idaho Springs, CO 80452

L-7 Services LLC
P.O. Box 1387
Golden, CO 80402

Worthington Miller Environmental, LLC
1027 W. Horsetooth Rd.
Suite 200
Fort Collins, Colorado 80526

Engineering Analytics, Inc.
1600 Specht Point Road
Suite 209
Fort Collins, Colorado 80526

Monadnock Mineral Services, LLC
342 7th Avenue Box 85
Ouray, CO 81427

TABLE OF CONTENTS

1.0 Executive Summary ... 1

2.0 Introduction and Overview ... 3

- 2.1 Background ... 3
- 2.2 Performance Operating Goals ... 4

3.0 Bulkhead Design – Geotechnical/Civil ... 5

- 3.1 Design Criteria (head, water volumes, longevity, access, etc.) ... 6
  - 3.1.1 Maximum Hydrostatic Head ... 7
  - 3.1.2 Evaluation of Reservoir Capacity ... 7
  - 3.1.3 Geotechnical Conditions ... 8
- 3.2 Design Methodology ... 10
  - 3.2.1 Bulkhead Location ... 10
  - 3.2.2 Bulkhead Design ... 13
- 3.3 Preliminary Design Details ... 15

4.0 Piping & Valves ... 16

- 4.1 Design Criteria ... 16
- 4.2 Design Methodology ... 16
- 4.3 Preliminary Design Details ... 17

5.0 Bulkhead Access ... 19

- 5.1 Design Criteria ... 19
- 5.2 Design Methodology ... 19
- 5.3 Design Details ... 20
  - 5.3.1 Upstream, In-Swing Pressure Door: ... 20
  - 5.3.2 Downstream, Out-Swing Pressure Door: ... 21
  - 5.3.3 Stop Log System: ... 23
  - 5.3.4 Selection Matrix ... 24
  - 5.3.5 Door Alternative Selection ... 24

6.0 Instrumentation and Controls ... 26

- 6.1 Design Criteria ... 26
- 6.2 Design Methodology ... 26
- 6.3 Design Details ... 27

7.0 Electrical 29
7.1 Design Criteria 29
7.2 Design Methodology 29
7.3 Design Details 30
8.0 Permanent Downstream Tunnel Ventilation 31
8.1 Design Criteria 31
8.2 Design Methodology 31
8.3 Design Details 32
9.0 Permanent Downstream Tunnel Support 34
9.1 Design Criteria 34
9.2 Design Methodology 37
9.3 Design Details 37

LIST OF TABLES

Table 5-1 Bulkhead Access Options Matrix 25
Table 8-1 Spreadsheet Used to Derive Total Head 33
Table 9-1 Approx. Stationing: Existing Adit Support System 34

TABLE OF FIGURES

Figure 01 - Idarado 2900 Mill Level Adit Mine Map (1”=500 lf on scale shown) 5
Figure 02 - Mill Level Adit Layout (per Monadnock Mineral Services (2016) 8
Figure 03 - USGS Geologic Map of the Telluride Quadrangle (1966) 9
Figure 04 - Snowy Mountain Rock Cover Criteria (per Brekke & Ripley 1993) 11
Figure 05 - Snowy Mountain Rock Confinement Criteria for Bulkhead at Station 09+75 . 12
Figure 06 - Existing Adit Surface Profile at Station 10+30 (per Monadnock Mineral Services (2018)) 13
Figure 07 - Taper Plug Configuration (per Abel 1998 Bulkhead Design for Acid Mine Drainage) 14
Figure 08 - Basic Bulkhead Layout 15
Figure 09 - 30-Inch Pipe Flow at Various Heads 18
Figure 10 - Dimensions for JCI 125M LHD 19
Figure 11 - Example of a Dutch Pressure Door (Low Pressure Door from Centex Marine)21
Figure 12 - Preliminary Concept of Outswing Pressure Door 22
Figure 13 - Preliminary Concept of Stop Log System 24
Figure 14 - Existing Steel Sets and Concrete Box Structure (looking out of portal) 35
Figure 15 - Existing Rock Bolts, Chainlink Mesh, and Mine Strap Support (Outby of Air Door) 35
Figure 16 - Existing Rock Bolts, Chainlink Mesh, Mine Strap, and Flashcrete Support 36

Figure 17 - Existing Rock Bolts, Channel Plates, and Flashcrete Support 36
Figure 18 - Typical Supplemental Adit Support 38

LIST OF APPENDICES

Appendix A	Design Drawings
Appendix B	Idarado Isometric with Proposed Bulkhead
Appendix C	Available Mine Storage Evaluation
Appendix D	Geotechnical Overview and Laboratory Rock Test Results
Appendix E	Rock Core Logs
Appendix F	Rock Core Photos
Appendix G	Lateral Confinement Evaluation and Bulkhead Preliminary Design Calculations
Appendix H	Finite Element Analysis
Appendix I	Seismic Evaluation
Appendix J	Routine Monitoring Plan
Appendix K	Contingency Plan

1.0 Executive Summary

Idarado Mining Company (Idarado) is proposing to install a bulkhead in the Mill Level Tunnel (also referred to as the 2900 level) at the Idarado Mine located in Telluride, Colorado. This Basis of Design report provides stakeholders, including the Colorado Department of Public Health and Environment (CDPHE) and Colorado Division of Mining Reclamation and Safety (CDRMS), with the background, design considerations, and design elements for the preliminary design of the Mill Level Tunnel Bulkhead (Bulkhead). This preliminary design report is intended to provide the State with the information necessary for the purpose of stakeholder review, comments, and feedback, and is not intended to be a final design document.

Idarado's design objectives for the Bulkhead include:

1. Provide the ability to manage the seasonally variable mine-water flow rates from the Mill Level Tunnel for the ongoing protection of human health and the environment while impounding as little water as possible;

2. Provide for long-term operational flexibility to manage future mine water flows;

3. Maintain access to the underground mine workings, upstream and downstream from the flow-through Bulkhead;

4. Provide long-term sustainable operability with minimal maintenance requirements over the design life of 100-years.

Idarado, in an effort to implement sustainable, long-term hydraulic (water) management and control at the Mill Level Tunnel (Tunnel), is proposing the installation of a flow-through bulkhead to be located approximately 1,000 feet into the Tunnel. Water flow from the Tunnel varies seasonally. That is, in the late summer and early fall, flows are low, and flows increase and surge during spring snowmelt. These seasonal phenomena is seen in creeks and rivers across the western slope of Colorado. The flow-through bulkhead is the culmination of an ongoing dialogue with the CDPHE over the course of 2014-2017.

Idarado currently conveys water from the Tunnel to infiltration ponds, an infiltration ditch, and/or pumps water to an infiltration area just east of the infiltration ponds, all located on Idarado property. Installation of a flow-through bulkhead will provide an ability to control the flow rate to these areas, especially during the peak flow period of the spring snowmelt.

The proposed flow-through bulkhead has been engineered for the unlikely event that the flow-through ability is lost and water is stored to the next highest water discharge point from the mine, the Meldrum Portal. Materials for the flow-through bulkhead, conveyance pipeline, and related controls have been selected for safety, functionality, and long-term sustainability. Additional information on bulkhead design criteria, methodology, and details are presented in Section 3.0.

The flow-through Bulkhead will have a nominal capacity of 10,000 gallons per minute (gpm) with no hydraulic head behind the Bulkhead. Typical flows during the majority of the year are less than 6000 gpm. The flow-through bulkhead will convey water through a pipeline to the Mill Level Tunnel Portal (Portal). Remotely operated valves will be located at various locations on its downstream side. The valves include an emergency shutoff, and both an operational shutoff and flow-throttling capability. On the upstream side of the flow-through bulkhead, a primary water collection pipe, with redundant intakes, and an overflow pipe valved and plumbed to the main line will be installed. The overflow pipe will also provide ventilation through the flow-through bulkhead by use of a wye and valve, plumbed to the ventilation ducting. Additional piping information, design rationale, and details are provided in Section 4.0.

The flow-through bulkhead will have an access way to allow workers to go behind it for inspections and maintenance. Several access way options are still being evaluated and are presented in Table 5-1, Bulkhead Access Options. The preferred access way design utilizes an upstream in-swing Dutch-door. In the event debris restricts the lower portion of the door from opening, the top portion of the door that can be opened to clean out any material that collects behind the lower portion of the door. Additional information regarding bulkhead access is provided in Section 5.0.

Instrumentation will be installed to monitor discharge flow, including pH, conductivity and hydrostatic head. Remote readouts for the instrumentation will be utilized through a radio system, which will also allow the remote operation of the various valves. Further description of the instrumentation and controls is provided in Section 6.0.

The proposed Bulkhead electrical components include lighting, electric valves, ventilation fans, and other electrical appurtenances. Electrical power will be provided from the existing mine office electrical substation. Lighting will be installed from the portal to the flow-through bulkhead using energy efficient LED’s for operational and emergency egress lighting. Electrical components for operating the ventilation system will utilize 480-volt power. Equipment and outlets will utilize ground fault circuit interrupter breakers and water resistant receptacles. The full description for installed electrical components is provided in Section 7.0.

Section 8.0, Tunnel Ventilation, provides details regarding how the tunnel segment between the Portal and the Bulkhead will be ventilated during a condition where the access door is closed and natural mine ventilation is disrupted. In addition to the ventilation, the oxygen concentration within the Tunnel will be monitored by sensors to ensure safe access for tunnel maintenance.

The Mill Level Tunnel will continue to be maintained from the Portal to the flow-through Bulkhead. The Tunnel will be inspected to assure ongoing access and to ensure a safe working environment for access to the Bulkhead. As deemed necessary, supplemental ground control will be placed to assure long-term stability. Additional details regarding downstream tunnel support are provided in Section 9.0.

A Routine Monitoring Plan and Contingency Plan have been developed for the operation of the flow-through bulkhead. Appendix J contains the Routine Monitoring Plan and Appendix K contains the Contingency Plan.

2.0 Introduction and Overview

Idarado is proposing to install a flow-through bulkhead in the Mill Level Tunnel (or 2900 Level) at the Idarado Mine located near Telluride, Colorado. This Basis of Design report provides stakeholders, including CDPHE and CDRMS with the background, design considerations, and design elements for the preliminary design of the Bulkhead. This preliminary design report is intended to provide the CDPHE and CDRMS with the information necessary for the purpose of stakeholder review, comments, and feedback, and is not intended to be a final design document.

2.1 Background

Idarado was formed in 1939 through the consolidation of mining properties in the Red Mountain District, located near Ouray, Colorado, including the Treasury Tunnel, Black Bear, Barstow, and Imogene properties. Underground mine development began in the 1880's and mining continued at Idarado until 1977.

The Portal represents the lowest elevation level in the underground mine and currently drains the majority of the water that enters the Idarado mine workings. The Mill Level Portal is approximately 900 feet lower than the Meldrum Tunnel Portal (2000 Level), which also drains waters from the Idarado mine. Both of these mine portals are connected via a labyrinth of underground mine workings that have been mined since the later part of the 19th Century. Only very isolated access remains to the underground mine workings.

The Mill Level Tunnel was initially driven in 1945 and over the next several years was developed to a length of 7,250 feet. The Tunnel is connected to mine workings via a number of vertical raises and ore passes. The majority of the historic underground mine workings are drained through the Portal. Water in the mine is from rain and snowmelt surface water inflow in the high country basins above the Portal, either into the naturally occurring rock fractures or through near surface mine workings. Mine water discharges from the Mill Level Tunnel Portal and the Meldrum Tunnel Portal are infiltrated into the groundwater system using dedicated infiltration areas.

Idarado has successfully managed water from the Tunnel since the mine closed in 1977, over 50 years ago. However; in recent years, observations of the peak flows from the Portal in the spring have been higher than expected and have occurred over shorter periods of time. One reason for this occurrence appears to be more rapid melting of the snowpack, which provides the surface water in the high country basins of which a portion enters the mine workings, due to climate variability. In response to this, Idarado, through discussion with CDPHE, initiated a hydrologic and operations review to determine management options for these anomalous flows, should they continue into the future.

This review effort was initiated in 2015 as documented in a November letter to CDPHE, which stated in part: "Idarado began preliminary investigations during the summer of 2015 to evaluate if a flow-through bulkhead in the Mill Level portal would be feasible and cost-effective in moderating flows from the Mill Level portal during periods of high flow conditions. The bulkhead would be utilized to temporarily moderate peak flow to best manage water in the conveyance piping and infiltration lagoons. If the bulkhead were to be constructed, Idarado has no intention of closing the bulkhead or storing water in the tunnel behind the bulkhead for any longer than necessary to equilibrate flows from the portal."

In October of 2017, Idarado held a workshop with CDRMS and CDPHE (Agencies) to outline and discuss the water management goals and to receive input from the Agencies on the project. Feedback on the proposed construction of a flow-through bulkhead from the Agencies was positive, and Idarado continued moving forward with design investigations throughout 2017 and the beginning of 2018, and these discussions are, and will continue to be, ongoing until such time as the design is complete and the project approved through the existing Remedial Action Plan modification process. Design of the flow-through Bulkhead and appurtenances is planned to be complete in 2018 with construction occurring in 2019. As part of the design, additional geotechnical and other engineering design evaluations are ongoing and will be completed in 2018.

2.2 Performance Operating Objectives

The objective of the flow-through Bulkhead is to develop an engineered control for water flow from the Portal. The design has been developed to allow water flows draining from the Tunnel and underground and surface water management infrastructure to continue to effectively operate into the future. For the majority of the year (>95%) the system will operate as it has during the last 50 years. However, during some periods of increased flow, typically over a short time period during the spring snowmelt, a portion of the flow will be retained in the mine workings to be discharged when the increased flow has abated, typically within a few hours to a few days. Access is to be maintained from the Portal to the flow-through Bulkhead to allow inspection of the Tunnel and Bulkhead, maintenance, future operational flexibility, and safety.

3.0 Bulkhead Design – Geotechnical/Civil

The proposed flow-through bulkhead will be located in the Tunnel and will allow the mine operator to regulate discharge flow volume from the mine complex. The conditions of the mine opening, the intended operating objectives and contingencies will frame the geotechnical and civil engineering component of the design for the flow-through bulkhead. As shown in Figure 01, the 2900 Mill Level Portal is at an elevation of 9062 feet above mean sea level (amsl). The bearing of the Mill Level Tunnel near the Portal is approximately North 41° East (N. 41° E.).

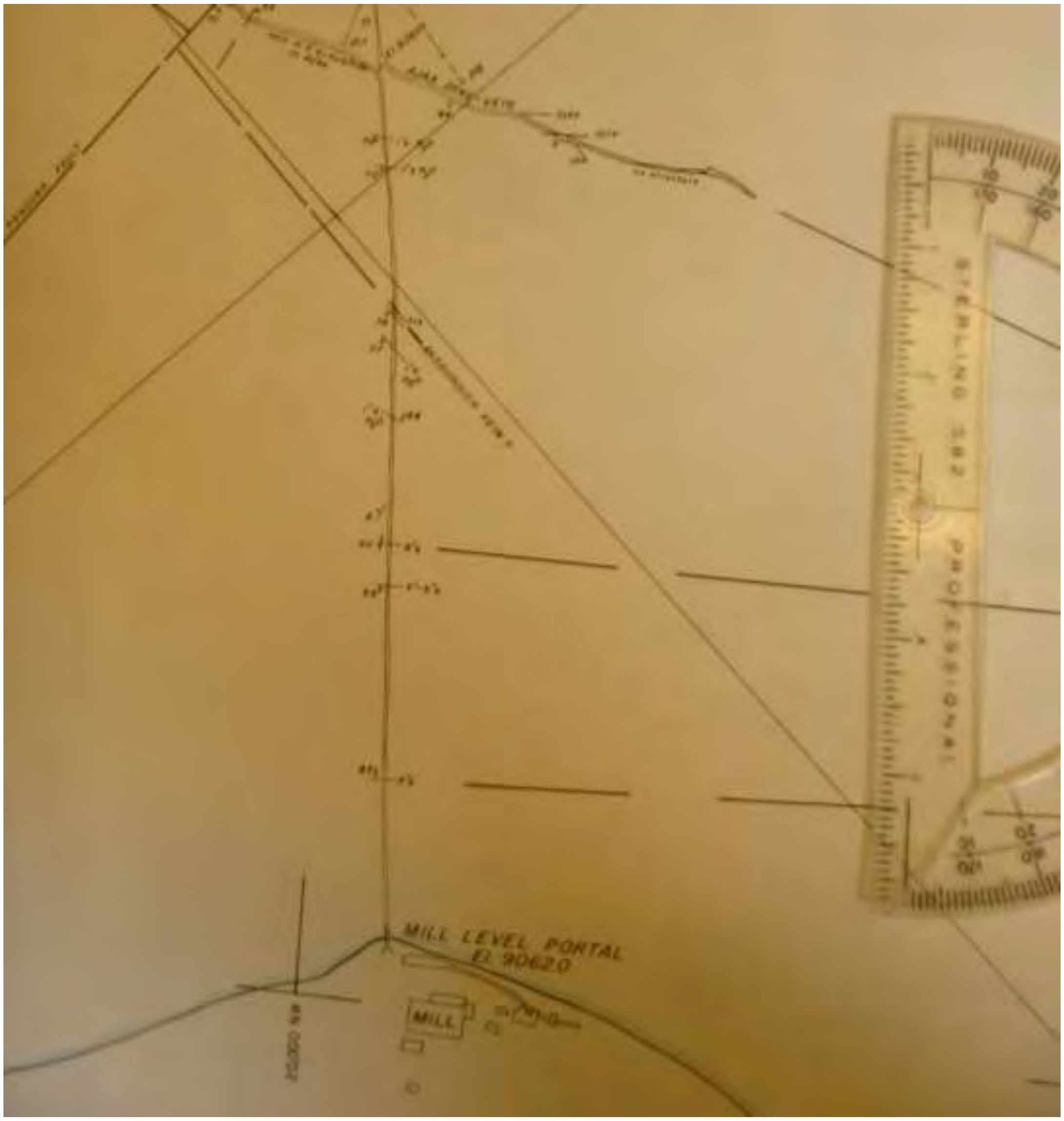


Figure 01 - Idarado 2900 Mill Level Adit Mine Map (1"=500 lf on scale shown)

3.1 Design Criteria

Idarado's design objectives for the flow-through Bulkhead as follows:

1. Provide the ability to manage the seasonally variable mine water flow rates from the Mill Level Tunnel for the ongoing protection of human health and the environment while impounding as little water as possible;

2. Provide for long-term operational flexibility to manage future mine water flows;

3. Maintain access to the underground mine workings, upstream and downstream from the flow-through Bulkhead;

4. Provide long-term sustainable operability with minimal maintenance requirements over the design life of 100-years.

The flow-through Bulkhead will allow the control of the of water discharged from the Mill Level Tunnel Portal to the infiltration areas in the Pandora Mill area, which historically has occurred year round, but is more intense for limited periods of time during spring snowmelt. Based on the historical data and observations since 1977, peak flow rates only last a few days to a few weeks and are dependent on snowpack volume, snowpack melt rate, rainfall and other climatic conditions. Even within that brief snowmelt period, the flows vary daily between morning to evening commensurate with the normal warming and cooling cycle of the day. The flow-through bulkhead will be engineered for a flow 12,500 gpm with 5 feet of hydrostatic head, which will convey a nominal 10,000 gpm under normal no head conditions. A pipe will be installed from the bulkhead and will convey water to the Portal. A number of valves will be installed to allow the management of the water to the Portal. It is recognized that there may be some seepage bypassing the Bulkhead and into the surrounding rock mass under higher hydrostatic head scenarios. However, the Bulkhead does not require stringent water tightness criteria and as such no extensive formation-grouting, which would reduce the rock mass permeability in the vicinity of the Bulkhead, is being considered.

Maintenance access upstream from the flow-through Bulkhead is an important design consideration. An adequately sized, large rectangular access opening (i.e., door) has been incorporated into the Bulkhead design. The access opening is aligned with the existing railroad tracks to maintain equipment, locomotive, and railcar access further into the mine workings.

The design life of the Bulkhead has been established as 100-years. However, this is considered a nominal design criterion and maintenance on pipelines, doors, and valves will be required. The actual stability of the Bulkhead itself should far exceed the nominal design life. While the water discharging from the mine is not acidic, stainless steel materials are currently proposed for the door and doorframe, as well as pipe penetrations and valves to minimize maintenance.

3.1.1 Maximum Hydrostatic Head

The Mill Level Tunnel is the lowest level in the Idarado Mine and, as such, the majority of the water that drains from the mine does so through the Mill Level Tunnel. However, this mine water enters the mine from surface water flows resulting from snow melt and rainfall in the high country well above the Portal. The water flows through the mine workings until it discharges from the Mill Level or Meldrum portals, up to 2500 feet below the high country inflow areas. There is a labyrinth of mine openings, stopes, drifts, cross-cuts, raises, etc. that connect the mine vertically from near surface to the Mill Level and Meldrum Portals. While the intended operational head of the flow-through Bulkhead during the majority of the year will typically be less than 10 feet, engineering consideration will be given to the unlikely event of water backing up behind the flow-through Bulkhead until it discharges from an alternative location (Meldrum Tunnel Portal) upgradient of the Mill Level.

Based on a review of the available mine level plans and long-sections, and as shown in Figure 02 and in a isometric of the mine (Appendix B), there is a direct connection between the Mill Level 2900 Level and the Meldrum 2000 Level via a number of underground raises and stopes. Therefore, the potential maximum hydrostatic pressure that may act on the Bulkhead corresponds to the difference in elevation between the flow-through Bulkhead and the 2000 Level mine workings. While there are a number of underground mine openings between levels, the 27A raise was used to represent the actual elevation difference for engineering purposes at the Meldrum Level Portal, which is 9956 feet amsl. Given the proposed Mill Level Bulkhead (Station 1,030) elevation of approximately 9067 feet amsl, the Bulkhead could potentially encounter approximately 900 vertical feet of hydrostatic water head if the flow through pipes were shut down or plugged. The hydrostatic head of 900 feet has been utilized for the engineering of the flow-through bulkhead a possible but unlikely scenario. It should be noted that this would not be an anticipated operating condition and would result in contingency plan processes as defined in Appendices J and K.

In the early 1990's, a borehole was drilled in the high country, above the Mill Level Tunnel Portal, to intersect with the 2900 Level to allow piping of water from high country portals to the 2900 Level, where it is collected with the 2900 Level water flow and ultimately infiltrated. This borehole intersects the 2900 Level upstream from the proposed location of the flow-through bulkhead. It is planned to construct a surface pipeline from the top of the borehole to an area near the portal.

3.1.2 Evaluation of Reservoir Capacity

The following is a hypothetical example of how the Bulkhead would be operated. Site management experience and observations indicate peak flow rates during spring snowmelt typically have duration of between 4 to 12 hours and are less than 10,000 gpm. Assuming the peak runoff was 12,000 gpm for 12 hours (both of which are conservative) and based on climatic conditions, available infiltration capacity, etc., the operators decide that a limit of 8,000 gpm should be sent to the infiltration facilities. Therefore, 4,000 gpm would need to be stored for 12 hours, which would require temporarily storing 2,880,000 gallons of water behind the Bulkhead. As the flow drops from the peak flow to below 8,000 gpm, the stored water would be allowed to drain to the infiltration facilities, thus emptying the water from behind the Bulkhead.

An evaluation of estimated mine volume that could store water, between the 2900 Level and the 2000 Level, has been performed. Per the Monadnock report (Appendix C), the 2900 Level Tunnel, intersecting tunnels, and drifts are in excess of 24,000 lineal feet. Assuming a 9’x9’ clear tunnel opening results in up to 14.6 million gallons of storage volume (1,951,000 cubic feet). The 2400 foot level, intersecting tunnels, and drifts would add approximately another 10 million gallons of storage. This preliminary estimate is likely conservative and additional underground surveying will be undertaken in 2018 to continue to refine the volume estimates of the workings. Appendix C provides additional details on the storage evaluation. Figure 02 provides a general schematic of the mine workings.

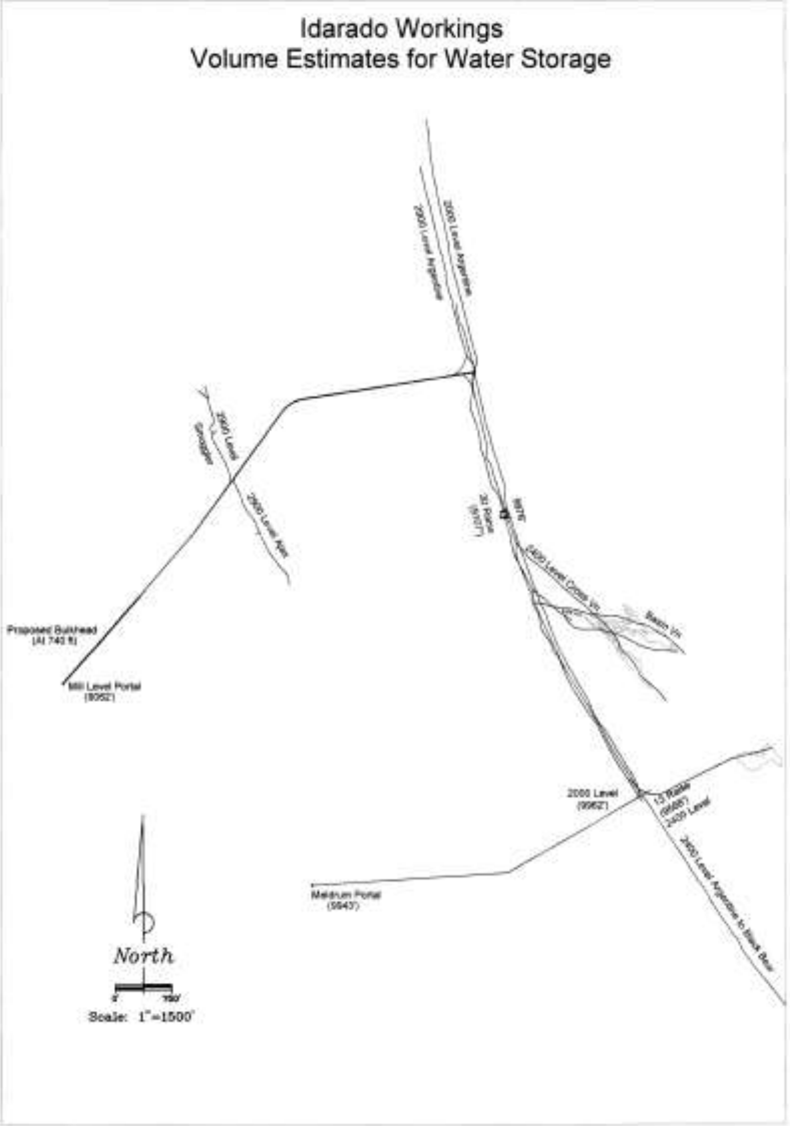
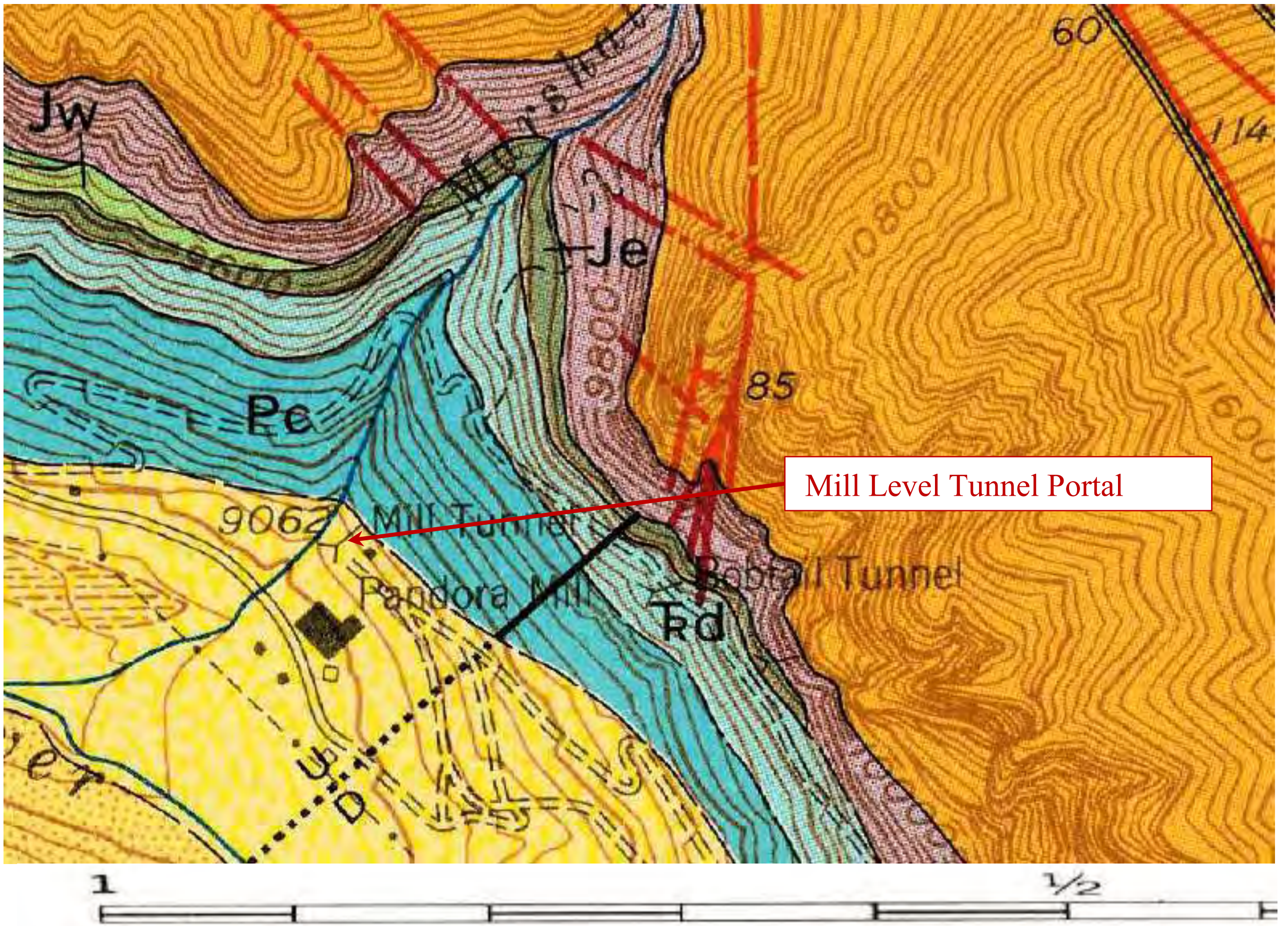


Figure 02 - Mill Level Adit Layout (per Monadnock Mineral Services (2016)

3.1.3 Geotechnical Conditions

The Bulkhead will be constructed within the Permian period Cutler Formation which comprised of sandstones, siltstones, shales, conglomerates, and claystones. Outcrop exposures of the Cutler Formation are plentiful in the Telluride valley and reveal relatively uniform, near horizontal beds of sedimentary rock. Local exposures near the Mill Level portal indicate and in the proposed location of the flow-through bulkhead indicate the Tunnel is excavated in fine-grained red sandstone/siltstone overlain by a well-cemented conglomerate approximately 10 feet above the Tunnel back. Based on the strata elevations shown on the United States Geological Survey (USGS) Telluride quadrangle and other physical geology maps, the top of the Cutler Formation has an apparent dip of approximately 1.6° following the bearing of the Tunnel across the valley and a steeper apparent dip of 4.3° measured further away on the Bear Creek outcrop. The apparent dip of the strata was confirmed by measuring a prominent rock layer on the southern rib of the Tunnel approximately 1,600 feet in from the portal with a dip angle of 8° into the tunnel relative to horizontal; this measurement was upstream of the large shear zone where vertical offset of the rock strata was observed and is considered to be representative of the strata dip beyond 1,380 feet into the tunnel. This indicates there is some variation to the strata dip in this region. The Geotechnical Overview contained in Appendix D provides addition information.

From the USGS online seismic design mapping tool (https://earthquake.usgs.gov/hazards/designmaps/usdesign.php) for the Idarado Mine (Pandora Mill area), the peak ground acceleration (PGA) associated with the maximum considered earthquake (MCE) is PGA = 0.179 * gravity (g).


Mill Level Tunnel Portal

2.0 (Scale in Miles)

Figure 03 - USGS Geologic Map of the Telluride Quadrangle (1966)

Two different locations have been considered for the Bulkhead as discussed in the following section. For the initial Bulkhead location (originally sited at 732 feet from the portal) a geotechnical investigation program was performed consisting of four borings extending 10 feet into the rock surrounding the Tunnel, above, below, and to the two sides. The typical rock at the initial Bulkhead location consists of red, fine-grained sandstone with occasional lenses of medium to coarse grained sandstone. Full or nearly full cores were collected and rock quality designation (RQD) ranged from 58% to 100%, with the majority of the rock core in the excellent range (>90%). An overview of the geotechnical investigation and the results of the laboratory testing are presented in Appendix D. The rock core logs and rock core photos are available in Appendices E and F, respectively. Laboratory testing results on the rock core samples indicated the following:

Unconfined compressive strength: 5,020 psi to 14,160 psi
Unit weight: 172 to 173 pounds per cubic foot (pcf)
Cohesion: 10.9 psi
Residual friction angle: 19.2°
Elastic modulus: 4410 to 9190 kilopounds per square inch (ksi)
Poisson's ratio: 0.20 to 0.23

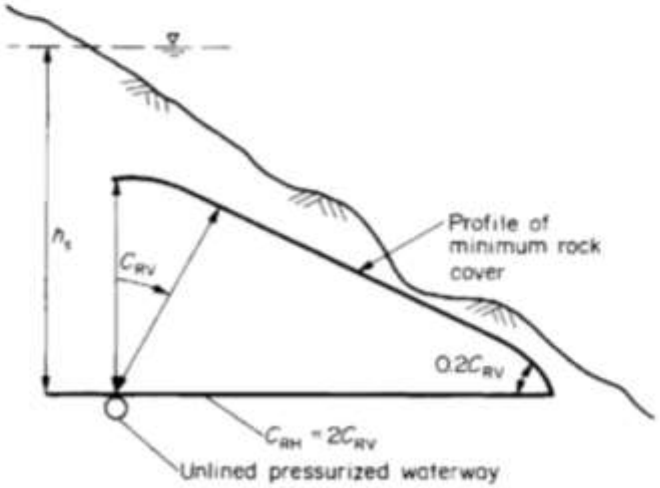
3.2 Design Methodology

3.2.1 Bulkhead Location

To properly design for the potential 900 feet of hydrostatic head, the minimum required rock cover required above the bulkhead is h_{min} = (900 feet)(62.4 pcf)/160 pcf, which equates to 351 feet of rock cover. As stated previously, the unit weight of the rock above the bulkhead has been conservatively evaluated to be 160 pcf, which represents the lower range of sedimentary rock. As indicated in Section 3.1.3, laboratory testing indicates a rock density greater than the conservative estimate used in the calculation, with densities of approximately 172 pcf. Additionally, for the rock reaction calculations, the resistance provided by the back or roof of the Tunnel has been conservatively not taken into account.

Based on ground surface surveys, an initial Bulkhead location was selected at Station 07+32 (current stationing 07+71) to satisfy the 351 vertical feet of minimum rock cover and to take advantage of decent rock conditions in the Tunnel. Exploratory rock cores were drilled at this location and laboratory testing performed on the core samples. However, during a 2017 site visit and internal review of the Bulkhead location, the proximity of the Marshall Creek ravine to the flow-through Bulkhead in the Tunnel and the potential for lateral hydrojacking was identified for further analysis.

Lateral confinement was checked utilizing the Snowy Mountain Confinement criteria for unlined pressure tunnels with a safety factor of 1.3. The Snowy Mountain criteria shown on Figure 04, unlike the commonly used Norwegian Rock Cover criteria, provides a rational basis for rock cover regardless of the position of the tunnel relative to the ravine and the inclination of the slopes.



Snowy Mountains criterion for confinement. C_{RV} = vertical rock cover ($= h_S\gamma_w/\gamma_R$), C_{RH} = horizontal rock cover, h_S = static head, γ_W = unit weight of water, γ_R = unit of weight of rock

Figure 04 - Snowy Mountain Rock Cover Criteria (per Brekke & Ripley 1993)

In addition to evaluating the appropriate bulkhead location using the more conservative of the two cover design methodologies, additional topographic mapping was developed to better characterize surface elevations in the Marshall Creek ravine. At 732 feet inside the portal where the Bulkhead was initially sited, the inclusion of the updated Marshall Creek ravine topography indicates that a safety factor close to 1.0 is achieved with the Snowy Mountain criteria, which is not an acceptable safety factor for this project. To provide the requisite 1.3 safety factor, it was determined the bulkhead needed to be located at approximately Station 975 feet or ~ 250-feet further in. Figure 05 presents the Snowy Mountain criteria with the 1.3 safety factor. Appendix G presents the lateral confinement evaluation.

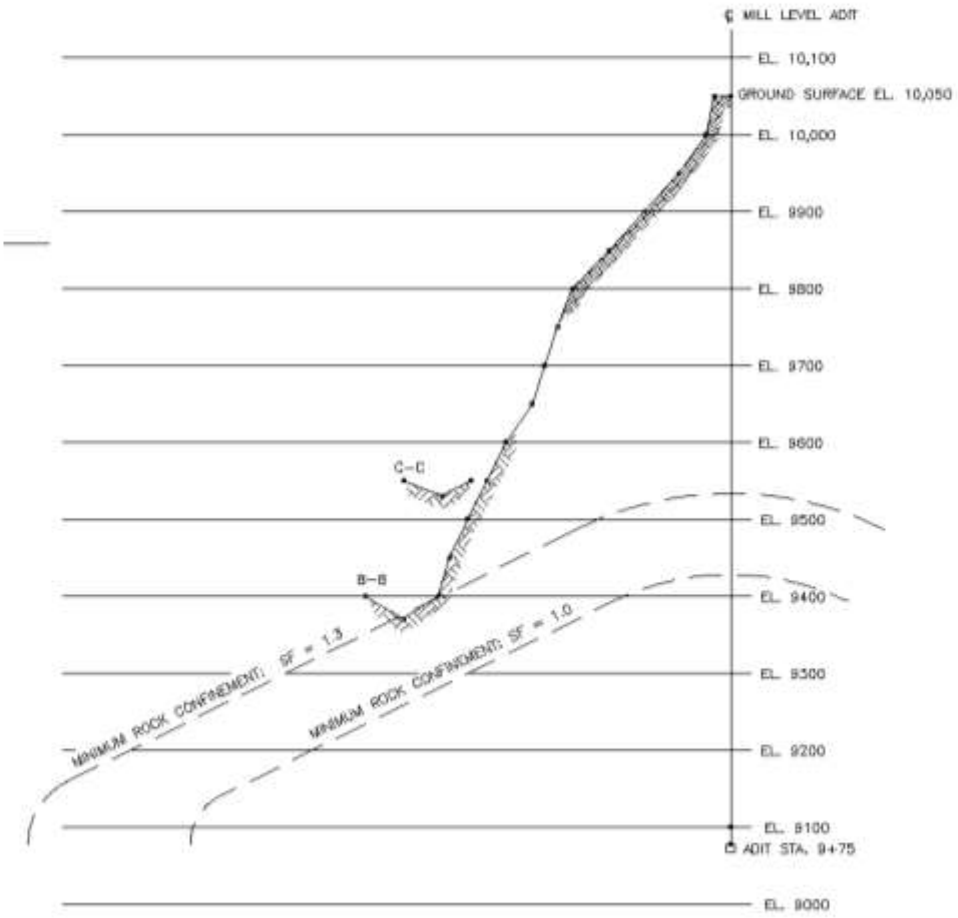


Figure 05 - Snowy Mountain Rock Confinement Criteria for Bulkhead at Station 09+75

During the Tunnel rehabilitation effort in January 2018, additional reconnaissance of the Tunnel was conducted to identify a new potential location for the Bulkhead at least 975 feet in to meet the required safety factor. A suitable potential Bulkhead location was identified in the vicinity of 1,030 feet which presented favorable Tunnel dimensions and potential competent bedrock at the tunnel back (roof) and ribs. Removal of the shotcrete was performed at the new location on the back and ribs to expose the rock and revealed that the rock conditions in the back were less than optimal, with thin beds, open joints, and scalable sandstone. Sounding of the back with a scaling bar indicated that the overhead rock is inconsistent throughout this area, while the sounding of the ribs indicated tight rock (albeit thinly bedded). Additional scaling of the back and rock bolting revealed that the inconsistent, thinly bedded zone extended only 12 to 18 inches above the Tunnel before tight, competent rock was encountered.

Given that the Bulkhead will require some rock excavation to create an adequate taper for hydrostatic pressure transfer to the surrounding bedrock, the thin bedded rock conditions near the back at 1,030 feet are not considered a significant issue, and the lack of significant vertical seams in the area is a benefit. The 1,030 foot location is currently the preferred bulkhead location with the understanding that additional rock removal in the back will be needed as part of Bulkhead construction.

As shown in in Figure 06, the updated Bulkhead site is approximately 260 feet from the location of the previous underground boring program and represents a strata shift, based on a minimum 1.6° apparent dip and Tunnel gradient of 0.005 ft/ft, of approximately 8.4 vertical feet at the back. Therefore, very little (maximum of 1.6 feet) of the 10 vertical feet core interval collected before is applicable to the current Bulkhead location and a second geotechnical exploration program is currently scheduled for the 1,030 foot location. Additionally, packer testing will be performed in the drill holes to better evaluate hydraulic conductivity of the formation rock.

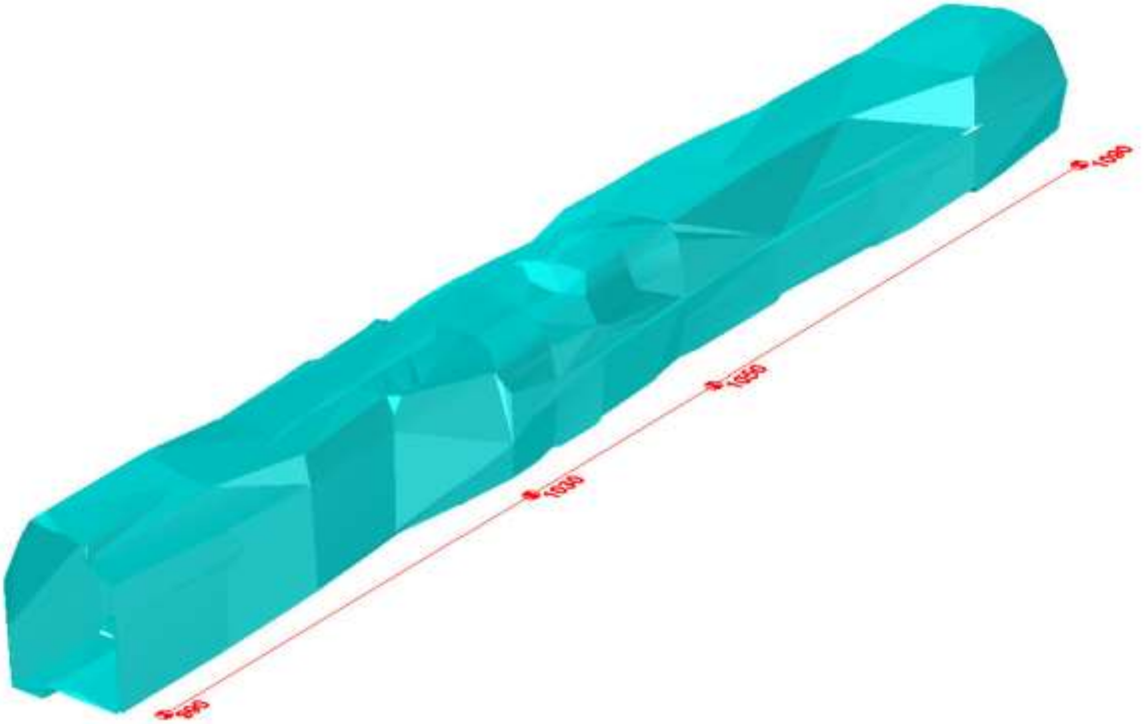


Figure 06 - Existing Adit Surface Profile at Station 10+30 (per Monadnock Mineral Services (2018))

3.2.2 Bulkhead Design

The preliminary length of the bulkhead has been calculated based on the bulkhead design methodology presented by Dr. Abel in his 1988 paper *Bulkhead Design for Acid Mine Drainage*. Preliminary Bulkhead design calculations are attached in Appendix G. The actual siting of the Bulkhead is controlled by the lateral confinement considerations discussed previously and results in additional vertical rock cover than the minimum calculated by either the Abel design methodology or by simple vertical dead weight of the overlying rock.

Based on the Bulkhead design criteria of being capable of storing 900 feet of hydrostatic head, a bulkhead length of between 10 and 15 feet is anticipated, depending upon the amount of concrete reinforcement incorporated into the Bulkhead (heavily reinforced vs. plain concrete respectively). Given the critical nature of the Bulkhead and the relatively minor cost increase associated with the additional concrete, a minimum bulkhead length of 15 feet with heavy reinforcement will be implemented for the final design. Using this length results in a very deep structural plug (1.5 depth to span ratio) with the primary load-bearing structural action primarily shear resistance between the concrete and the surrounding rock. To ensure adequate rock reaction, the existing shotcrete will be removed at the Bulkhead location, loosely bedded rock at the back will be removed, and a shallow excavation of the rock on the pressure side of the Bulkhead will occur to create a tapered key into the rock, as illustrated on Figure 07. The tapered plug maximizes the bearing area with the surrounding rock, which is crucial for high pressure bulkheads.

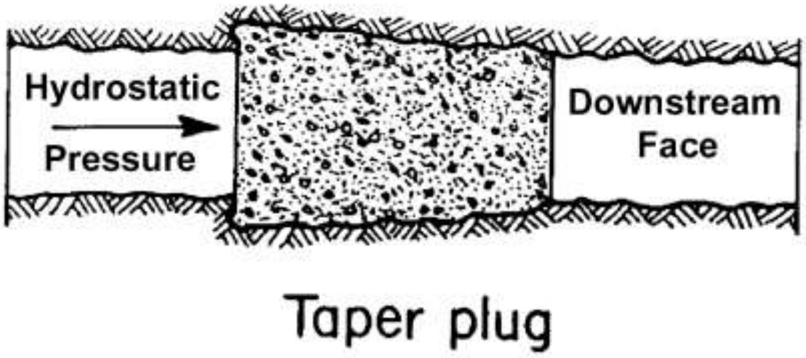


Figure 07 - Taper Plug Configuration (per Abel 1998 **Bulkhead Design for Acid Mine Drainage***)*

The Abel methodology is based on a monolithic plug and takes into account shearing stresses acting on a plug. For the Bulkhead, the large access opening and pipes will result in a substantial loss of concrete section and redistribution of pressure forces on the Bulkhead. The large access opening does provide a benefit of redistributing a significant portion of the pressure load closer to the Bulkhead perimeter where the rock reaction occurs. To assess the effect of these openings, a finite element analysis has been performed to quantify the stresses within the concrete and verify adequate structural capacity. The finite element analysis is presented in Appendix H.

Reinforced concrete design has been performed in accordance with the standard ACI 318 *Building Code Requirements for Structural Concrete* utilizing a minimum load coefficient of 1.4 for static loads. The Bulkhead will consist of 4000 psi (28 day compressive strength) self-consolidating concrete enhanced with a crystalline waterproofing admixture to improve long term water resistance. Steel reinforcement, primarily for shrinkage and crack control, is being considered for the both upstream and downstream concrete surfaces.

For the maximum seismic event, the seismic forces on the Bulkhead have been computed based on the seismic approach presented in Sawyer “A Method for Calculating Hydrodynamic Loads on Underground Bulkheads” published in the *Proceedings of the 2007 SME Annual Meeting* which adapt hydrodynamic loads for dams to underground bulkheads. Due to the relatively minor seismic ground acceleration in the Telluride area (PGA=0.179g), the total factored seismic load on the bulkhead remained below the total factored static load on the bulkhead and no special seismic provisions are needed. Appendix I contains the full seismic evaluation.

3.3 Preliminary Design Details

Many of the preliminary design elements of the Bulkhead are discussed in other sections and the details of the Bulkhead are best presented in the design drawings in Appendix A. The basic cross-section of the Bulkhead is shown in Figure 08.

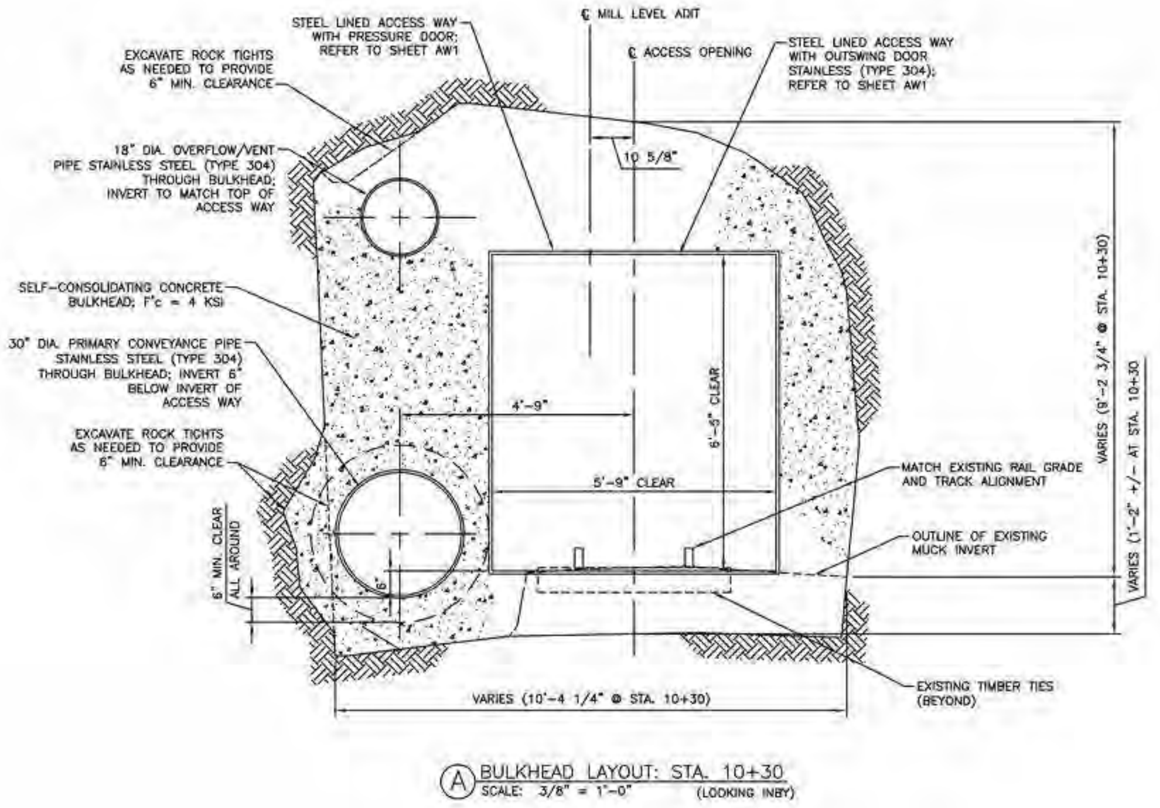


Figure 08 - Basic Bulkhead Layout

A minimum of 6” will be maintained between Bulkhead penetrations and the surrounding bedrock to allow the self-consolidating concrete mix to readily flow around the pipes and access way structure. Some minor additional rock excavation will be required to achieve this clearance around the pipes. Contact grouting of the rock/concrete interface will be performed to limit the potential seepage along the contact. Additional perimeter grout tubes will be utilized to further enhance the seal between the concrete and the rock.

4.0 Piping & Valves

4.1 Design Criteria

The piping design for the proposed Tunnel Bulkhead project consists of the pipe intakes, primary and backup pipes through the Bulkhead, conveyance pipeline, valves, fittings, and instrumentation from the Bulkhead to the Portal. The pipeline system is designed to handle 900 feet of hydrostatic head or approximately 423 pounds per square inch (psi) of pressure. The flow criteria for the project is based on historic flows from the Tunnel. The piping from the Bulkhead to the Portal outlet has been designed to be capable of conveying 12,500 gpm peak flow with approximately 5 feet of hydrostatic head behind the bulkhead.

Flow through the primary or overflow Bulkhead pipes will each be controlled by a motorized on/off valve with a manual override at the Bulkhead. This will ensure the safety of the operators during maintenance or emergency conditions relating to the conveyance pipeline downstream of the Bulkhead. The overflow line will provide backup flow conveyance capability from behind the Bulkhead, in the case that the primary line should plug with debris or require maintenance and will connect into the water conveyance line just downstream of the Bulkhead. The water conveyance pipeline will run from the motorized valve at the Bulkhead to near the Portal, where flow will be measured through a magnetic flow meter and controlled by either one large or two smaller modulating flow control valve(s). Conveying the flow in a pipeline from the Bulkhead to near the Portal allows for increased safety by minimizing time underground to inspect or manually adjust Bulkhead outlet valves and provides flexibility for upgrading the conveyance system in the future. A manual shutoff valve near the Portal and upstream of the flow meter and modulating valve(s) will allow operators to shut off flow and to perform maintenance on the flow meter or modulating valve(s).

In addition to the primary and overflow piping, a small pipeline will also be run to near the Portal to provide pressure measurements of the hydrostatic head behind the Bulkhead. This line will have a motorized shutoff valve with a manual override at the bulkhead and a manual shutoff valve near the Portal and upstream of the pressure sensor.

The primary intake manifold piping behind the Bulkhead will be designed with multiple intake locations to allow water to continuously flow in the event of debris buildup on one or more of the primary pipe inlets.

4.2 Design Methodology

The friction losses through the pipe, fittings and valves were modeled using the Hazen-Williams formula for gravity pipe flow at 12,500 gpm with 5 feet of hydrostatic head. The intake header upstream of the Bulkhead for the primary conveyance pipe will have a perforated inlet manifold to allow flow, prevent large debris from entering the pipe, and minimize the blockage potential of the pipe. In the event of a full blockage of the primary pipe, it is anticipated that the Tunnel will fill to the level of the overflow pipe and pumping will be required to lower the water level to allow access for cleaning of the primary pipe blockage behind the Bulkhead.

The conveyance pipeline from the Bulkhead to the Portal will be epoxy-lined carbon steel to protect it from corrosion. The outside of the pipe will be coated for exterior protection. The conveyance pipeline will have redundant valves in place consisting of electrically operated valves with a manual override located at the Bulkhead and a combination of manual and electrically operated valves at the Portal to control flow through the Bulkhead and provide water shutoff capability for safety and maintenance. The Bulkhead valves will be on/off valves while the valves located at the Portal will be a manual on/off valve and an electric modulating valve that controls the flow rate. A magnetic flowmeter capable of measuring a wide range of flows will be located near the Portal. The conveyance pipeline will discharge to an energy dissipation structure and into the Tunnel, before it is conveyed to the infiltration ponds through the existing conveyance pipelines.

4.3 Preliminary Design Details

As previously discussed, the primary conveyance pipe has been designed to flow 12,500 gpm with 5 feet of hydrostatic head behind the bulkhead and has a length of 1,050 feet. The slope of the pipeline from the bulkhead to the portal is approximately 0.005 foot per foot, based on existing mapping and survey information. This provides a conservative level of head loss for the flow evaluation, as the pipeline will likely end up shorter than 1,050 feet and there will be an additional 5 feet of head from the Bulkhead to the Portal.

The friction losses through the pipe, fittings and valves were modeled using the Hazen-Williams formula for gravity pipe flow to determine optimal sizing for the conveyance pipeline. Friction loss coefficients simulating internal corrosion potentially resulting in increasing roughness over time were also run to determine the potential loss in pipe flow capacity over time and long-term conveyance capacity. The roughness coefficient used for new pipe was 140 and for pipe that had been run for a period of time, the coefficient used was 100.

Figure 09 shows the conveyance pipeline flow rates at various heads, for different roughness coefficients, and for different materials. Figure 09 has a maximum shown head of 100 feet, because pipeline flows will be limited to a velocity of approximately 10 feet per second which equates to 20 feet of head with a friction coefficient of 100 and a flow rate of 20,000 gpm. Figure 09 is conservative in flow rates versus head, as the flows calculated use 5 feet of head behind the Bulkhead but do not account for the additional 5 feet of head from the Bulkhead to the Portal due to the slope of the Tunnel.

Based on the parameters stated above, the calculated pipe size to convey the desired flows is either a 30-inch diameter single pipe or dual 20-inch diameter pipes. Given room limitations in the bulkhead area, the preliminary design choice is for a single 30” primary conveyance pipeline. Flow through the single 30-inch conveyance pipe will be controlled by three valves, two shut off valves and one throttling valve, with one shut off valve located near the Bulkhead and one shut off valve and the throttling valve located near the Portal.

A potential alternative option to the single 30-inch throttling valve would be two 18-inch throttling valves on the 18-inch branches of a 30 x 18 x 18-inch wye. The conveyance pipeline would still be 30 inches, with the reducing wye located near the Portal. This would allow redundant flow controls and potentially more accurate control of flows. Under this option, manual shut off valves would be installed upstream of both modulating valves on the 18-inch lines in addition to the 30-inch electric on/off valve installed near the bulkhead. The modulating valve(s) would allow for control of the flows as needed to either temporarily restrict or stop flows and inundate the Tunnel behind the bulkhead, as required for operations.

The overflow/ventilation pipeline will be 18 inches, as it is intended to only provide backup and contingency flexibility for temporary periods. The pressure monitoring line will be a 1-inch stainless steel pipe running the length of the tunnel from the bulkhead to the termination of the conveyance pipeline.

The primary conveyance pipe intake header will extend behind the bulkhead along the floor for approximately 50 feet. There will be a flared inlet at the intake of the main pipe with a trash rack to capture large debris. Along the header, there will be a series of tees connected to short vertical pipe sections with perforations. The perforations in the vertical sections of pipe will be large enough to allow water to flow into the tee and subsequently into the main conveyance pipe, and they will be spaced to maintain pipe integrity. These tees will allow water to continue to flow into the pipe in the event that debris plugs the primary pipe intake. The intake header material will be fused high density polyethylene (HDPE), as this section of the pipe will not be pressurized.

The intake header for the overflow pipe will extend behind the bulkhead along the back of the tunnel for approximately 5 feet. There will be an open end at the inlet to allow for installation of a temporary pump in the event the primary line becomes plugged. The intake header material will be stainless steel. The primary and overflow pipes through the bulkhead will be stainless steel and flanged on both sides of the bulkhead.

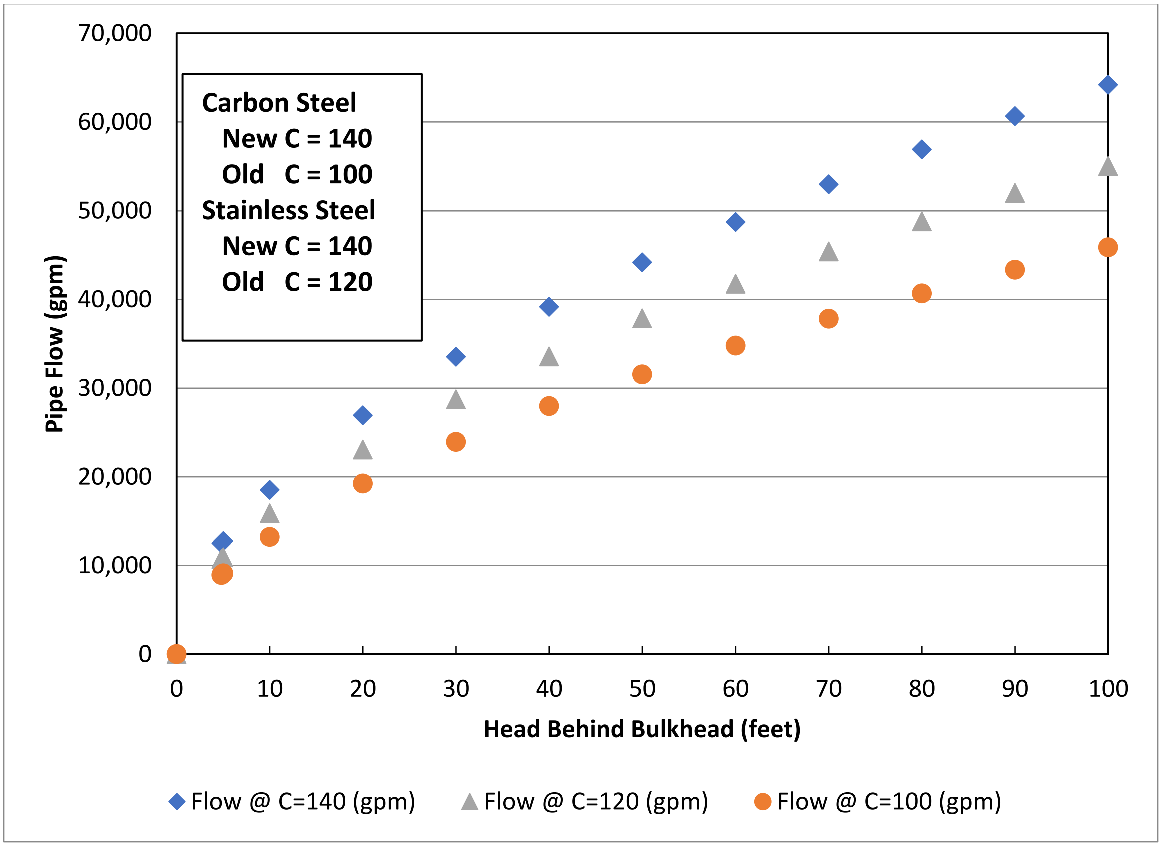


Figure 09 - 30-Inch Pipe Flow at Various Heads

5.0 Bulkhead Access

5.1 Design Criteria

Idarado has established a design objective to maintain access beyond the Bulkhead for Tunnel maintenance, debris removal, and for flexibility of future operations. Several variations of access have been considered including limited man access via small openings to large, rail accommodating access for workers and heavy equipment. The preliminary design calls for a large access way incorporated into the Bulkhead with dimensions matching the existing access dimensions downstream of the Bulkhead to the Portal. These larger dimensions will permit passage of a small load-haul-dump machine (LHD), such as the JCI 125M LHD, shown in Figure 10, or mine rail equipment to allow significant maintenance or debris removal beyond the Bulkhead.

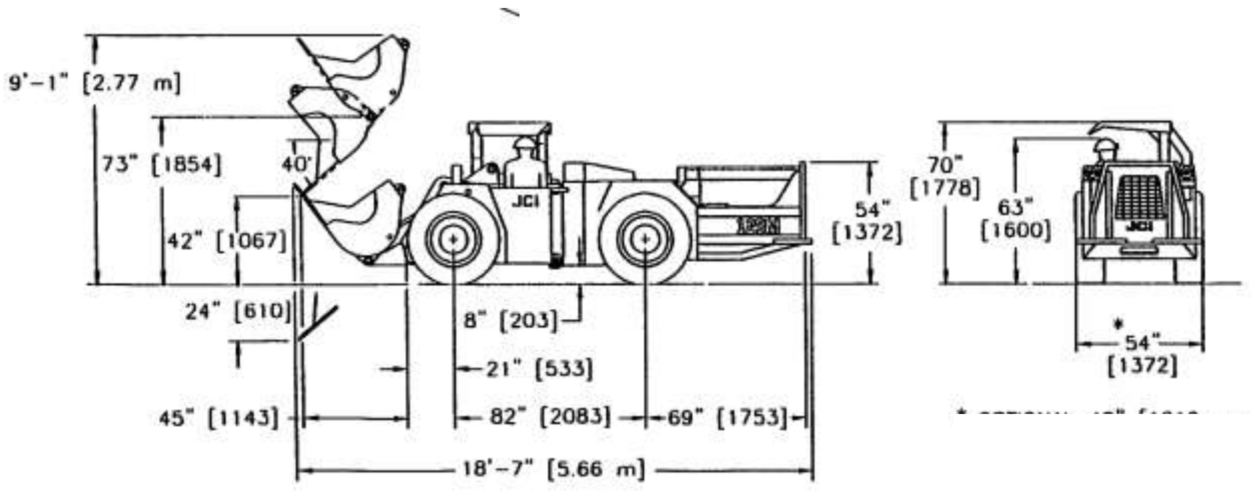


Figure 10 - Dimensions for JCI 125M LHD

All Bulkhead concrete penetrations, including conveyance pipelines and ventilation pipelines, will need to be cased to prevent collapse/failure of the penetrations if subjected to the conservative hydrostatic design pressure. This is based on the penetrations being subjected to potentially significant external water pressure (i.e. water at interface between casing and concrete). The casing will also be needed to prevent flow through cracks and other concrete defects near the pressure side of the Bulkhead. The cased penetrations will also serve as stay-in-place formwork for the Bulkhead concrete pour and will need to capable of resisting a fluid concrete pressure plus a surcharge pressure of up to 50 psi associated with filling the concrete forms completely. To allow for access over the long-term, a pressure door will be required to fully resist the maximum potential hydrostatic head of approximately 900 feet without experiencing deformation. To ensure longevity in the underground environment, it is anticipated that stainless steel will be utilized for the door, forms, access way, and pipe penetrations.

5.2 Design Methodology

All steel designs will be performed in accordance with design methodologies and criteria presented by the American Institute of Steel Construction (AISC) in the most recent publication of the *Steel Construction Manual*. Aluminum design (potentially for a stop log access way option) will be performed according to the most recent version of the *Aluminum Design Manual* published by the Aluminum Association. Although the Bulkhead is currently intended to be operated in a flow-through manner, there is the potential that unforeseen events or circumstances may change the operation and a fully inundating bulkhead must be considered as part of the design. Accordingly, the access way will be designed utilizing conventional safety, load, and strength reduction factors associated with permanent steel or aluminum structures for the maximum potential hydrostatic head. This will result in a significantly over-engineered pressure door and access way for the intended flow-through Bulkhead operation.

Several types of door have been evaluated and designs progressed to various levels, with each design evaluation identifying both design and operational advantages and disadvantages. The door design details will also affect the access way design. Refer to the following section for description of the door/access way alternatives under consideration.

5.3 Design Details

Several Bulkhead door options have been evaluated for safety, worker and equipment access, and long-term durability and operational flexibility. Three primary door options have been identified with a few potential variations for each option: 1) an in-swing door on the upstream side of the Bulkhead, 2) an out-swing door on the downstream side of the bulkhead, and 3) a stop log system which utilizes a series of aluminum beams placed across the access way. The current preferred alternative is an upstream, in-swing door split door (e.g., Dutch) with a top that can be opened to clean out silt and detritus to allow the bottom portion of the door to open freely.

A brief description of each door and the characteristics associated with each are presented in this Section. A drawing that shows a generalized cross section of each door is presented in Appendix A, Design Drawings.

5.3.1 Upstream, In-Swing Pressure Door:

An upstream, in-swing door is a relatively simple door that is designed for swinging into the upstream side of the Bulkhead with any hydrostatic pressure acting to close the door and assist in maintaining a water seal. The upstream swinging door would be located near the upstream end of the Bulkhead to allow the door pressure to be transferred to the pressure side of the Bulkhead.

An upstream, in-swing bulkhead door would be supplemented with trash racks upstream of the Bulkhead which span the full Tunnel width and height, to catch any large debris. The primary disadvantage with an upstream, in-swing door is the potential for sediment, debris, and obstructions to accumulate on the upstream side preventing the door from opening. Provisions can be made for a secondary, smaller manway to allow for manual debris/muck removal to clear the door swing area for opening. One variation for providing alternative access for sediment removal is breaking the door into an upper half and a lower half (similar to a Dutch door), which would enable the upper half to be opened to allow debris/muck removal from in front of the lower half. An example of the Dutch door concept is shown in Figure 11. Currently, specialty door manufacturers are being consulted to evaluate the feasibility of a high-pressure version of the Dutch door concept.

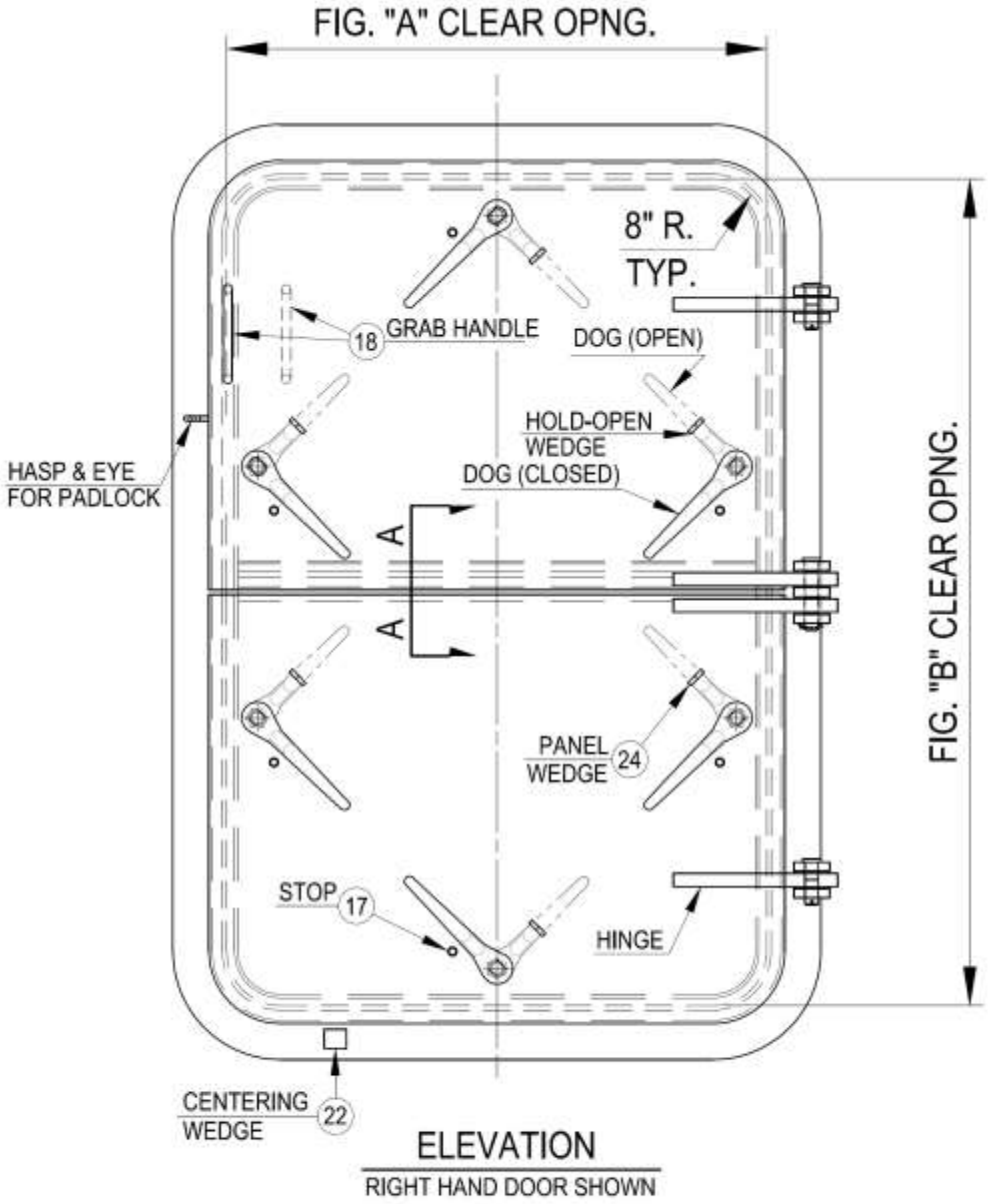


Figure 11 - Example of a Dutch Pressure Door (Low Pressure Door from Centex Marine)

5.3.2 Downstream, Out-Swing Pressure Door:

A downstream, out-swing door orientation to the non-pressure side of the Bulkhead is attractive for ensuring that the door will always be able to open regardless of debris buildup on the upstream side of the Bulkhead. However, this type of door requires a much more complicated locking and sealing mechanism to ensure that the door is capable of resisting the full 900 vertical feet of hydrostatic pressure. This style of door would be more difficult to seal than the upstream, in-swing door option. Preliminary discussions with specialty door manufacturers indicate that this style of door is not commonly utilized for high pressure head scenarios and that design and fabrication costs would be significantly greater than with an in-swing door, if it was feasible at all. Initial calculations show a significant number of bolts would be required to maintain door closure under the high head scenario, but that it could be a feasible option. The access way would need to be designed to resist internal pressure and to transfer the tensile reaction of the door to the front of the bulkhead. Preliminary drawings were developed to demonstrate one potential outswing door concept, shown in Figure 12. Recent conversations with a specialty pressure door manufacturer (Walz & Krenzer Doors) indicate that alternative arrangements of the bolts may reduce the size and number of required bolts.

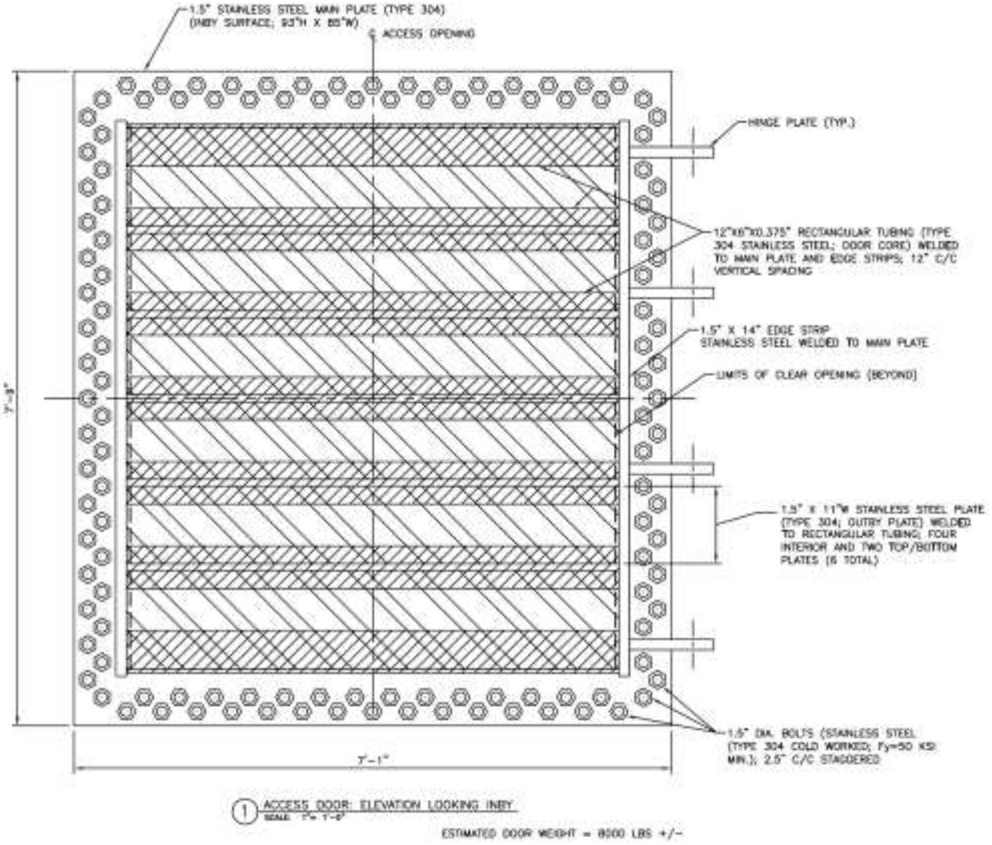


Figure 12 - Preliminary Concept of Outswing Pressure Door

5.3.3 Stop Log System:

A stop log system was identified as potential option to provide reliable structural strength to resist the 900 feet of hydrostatic head (with some leakage) while allowing for worker and equipment access. Figure 13 shows a conceptual stop log access way design. In lieu of a conventional hinged bulkhead door, the access way would be comprised of stacking stop logs which would avoid the expense of an out-swing door and the potential blockage issues associated with an in-swing door. This concept was progressed and similar to the previously discussed hinged doors, appears to be a viable option. Design calculations indicate that the 900 feet of design head will require relatively heavy steel shapes for the stop logs and guides which would require a secondary hoisting/winching system to move each stop log. To reduce the weight of the stop logs, both fiberglass and aluminum were evaluated with a 4-inch high aluminum stop log having the necessary strength and a relatively light weight of approximately 120 pounds each. Intermediate vertical beams were considered but have the disadvantage of concentrating loads and would require significantly heavier steel members than a simple horizontal stop log system. To minimize handling within the Tunnel and to maximize safety, a horizontal overhead stop log storage rack could be incorporated into the Bulkhead for the stop log system alternative.

Provisions have been incorporated into the preliminary stop log design to minimize leakage given that the potential maximum hydrostatic head would create significant pressurized streams, if unimpeded. A heavy duty ethylene propylene diene monomer rubber (EPDM) curtain could be attached to the upstream side of the Bulkhead above the door opening and secured below the door prior to placement of the stop logs. When access would be desired, the curtain could either be rolled up and secured above the door or draped forward and secured to the Tunnel back. The EPDM curtain would conform to minor irregularities in the door geometry but may have limitations under full design hydrostatic pressure. A secondary sealing system would include compressible gaskets placed horizontally between the individual stop logs and vertically between the stop log guide beam and the stop log. A rear steel backer guide plate or a tongue and groove system on above and below each stop log could be included to prevent the horizontal compressible gasket from dislodging under pressure.

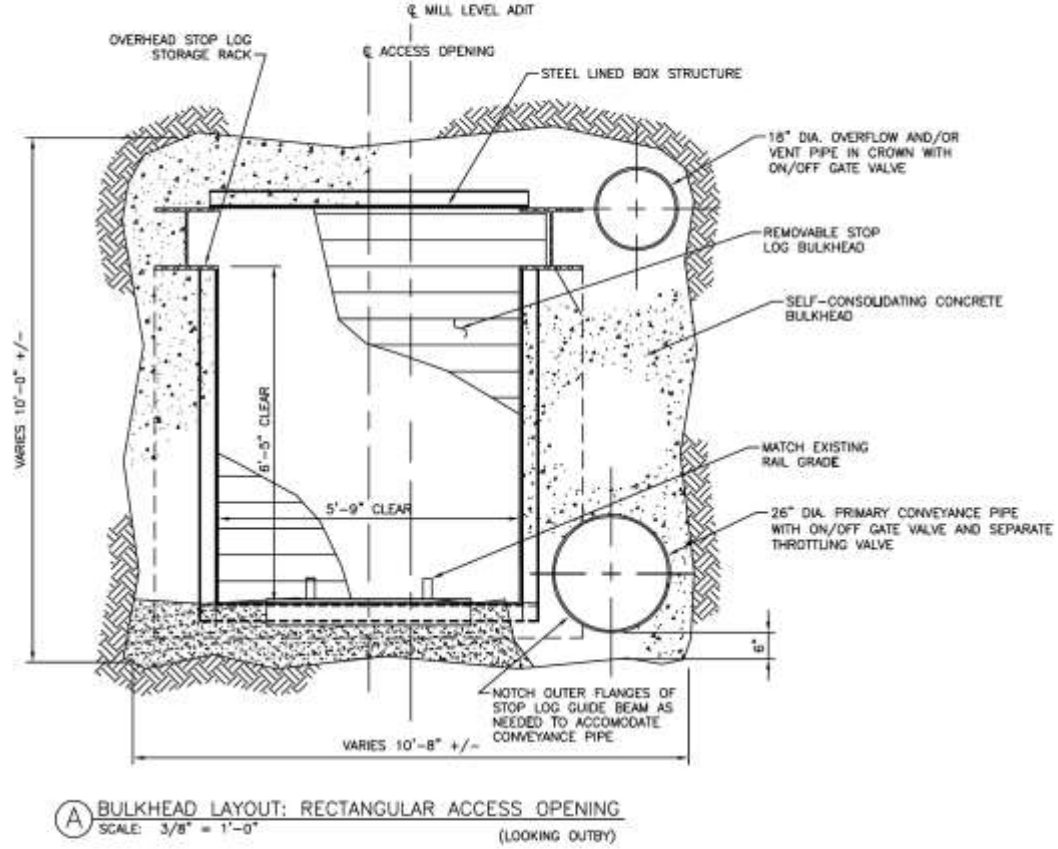


Figure 13 - Preliminary Concept of Stop Log System

5.3.4 Selection Matrix

Based on the evaluation performed to date, all three primary door alternatives appear to be technically feasible with each having their own advantages and disadvantages. To assist in selection, a preliminary Multiple Criteria Decision Analysis (MCDA) summary matrix is presented in Table 5-1 for the various door alternatives currently in consideration.

As stated in Section 5.3, the current preferred alternative is an upstream, in-swing door with a Dutch door top that can be opened to clean out silt and detritus to allow the bottom portion of the door to open freely.

5.3.5 Door Alternative Selection

No final decision has been made on the preferred door alternative, although the upstream Dutch door alternative is currently the preferred option pending stakeholder agreement. It is anticipated that a specialty door fabricator will be enlisted during the final design phase to design, fabricate, and supply the preferred pressure door for the bulkhead.

Table 5-1 Bulkhead Access Options Matrix

Option	Tunnel Maintenance Accessibility	Advantages	Disadvantages	Safety Concerns
No Door	None	Simple design and construction	Eliminates access to tunnels; No ability to perform future maintenance to workings; Does not meet design objectives	Routine Construction Safety; No ability to maintain Tunnel
No Door – large pipe overhead for access to clean primary drain inlet	Very Limited	Simple design and construction; Provides worker access to underground	Limited ability to maintain workings; No rail access for heavier work behind bulkhead; Safety issues and confined space requirements	Slow egress; Confined spaces; Tight entrance/exit;
6' x6.5' Access with upstream stop logs	Good	Low risk of silting in; Allows top-down removal of stop logs to facilitate clearing stacked door debris; No issues with door swing radius below track grade	Sealing difficulty /High Pressure spray concerns;; Log handling complexity, danger, potential to seize up; Unique, one-off, untested design; Structural complexity for design	High pressure spray; Stop Log Handling
6' x6.5' Access with outswing door on downstream side	Good	No risk of silting in or being blocked by debris	Outswing could be more dangerous due to hydrostatic pressure forcing it open; Outswing will be heavier and more expensive; Difficult to seal; Very heavy, more difficult to construct and install; Structural complexity for design	High pressure spray potential; Very heavy; Reliant on equipment to determine if safe to open
6' x6.5' Access with inswing monolithic door on upstream side, +/- overhead emergency access pipe for silt muck out	Good	Intrinsically safer than outswing, uses withheld pressure to stay shut; Less leakage likely	Likely to get silted in at bottom; Access pipe adds complexity to design, makes ventilation more difficult; Confined space considerations;	Confined space considerations for silt removal
6' x6.5' access with inswing "Dutch door" on upstream side	Good	Intrinsically safer than outswing, uses impounded water pressure to stay shut; Less leakage likely than stop log or outswing; Silt can be cleaned via top half of door; Safer with no confined spaces; Ventilation system doesn't need to be modified to act as emergency access way; Cheaper than outswing	Possibility for some leakage relative to single-piece door; Slightly more expensive than single-piece upstream door; Upper door could silt in under unusual or unforeseen circumstances	-
Larger access with inswing monolithic door on downstream side into corridor and stop logs on upstream side to protect inswing door from silt/debris	Moderate	Redundant Safety; Low Leakage; Mitigated silt issues	More complicated design; Most expensive option; Heavy outswing door has to be designed to withhold 900 ft of head w/ bolts and additional reinforcement without the benefit of hydrostatic pressure holding it shut; Requires more work and time underground to open and close	Stop log handling hazards;

6.0 Instrumentation and Controls

6.1 Design Criteria

The primary design criteria for the instrumentation and controls are to monitor water levels behind the bulkhead, control flows from the bulkhead, monitor oxygen levels within the Tunnel, and record data from these instruments. All instrumentation and controls installed in the conveyance pipeline will be designed for potential pressures of at least 900 feet of hydrostatic head and all controls and instrumentation will be moisture resistant, water splash resistant, and/or submersible, as applicable.

The instrumentation and controls for the Tunnel bulkhead project will include a programmable logic controller (PLC), human machine interface (HMI), pressure element, flow meter, oxygen sensors, electric valve control, and radio communication system. Instrumentation installed in the Tunnel will meet National Electric Manufacturing Association (NEMA) requirements for hose directed water and temporary immersion at a limited depth. Cabinets installed in the Tunnel will meet NEMA requirements for splashing and hose directed water.

The PLC/HMI system will control the valves, monitor water flow rates, monitor water pressure behind the bulkhead, monitor oxygen levels in the Tunnel and communicate with a computer system located at the office. The HMI system at the office will communicate with the PLC/HMI at the portal through a radio system, will allow remote monitoring and control of the instrumentation/valves in the Tunnel and at the Bulkhead, and will save the collected data.

The flow meter and pressure transducer will be designed to a potential pressure of at least 900 feet of head. The flow meter will monitor the flow rate through the water conveyance pipeline from the Bulkhead. The pressure transducer will monitor the water level behind the Bulkhead in psi which will be converted by the HMI system to feet of head.

The conveyance pipeline will have redundant electrically operated valves in place, located at the bulkhead and near the portal to control flow through and from the Bulkhead. The Bulkhead valves will be on/off valves while the valve located near the Portal will be an on/off and a modulating valve that controls the flow rate.

For worker protection, there will be three oxygen sensors installed in the Tunnel that will be monitored by the PLC for oxygen concentrations.

6.2 Design Methodology

The design of the instrumentation and controls system consisted of performing a “What–If” style of analysis which includes selecting equipment and control systems that have replacement parts readily available, proven in their operation, and are of robust design. The system will consist of placing a PLC/HMI at the Portal to collect the flow rates from the new flow meter transmitter located on the flow conveyance pipeline. The flow rate of the conveyance pipeline will be regulated using either one large modulating flow valve or two smaller modulating flow valves located near the Portal. The modulating flow valve(s) will receive control set point(s) for flow or percent open from an operator input set point on either the HMI located at the portal or a second HMI located at the mine office.

There will be two electrically operated valves, with manual overrides, installed on the primary and backup conveyance pipes located at the Bulkhead to allow either remote or local shut off of water flow from the Bulkhead. The Bulkhead valves will be either fully open or fully closed; the throttling of the flow rate will be controlled with the modulating valve(s) near the Portal. A redundant open/close valve will also be located before the modulating valve(s) near the Portal.

The PLC will monitor the pressure element installed on new pipe through the Bulkhead to monitor water pressure behind the Bulkhead. The pressure signal will be sent from the Portal PLC to the office HMI over the radio system to ensure the pressure can be monitored both locally and remotely by the operators.

To help ensure the safety of workers and operators in the tunnel area, three oxygen sensors will be installed in the Tunnel and oxygen concentrations will be monitored by the PLC. A safe oxygen concentration beacon will be placed outside the Portal to alert the operators when the Tunnel is safe or unsafe to enter. Given that the Portal entrance will be left open to the atmosphere it is anticipated that the atmosphere will remain safe, but this system will provide an additional level of worker safety.

The HMI system will have the capability of communicating the Tunnel system status and control information from the Portal to the mine office using a radio communication system. The radio system will allow the operators at the office to remotely monitor and control the modulating flow valve(s) and electric on/off valves. The HMI at the office will have the capabilities of storing historical data to allow the operators to evaluate and use the discharge flow rates, Bulkhead pressure, and oxygen systems data for trends and reporting. In addition, the office HMI will have the capabilities to call out, via a phone system, if a problem arises in the Tunnel operations.

6.3 Design Details

A new PLC/HMI system will be designed and installed at the entrance to the Tunnel and will collect the conveyance discharge flow, bulkhead pressure and oxygen level data, which will then be transmitted to the office HMI. The PLC will collect the pressure from the pressure transmitter located in the Portal. There will be an electrically operated valve, with a manual override, installed on the pressure transmitter pipe and located at the Bulkhead to remotely or locally shut off water within the pipe. The Bulkhead valve for the pressure line will be either fully open or fully closed. A redundant open/close valve will also be located before the pressure transmitter near the Portal.

The PLC/HMI system will monitor the flow in the conveyance discharge pipeline using a magnetic style flow indicating transmitter. The signal from the flow meter will be transmitted to the PLC and the flow information will be used to help control either a 30-inch or two 18-inch motor driven modulating flow valve(s) located near the Portal. The flow valve(s) will be powered from the Portal entrance 480 Volt power panel, HV-MP-1, and controlled by the PLC. The PLC will also control the electrically operated valves located on the primary and backup discharge piping at the tunnel Bulkhead. The valves located on the Bulkhead primary and backup piping will provide on/off flow control of the Bulkhead discharge piping and will receive power from the new 480 V electrical power panel, HV-BH-1, installed near the Bulkhead.

The PLC/HMI will be connected to a radio control system with an antenna placed outside the portal entrance on a new pole and will send the signal to the office building. A new antenna will be installed at the office and connected to a new local HMI to allow the operators to view the current information from the installed instruments and control the valves located inside the Tunnel.

The three oxygen level sensors will provide input to the PLC to indicate, through an exterior mounted blue colored steady output safety light, a safe oxygen level is present in the tunnel. The first oxygen sensor will be installed near the portal entryway, the second sensor will be located halfway down the tunnel and the third sensor will be located near the Bulkhead. The HMI will be programmed for multiple alarms including: 1) high water pressure behind the bulkhead, 2) high flow from the conveyance pipeline flowmeter, 3) no flow from the conveyance pipeline flowmeter, 4) loss of power, and 5) loss of instrument signal. The PLC/HMI cabinet will have a 30 minute uninterruptible power supply (UPS) installed in the cabinet to maintain power to the PLC and provide indication of a power outage. The power outage signal will be sent over the radio control system to the office HMI to allow the operators to assess the problem and restore the power to the system.

The design will meet the current National Electrical Code, NEC70:2017, requirements and the control panels installed in the tunnel will be rated, NEMA 4 to protect from falling dirt, splashing and hose directed water. Instrumentation will be installed with an IP67 rating to protect from falling dirt, dust, splashing and hose directed water and be able to be immersed in water for short durations.

7.0 Electrical

7.1 Design Criteria

The proposed Tunnel and Bulkhead electrical work will include lighting, electric valves, and appurtenances which will require installation of a new electrical power circuit from the office substation to the Portal and then to the Bulkhead. Electrical power will originate from the onsite office substation and travel via an overhead line to the Portal. Electrical equipment outside the Portal will include a new, approximately 50 horsepower (HP), ventilation blower. Electrical equipment in the portal will include a new PLC panel, waterproof receptacles, motorized valves, and associated instrumentation. Electrical equipment at the Bulkhead will include a new welding receptacle, waterproof receptacles, motorized valves, and associated instrumentation. Voltage drop will be a major concern, due to distance between the Portal and Bulkhead, and equipment and cable will be evaluated to determine the best voltage and wire sizing to assure proper operation.

A new lighting system will allow workers to safely traverse and work in the Tunnel. Emergency lighting will allow egress of the Tunnel in case of a power outage. The lighting system will include a security light emitting diode (LED) light outside the Portal, a LED light in the Portal entryway near the PLC panel, LED rope lighting in the Tunnel from the Portal to the Bulkhead, a LED light at the Bulkhead, and emergency lighting in the Tunnel from the Portal to the Bulkhead. Multiple styles of LED lighting will be evaluated to determine the safest and most cost effective lighting equipment for the operational lights and emergency egress lights.

7.2 Design Methodology

The electrical power system will be designed to meet all current code and safety requirements and be built with a robust design. The electrical power requirements will be examined to provide the safest and most cost-efficient design for the electrical needs of the project. LED lighting will be used as these have a long life and to help eliminate voltage drop in the lighting system because LED lights are long lived and the most efficient among current lighting alternatives. Both rope style LED and standard LED fixtures will be evaluated to determine which style will best fit the design and safety criteria. Rope style LED lighting will be evaluated since it is water resistant and can provide a continuous lighting system down the entire length of the tunnel without having any ”dark” areas between lights, as is the case with individually spaced lighting fixtures. This will be important since the Bulkhead is 1,030 feet in from the Portal and the lower power requirement will mean lower voltage loss over this distance.

The electrical system will be designed to provide a safe power supply to equipment being used at the Portal and Bulkhead. 480 Volt power is available at the mine office substation and power will be transmitted at that voltage to the Portal entrance and to the Bulkhead area to minimize voltage drop. Ground fault circuit interrupter (GFCI) breakers and receptacles will be used due to the presence of water and moisture in the Tunnel.

7.3 Design Details

The criteria for the project electrical design will be to provide power for the new equipment installed in the Portal and Bulkhead areas of the Tunnel. The design will meet the current National Electrical Code, NEC 70: 2017, and OSHA 1926 Lighting requirements. The new power will be brought to the Portal from the existing office substation using an overhead quadplex conductor on existing or possibly new poles. The electrical facilities will incorporate a new 480/277 Volt three-phase panel at the Portal that will be powered from the existing onsite substation. The new Portal 480 Volt panel will provide power to a new 480/277 Volt panel located at the Bulkhead. The primary 480 Volt panel will also provide 120/208 Volt power through a stepdown transformer to power the Portal receptacles, new PLC control panel, and associated instrumentation. The main 480 Volt panel will also provide power to the new electric flow-modulation valve(s) and the approximately 50 HP blower, to be installed at the Portal to provide ventilation in the Tunnel. The secondary 480/277 Volt panel located at the Bulkhead will supply 480 Volt power to a new welding receptacle as well as 120/208 Volt power through a step down transformer for 120 Volt GFCI receptacles, lighting, electric valves, and other equipment requiring power.

New lighting in the tunnel will meet the requirements of OSHA 1926 and will be provided by either a section of LED rope lights installed on the tunnel roof or individual LED area lights spaced along the tunnel walls. The LED rope lights or individual lighting fixtures will be powered from the 120/208 Volt panel at the entrance of the tunnel for the first 525 feet, and the remaining 505 feet will be powered by the 120/208 Volt panel located in the Bulkhead area to help eliminate voltage drop in the lighting conductor. A series of battery-powered emergency backup LED lights will allow egress of the Tunnel in case of a power failure.

8.0 Permanent Downstream Tunnel Ventilation

The intent of the ventilation system is to support safe access for inspection and any future maintenance or rehabilitation of the tunnel segment from the Portal to the Bulkhead dry side face, under a condition where the bulkhead access door is closed and does not have natural flow-through ventilation.

8.1 Design Criteria

The site is no longer an active mine subject to MSHA regulations, to any future tunnel repair work would be governed by OSHA 1926.800, Underground Construction (Tunneling) regulations.

Within these regulations, ventilation requirements are:

- 1926.800(K)(2) - 200 Cubic Feet Per Minute (CFM) per person, and;
- 1926.800(K)(10)(ii) – 100 CFM per horsepower of diesel equipment in use underground

The tunnel is not considered a 'gassy' tunnel capable of liberating significant amounts of methane or other potentially flammable gases. This determination is supported by site history, geologic setting and numerous past ventilation measurements. However, as discussed in the instrumentation and controls section, automatic oxygen sensors will be in continuous use within the Tunnel, if workers are present or not.

For design purposes, we are assuming that the maximum diesel horsepower is represented by either a mine locomotive or small (e.g. 1.25 cubic yard) LHD unit, with a 60 horsepower engine. A work crew is assumed to be a team of workers plus inspectors of6 individuals.

The minimum ventilation required under this scenario would be:

- 60 HP x 100 CFM/HP = 6,000 CFM
- 6 People x 200 CFM/Person = 1,200 CFM
- Design Minimum Airflow = 7,200 CFM

8.2 Design Methodology

Because the ventilation system is intended to be effective under conditions where the Tunnel is shut at the Bulkhead, a duct type ventilation system is appropriate.

The governing equation for determining the required ventilation fan is below. This equation relates required airflow, duct diameter and type, and duct length.

$$\Delta H = \left(\frac{K\,L\,O\,Q^2}{5.2\,A^3}\right)\left(\frac{\rho}{.075}\right)$$

Where:

ΔH = Pressure loss in inches water gauge (WG)
C = Loss coefficient
V = Air velocity in feet per minute (FPM)
L = Length of duct in feet
O = Perimeter of duct in feet
Q = Air Quantity in units of 100K CFM
P = Air Density (0.075 pounds per cubic foot (lb/Ft^3) is standard air, altitude correction is applied)
A = Area of duct in square feet (ft^2)
K = Friction factor of duct material

Using this equation, the head pressure at the required airflow for various duct sizes can be obtained. Once that pressure/volume relationship is known, the appropriate fan size can be determined.

8.3 Design Details

For design purposes, the required ventilation at the fan is calculated to be 8500 CFM, which includes a factor of safety for unknown items such as leakage. Using the average summer temperature at the Portal and elevation of 9062 feet amsl, the calculated density factor is approximately 0.0525 lb/Ft^3, resulting in a correction factor of 0.7.

Due to the need to keep the duct diameter as small as possible, the design a rigid plastic duct with a low K factor, such as that offered by EP Ventilation. While more costly to purchase, the low resistance cuts the power requirement approximately in half, when compared to steel ducting, and this type of duct is not subject to rusting that would occur with steel.

A spreadsheet is used to perform the calculations and derive the total head. A copy of the inputs and results is presented in Table 8-1.

Table 8-1 Spreadsheet Used to Derive Total Head

DATE: 08-Mar-18			
MINE/PROJECT: Idarado Mill Level - Portal to Bulkhead Location			
REQUIREMENTS:			
Cubic feet/min (cfm)	8500	CFM	INPUT
Length of duct (ft)	1050	FT	INPUT
Diameter of duct (in)	18	" DIA.	INPUT
Number Of 90 degree elbows	0		INPUT
Number Of 45 degree elbows	0		INPUT
Friction factor	7		INPUT
Entrance loss	1		INPUT
Exit loss	1		INPUT
RESISTANCE CALCULATIONS:			
Static resistance	8.7206	" WG	CALC
Elbow resistance	0.0000	" WG	CALC
Entrance loss	1.4424	" WG	CALC
Exit loss	1.2260	" WG	CALC
TOTAL STATIC RESISTANCE	11.3891	" WG	CALC
CALCULATED PARAMETERS:			
Diameter of duct (ft)	1.50	FT	CALC
Velocity pressure loss	1.4424	"WG	CALC
Perimeter (ft)	4.7124	FT	CALC
Area of duct (ft2)	1.767	FT2	CALC
Feet per minute	4810	FPM	CALC

The head pressure and air volume required is then used for sizing and selection of the required fan, using fan curves supplied by various manufacturers. The fan sizing and selection will be completed during final design.

9.0 Permanent Downstream Tunnel Support

9.1 Design Criteria

To ensure safe and reliable access, maintenance, and operation of the Bulkhead, the existing area downstream of the Bulkhead location must remain open and accessible. Currently the Tunnel is primarily supported by rock bolts with a thin layer of shotcrete (flashcrete) and either chain link mesh and minestraps or channel plates. A summary of the existing rock supports to the Station 10+30 bulkhead location are presented in Table 8-1 and examples of the supports are show in Figures 14-17.

Table 9-1 Approx. Stationing: Existing Adit Support System

Portal	Concrete box structure
0+20 to 0+40	Square rib sets with overhead timber lagging
0+40 to 1+42	Rock bolts, chainlink mesh, and minestraps
1+00 to 3+85	Rock bolts, chainlink mesh, minestraps, and flashcrete
3+85 to 6+20	Rock bolts, channel plates, and flashcrete
6+20 to 6+85	Rock bolts, chainlink, minestraps, and flashcrete
6+85 to 7+60	Flashcrete
7+60 to 7+80	Rock bolts, chainlink mesh, minestraps, and flashcrete
7+80 to 8+10	Rock bolts, chainlink mesh, and flashcrete
8+10 to 10+55	Rock bolts, channel plate, and flashcrete
10+55 to 16+00	Rock bolts, chainlink mesh, minestraps, and flashcrete
16+00+	Rock bolts, channel plates, and flashcrete

Figure 14 - Existing Steel Sets and Concrete Box Structure (looking out of portal)

Figure 15 - Existing Rock Bolts, Chainlink Mesh, and Mine Strap Support (Outby of Air Door)

Figure 16 - Existing Rock Bolts, Chainlink Mesh, Mine Strap, and Flashcrete Support

Figure 17 - Existing Rock Bolts, Channel Plates, and Flashcrete Support

The primary design criteria for the downstream area from the Tunnel to the Bulkhead is to remain open and stable and allow for safe access to the Bulkhead. The access will be needed for maintaining the mechanical and electrical equipment at the Bulkhead (including the valves, pressure gages, lighting, electrical supply, and pressure door) as well as for potential maintenance of the Tunnel and inlet manifold upstream of the Bulkhead.

9.2 Design Methodology

During several site visits in2016, 2017, and 2018, the Tunnel appeared to be stable with very little evidence of rock falls questionable rock integrity. However, the rock support systems have been in place for decades and the integrity (particularly of the rock bolts) and remaining service life of the supports are uncertain. Given the length of service of the existing rock support systems, Tunnel supports will be supplemented by installation of new pattern rock bolts and wire mesh in the back to ensure reliable Tunnel support for the future. The ribs (sidewalls) of the Tunnel currently have little to no support and have not demonstrated any significant degradation. Scaling, spot bolting, and meshing will be installed as needed to stabilize any potentially problematic zones. As an alternative to welded wire mesh, fiber reinforced shotcrete could be applied to provide positive rock support. Resin grouted rock dowels will provide adequate anchorage in the Cutler sandstones, siltstones, and conglomerates and the resin encapsulation will extend the service life of the bolts. Because the Tunnel is relatively dry and given the longevity of the current support, it is anticipated that no special coatings or materials will be needed.

For the Portal area, new steel rib sets with overhead steel channel lagging will be used to renew the support within the existing steel ribs and lagging area. Square steel sets of comparable size to the existing steel sets will be inserted as jump sets between the existing sets. No particular structural issues were noted with the concrete box structure water collection structure for conveyance to the infiltration, and no retrofit measures are currently anticipated for the box structure.

9.3 Design Details

Given the relatively consistent dimensions of the Tunnel, a rock bolt pattern consisting of three 5 foot long bolts spaced every 4 feet along the tunnel axis will result in roughly a 4 foot center-to-center spacing grid and provide adequate pinning of the welded wire mesh. A typical support detail is shown in Figure 18.

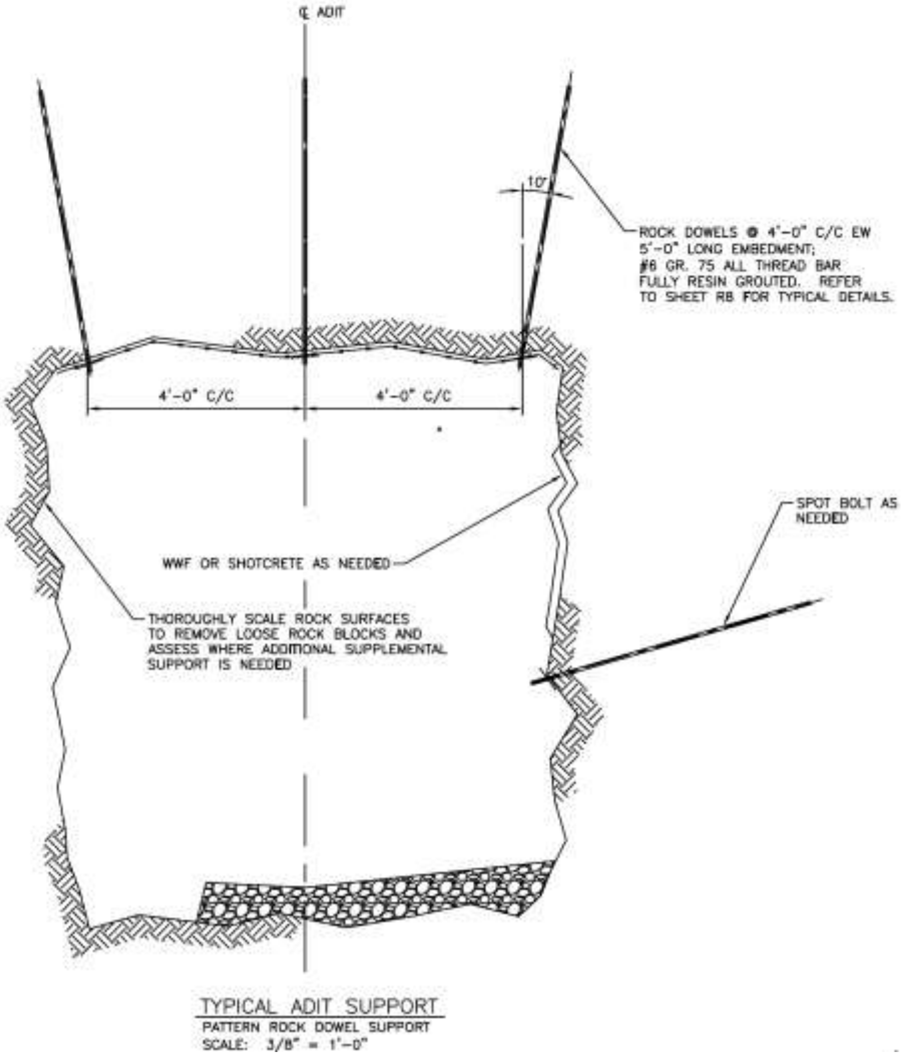


Figure 18 - Typical Supplemental Adit Support

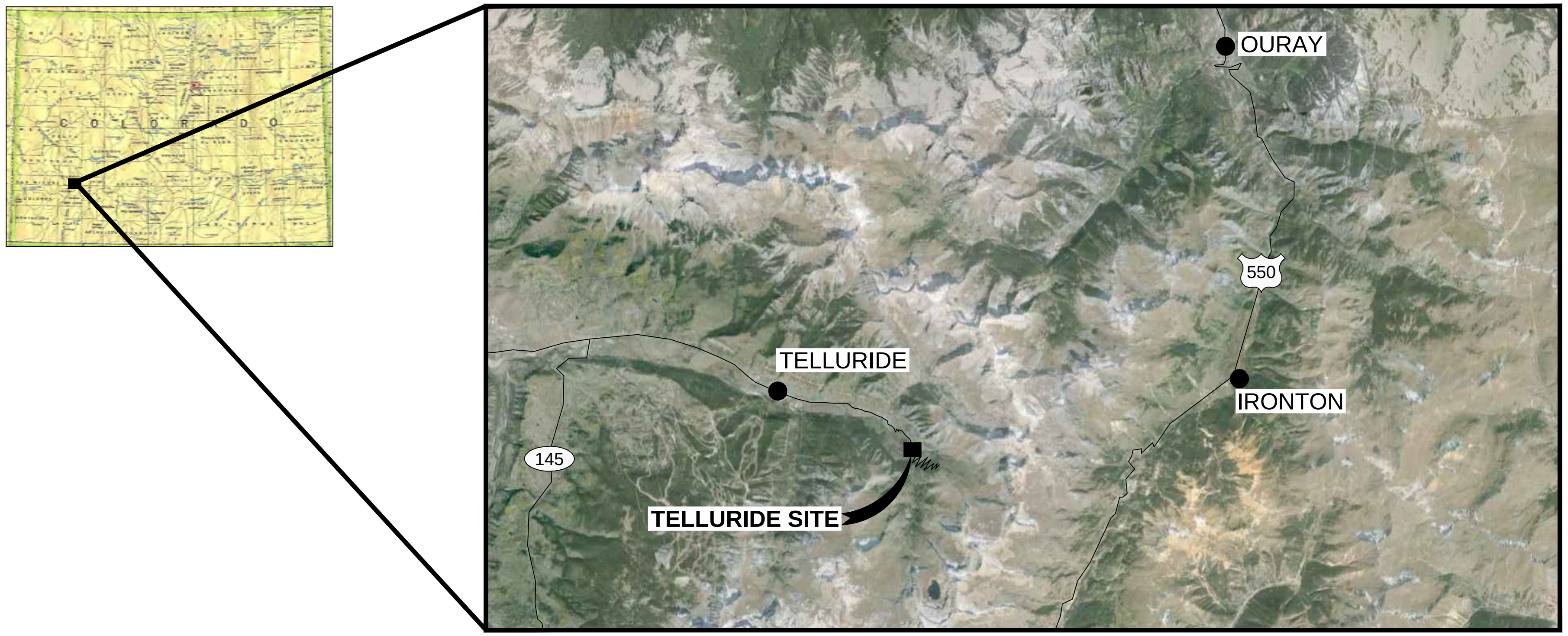
Appendix A
Design Drawings

IDARADO MINE 2900 MILL LEVEL BULKHEAD

CONSTRUCTION SET

TELLURIDE, COLORADO

MARCH 2018



PROJECT LOCATION
NTS

DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\General.dwg SAVED: 3/9/18 PRINTED: 3/9/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT					3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

NEWMONT

TITLE

TITLE SHEET

PROJECT:	IDARADO	DATE:	MARCH 12, 2018	DRAWING	REVISION
SCALE:	NTS	FILE:	GENERAL	T1.0	1

SHEET INDEX

T1.0	TITLE SHEET
G1.0	SHEET INDEX, LEGEND, AND GENERAL NOTES
CIVIL	
C1.0	MILL LEVY BULKHEAD BULKHEAD LOCATION
C2.0	MILL LEVY BULKHEAD BULKHEAD SECTIONS
C3.0	PIPING SCHEMATIC
C4.0	BULKHEAD AREA PIPING PROFILE
C5.0	INTAKE DETAIL
ELECTRICAL	
E1.0	ELECTRICAL SITE PLAN
E2.0	ELECTRICAL TUNNEL SITE PLAN
E3.0	MAIN DISTRIBUTION ELECTRICAL ONE-LINE
E4.0	PORTAL ELEVATIONS
E5.0	BULKHEAD ELEVATIONS
E6.0	PORTAL AND BULKHEAD - PLAN VIEW
E7.0	LOCATION OF LIGHTING IN TUNNEL
E8.0	PANEL SCHEDULES -1
E9.0	PANEL SCHEDULES -2
E10.0	LIGHT FIXTURE SCHEDULE
CP1.0	INSTRUMENT AND CONTROL FUNCTIONAL DESCRIPTION
CP2.0	INSTRUMENT AND CONTROL FUNCTIONAL DESCRIPTION
STRUCTURAL	
S1.0	MILL LEVY BULKHEAD ACCESS WAY AND DOOR

LEGEND AND ABBREVIATIONS

GENERAL

D	DEPTH
ELEV	ELEVATION
FT or '	FEET
IN or "	INCHES
INV	INVERT
L	LENGTH
NOM	NOMINAL
O.C.	ON CENTER
SCH	SCHEDULE
STA	STATION
TYP	TYPICAL
WTP	WATER TREATMENT PLANT
W	WIDTH

INSTRUMENT AND CONTROLS

	LOCAL ALARM BOX
	MAGNETIC FLOW METER
M	MOTORIZED CONTROL VALVE
O_2	OXYGEN
	OXYGEN SENSOR
%	PERCENT
	PRESSURE TRANSMITTER
B	SAFE O_2 BEACON
BF	BUTTERFLY VALVE
FIT	FLOW INDICATING TRANSMITTER
FCV	FLOW CONTROL VALVE
FLV	FLOW LIMITING VALVE
PT	PRESSURE TRANSMITTER
PLC	PROGRAMMABLE LOGIC CONTROLLER
UPS	120 VAC UNINTERRUPTIBLE POWER SUPPLY

ELECTRICAL

	BREAKER
	DISCONNECT, FUSE
	DISCONNECT, NON-FUSE
	EMERGENCY LIGHT FIXTURE
	FUSE CUT OUT
	LIGHT FIXTURE
S	MANUAL LIGHT SWITCH
	METER
	OVERLOAD HEATER
	RECEPTACLE
	480 V RECEPTACLE
	TRANSFORMER
	VENTILATION FAN
	WEATHERHEAD
	WIRE (CONDUCTOR)
AC	ALTERNATING CURRENT
A, AMPS	AMPERE
AIC	AMPERE INTERRUPTING CAPACITY
CU	COPPER
DC	DIRECT CURRENT
FCP	FOOT CANDLE POWER
GFCI	GROUND FAULT CIRCUIT INTERRUPTER
GFI	GROUND FAULT INTERRUPTER
GND, GRD	GROUND
GRC	GALVANIZED RIGID STEEL CONDUIT
HP	HORSE POWER
LED	LIGHT-EMITTING DIODE
P	PHASE OR POLE
PVC	POLYVINYL CHLORIDE
SOV	SOLENOID VALVE
UG	UNDERGROUND
V	VOLT
W	WATTS

CIVIL

	AUTOMATIC FLOW LIMITING VALVE
	BALL VALVE
	BUTTERFLY VALVE
	GATE VALVE
	KNIFEGATE VALVE
	MANUAL VALVE OPERATOR
	ELECTRIC VALVE OPERATOR
	FLANGE JOINT
	DASHED LINE INDICATES "DEMO"
	SURVEY BENCHMARK
DR	DIMENSION RATIO (FOR HDPE PIPE)
HDPE	HIGH-DENSITY POLYETHYLENE
S.S.	STAINLESS STEEL

GENERAL NOTES

1. EXISTING PIPING AND CONTROLS TO REMAIN SHALL BE INSPECTED AS REQUIRED IN PLANS AND SPECIFICATIONS.
2. ELECTRICAL CONTRACTOR TO PROVIDE AS-BUILT DRAWINGS REPRESENTING PANEL SCHEDULES, JUNCTION BOXES, AND CIRCUITS INTO TUNNEL.

DRAFT
FOR REVIEW ONLY

O:\18 Idarado\17a Bulkhead Piping\General.dwg SAVED: 3/13/18 PRINTED: 3/13/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT					3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

NEWMONT

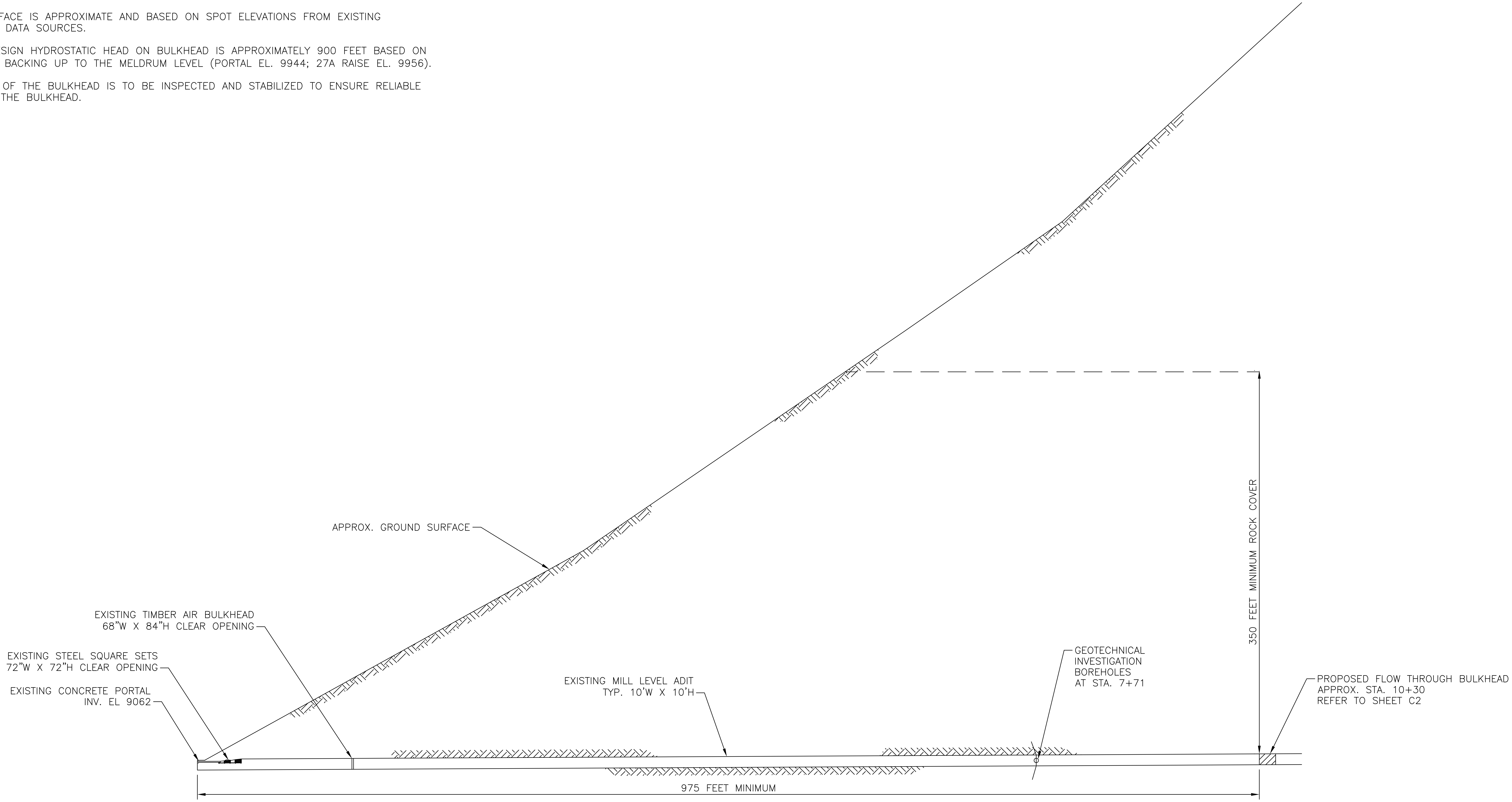
TITLE

SHEET INDEX, LEGEND, AND GENERAL NOTES

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: GENERAL
DRAWING G1.0
REVISION 1

NOTES:

1. GROUND SURFACE IS APPROXIMATE AND BASED ON SPOT ELEVATIONS FROM EXISTING TOPOGRAPHIC DATA SOURCES.
2. MAXIMUM DESIGN HYDROSTATIC HEAD ON BULKHEAD IS APPROXIMATELY 900 FEET BASED ON MINE WATER BACKING UP TO THE MELDRUM LEVEL (PORTAL EL. 9944; 27A RAISE EL. 9956).
3. ADIT OUTBY OF THE BULKHEAD IS TO BE INSPECTED AND STABILIZED TO ENSURE RELIABLE ACCESS TO THE BULKHEAD.



ELEVATION
SCALE: 1" = 50'

C:\Users\kbrau\Documents\L-7 Services\Idarado Mine Bulkhead\Idarado Blkhd A.dwg SAVED:3/13/18 PRINTED:3/13/18 BY:KBRAU

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
△					
△					
△					
△					
△					
△					
△					

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

L-7 SERVICES LLC
P.O. BOX 1387
GOLDEN, CO 80402

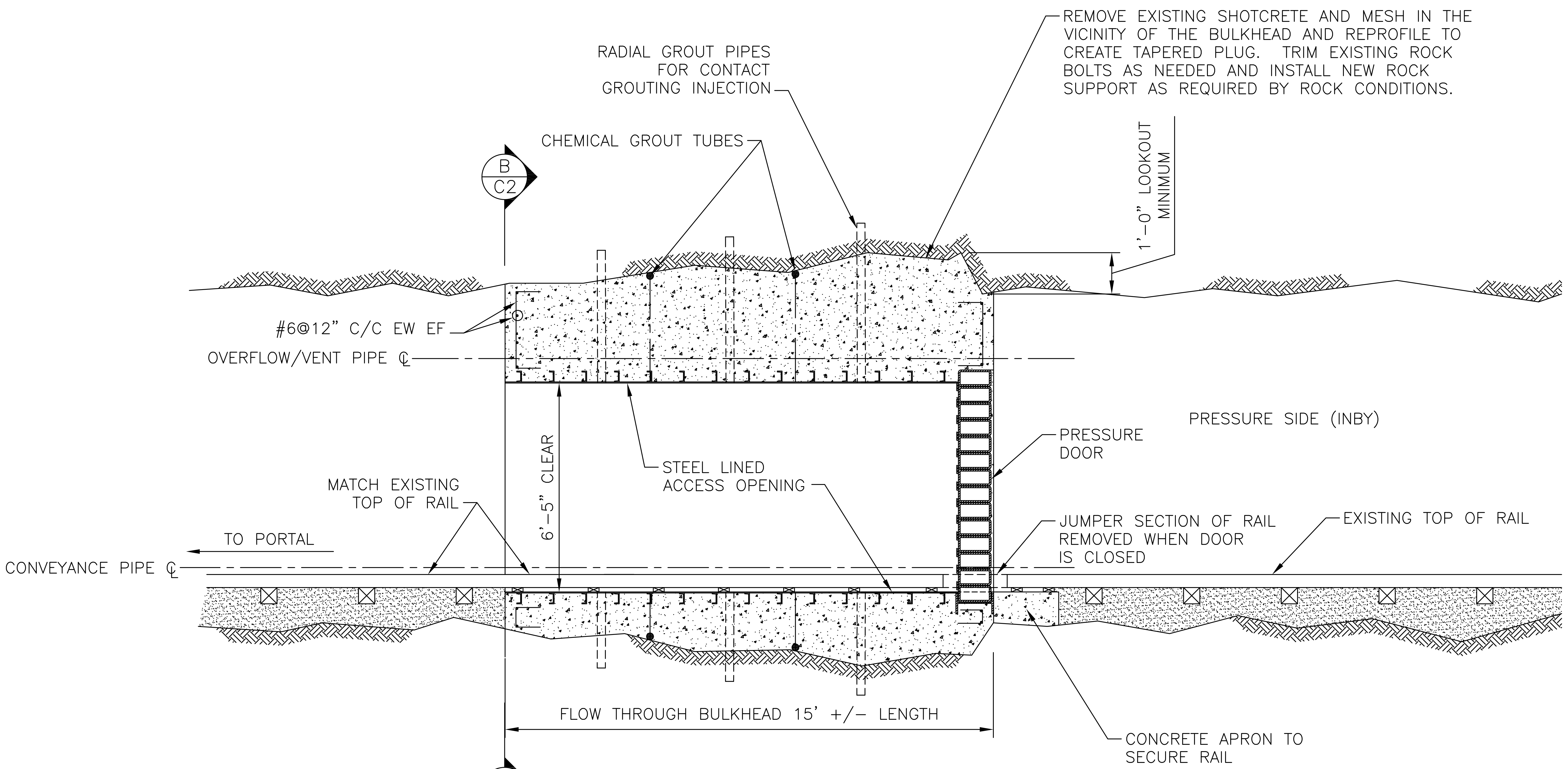
PREPARED FOR

NEWMONT

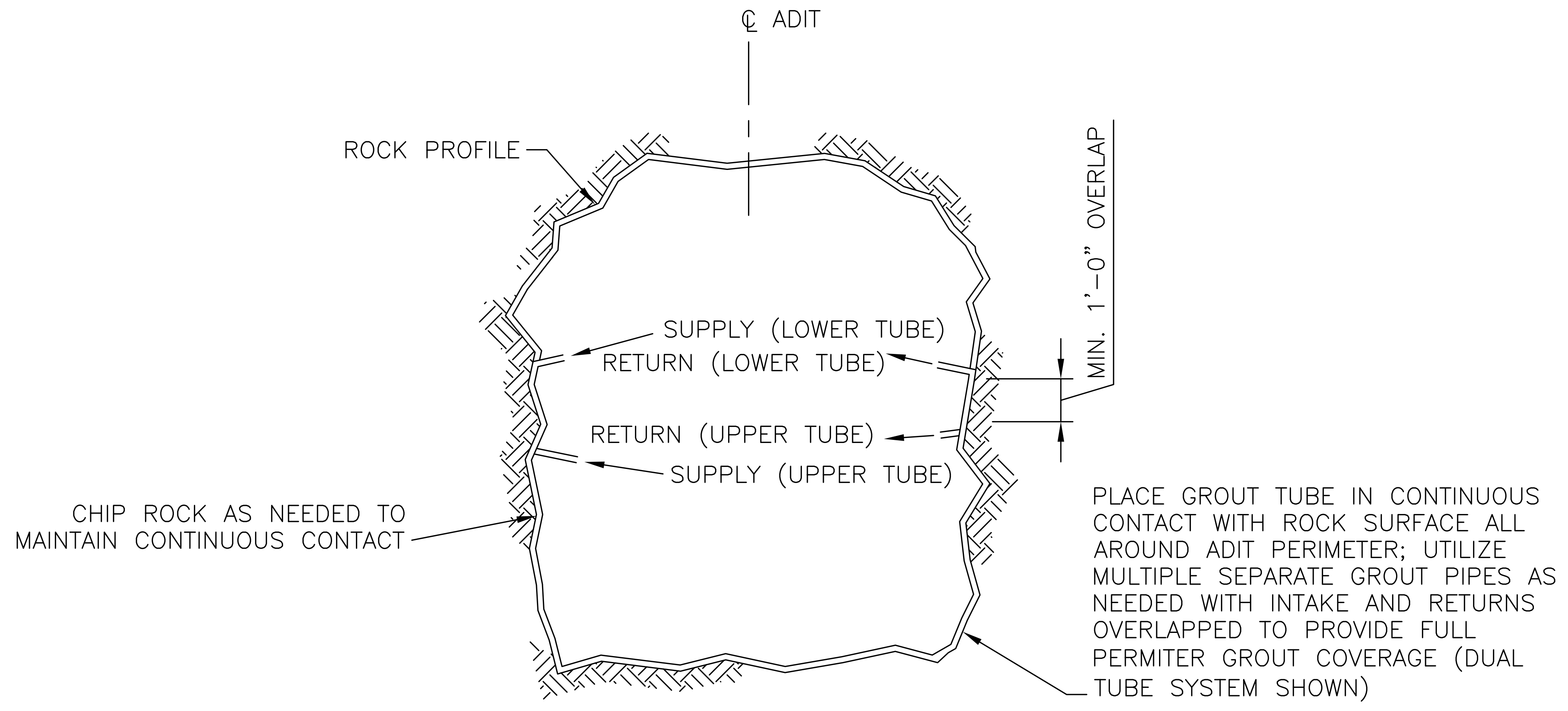
TITLE

MILL LEVEL BULKHEAD
BULKHEAD LOCATION

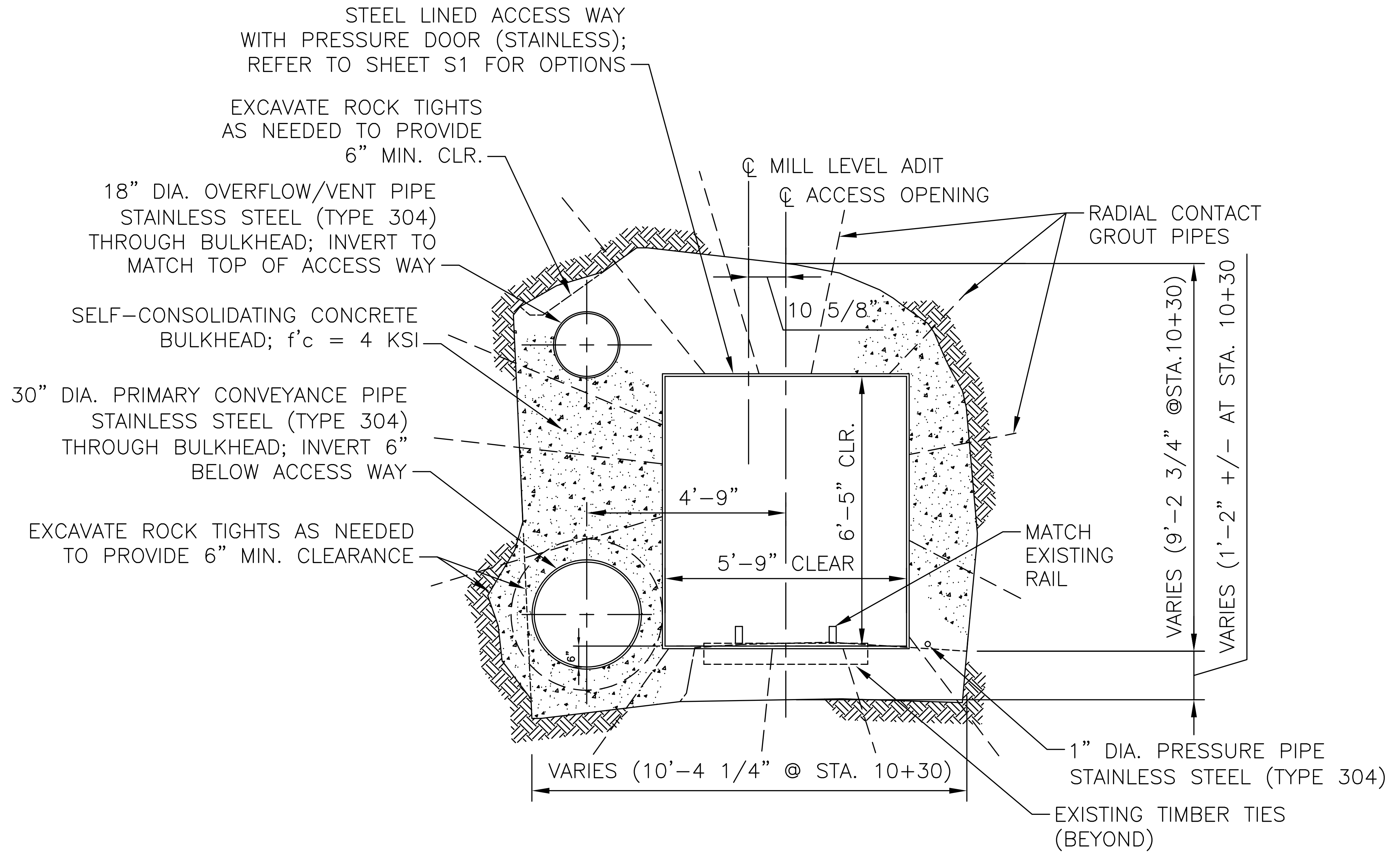
PROJECT: IDARADO	DATE: MARCH 2018	DRAWING C1	REVISION △
SCALE: AS SHOWN	FILE: IDARADO BLKHD A		



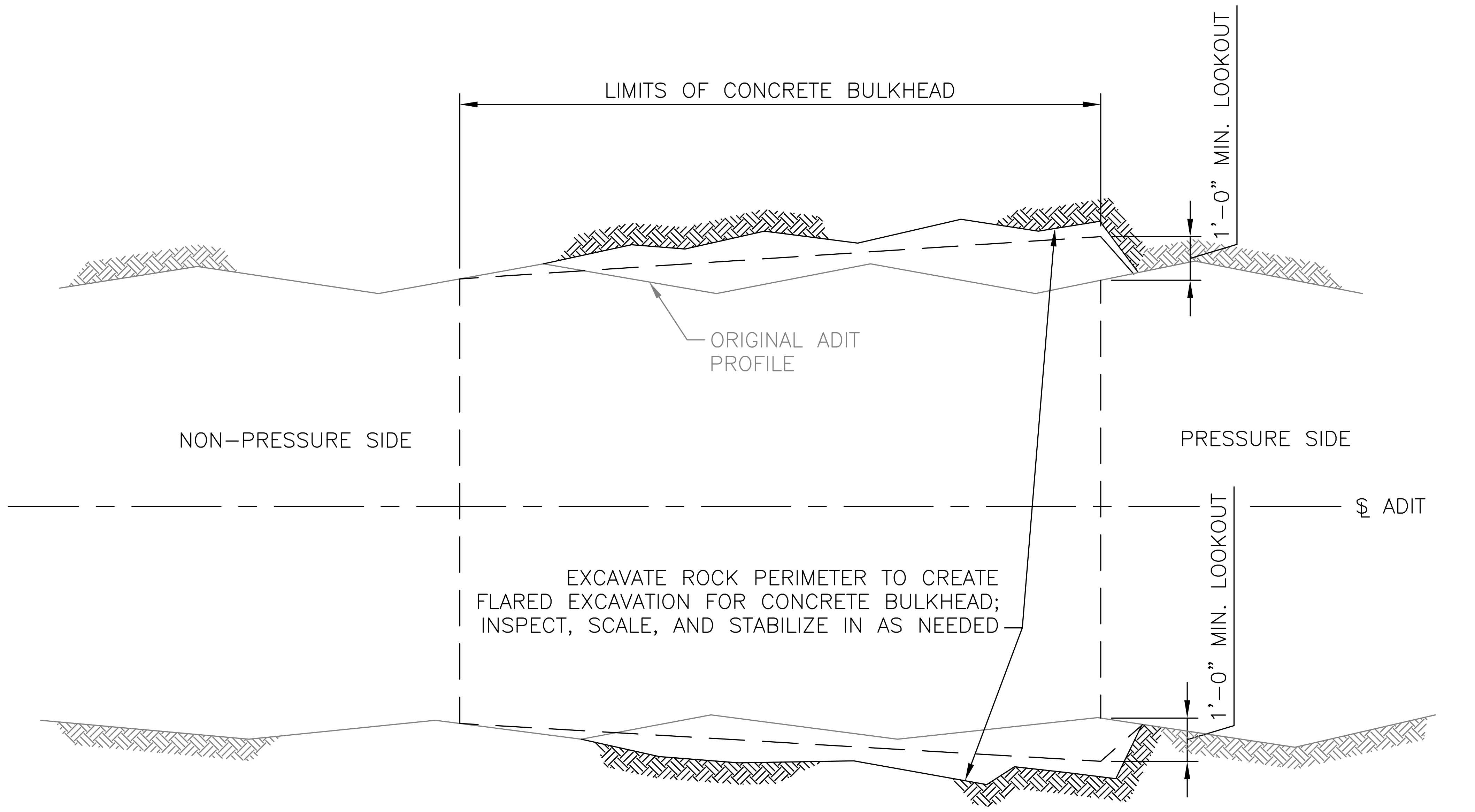
A BULKHEAD LAYOUT: ELEVATION
SCALE: 3/8" = 1'-0"



C ELEVATION: CHEMICAL GROUT TUBE LAYOUT
SCALE: 3/8" = 1'-0"



B BULKHEAD LAYOUT: STA. 10+30
SCALE: 3/8" = 1'-0" (LOOKING INBY)



D ELEVATION: DETAIL OF ADIT ENLARGEMENT
SCALE: 3/8" = 1'-0"

NOTE: ELEVATION SHOWN, ADIT ENLARGEMENT WILL BE SIMILAR IN PLAN VIEW.

C:\Users\kbrau\Documents\L-7 Services\Idarado Mine Bulkhead\Idarado Blkhd A.dwg SAVED:3/13/18 PRINTED:3/13/18 BY:KBRAU

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
△					
△					
△					
△					
△					
△					
△					

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY
L-7 SERVICES LLC
P.O. BOX 1387
GOLDEN, CO 80402

PREPARED FOR
NEWMONT

TITLE
MILL LEVEL BULKHEAD
BULKHEAD SECTIONS

PROJECT: IDARADO
DATE: MARCH 2018
SCALE: AS SHOWN
FILE: IDARADO BLKHD A
DRAWING C2
REVISION △

LEGEND

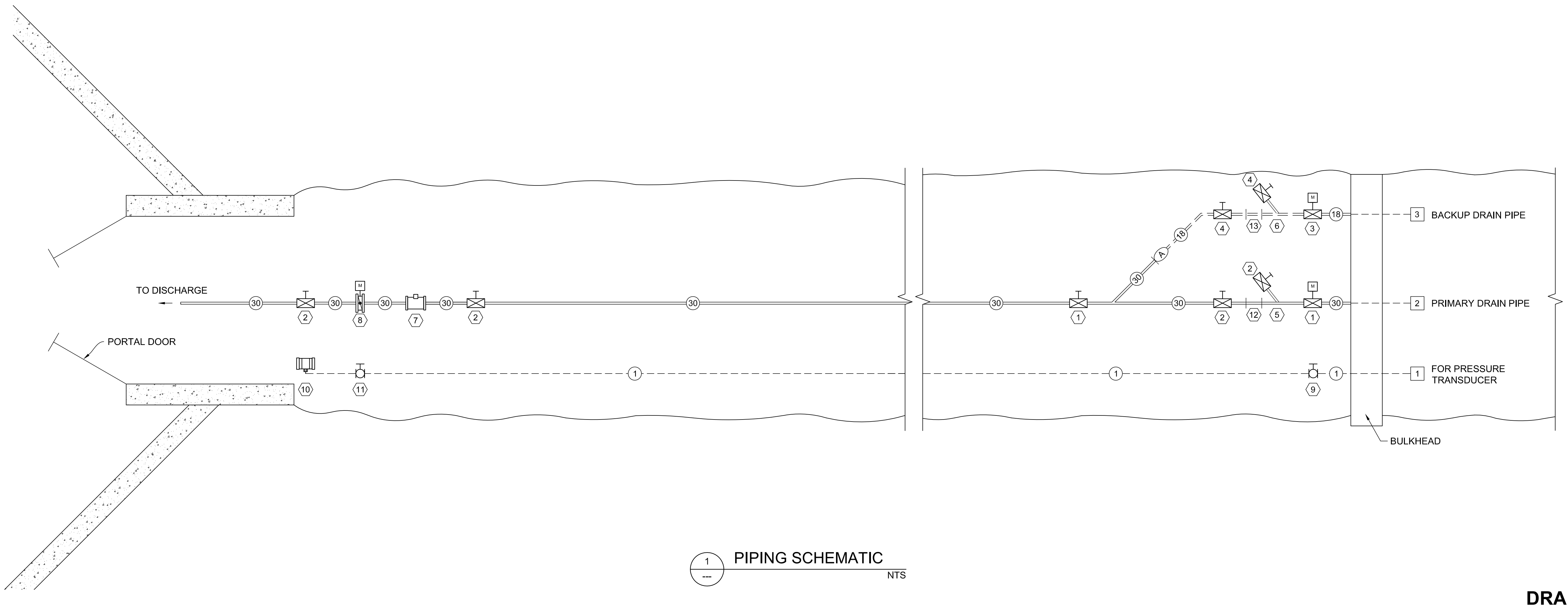
- - - 1	1-IN STAINLESS STEEL PIPE THROUGH BULKHEAD
- - - 2	30-IN STAINLESS STEEL PRIMARY DRAIN PIPE THROUGH BULKHEAD
- - - 3	20-IN STAINLESS STEEL BACKUP DRAIN PIPE THROUGH BULKHEAD
= = (18) = =	18-IN BACKUP DRAIN PIPE
(30)	30-IN PRIMARY DRAIN PIPE
- - (1) - -	1-IN STAINLESS STEEL PIPE (FOR HYDROSTATIC PRESSURE MEASUREMENTS)

1	30-IN MOTORIZED GATE VALVE
2	30-IN MANUAL GATE VALVE
3	18-IN MOTORIZED GATE VALVE
4	18-IN MANUAL GATE VALVE
5	30-IN WYE WITH BLIND FLANGE
6	18-IN WYE WITH BLIND FLANGE
7	30-IN MAGNETIC FLOW METER
8	30-IN MOTORIZED FLOW CONTROL VALVE
9	1-IN MOTORIZED BALL VALVE
10	PRESSURE TRANSDUCER
11	1-IN MANUAL BALL VALVE
12	30-IN DIA. PIPE - 16-IN SPOOL
13	18-IN DIA. PIPE - 16-IN SPOOL

A	30-IN x 18-IN PIPE REDUCER

NOTES

1. LOCATIONS OF DRAIN PIPES ARE PRESENTED FOR CLARITY AND DO NOT REFLECT THE ACTUAL CONFIGURATIONS.
2. SEE SHEETS CP1.0 AND CP2.0 FOR CONTROLS AND ELECTRICAL WIRING.
3. SEE SHEETS E4.0 - E7.0 FOR EMERGENCY LIGHTING AND O_2 SENSORS.



1

PIPING SCHEMATIC
NTS

DRAFT
FOR REVIEW ONLY

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	JAN	TRR		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

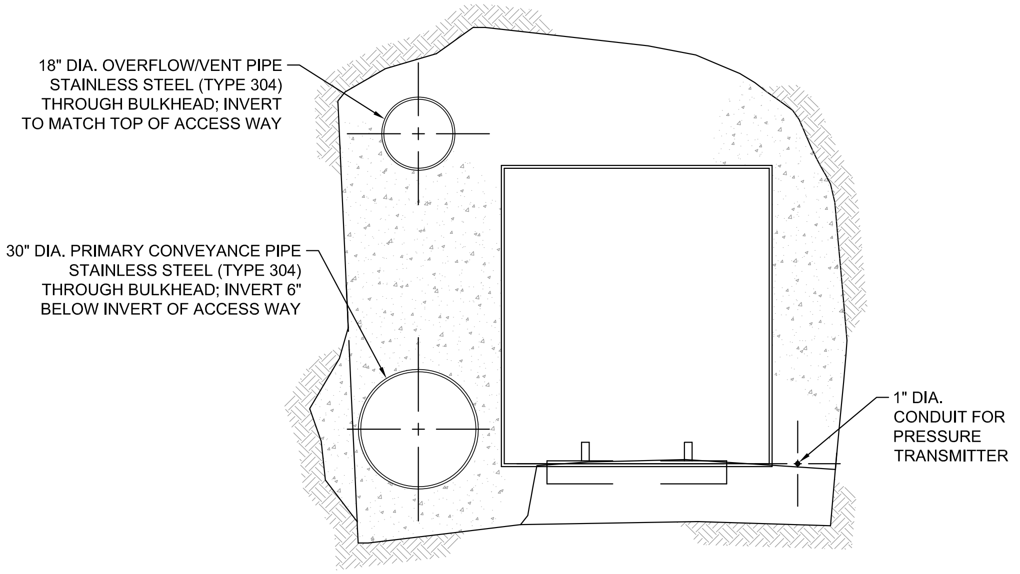
ENGINEERING RECORD	BY	DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

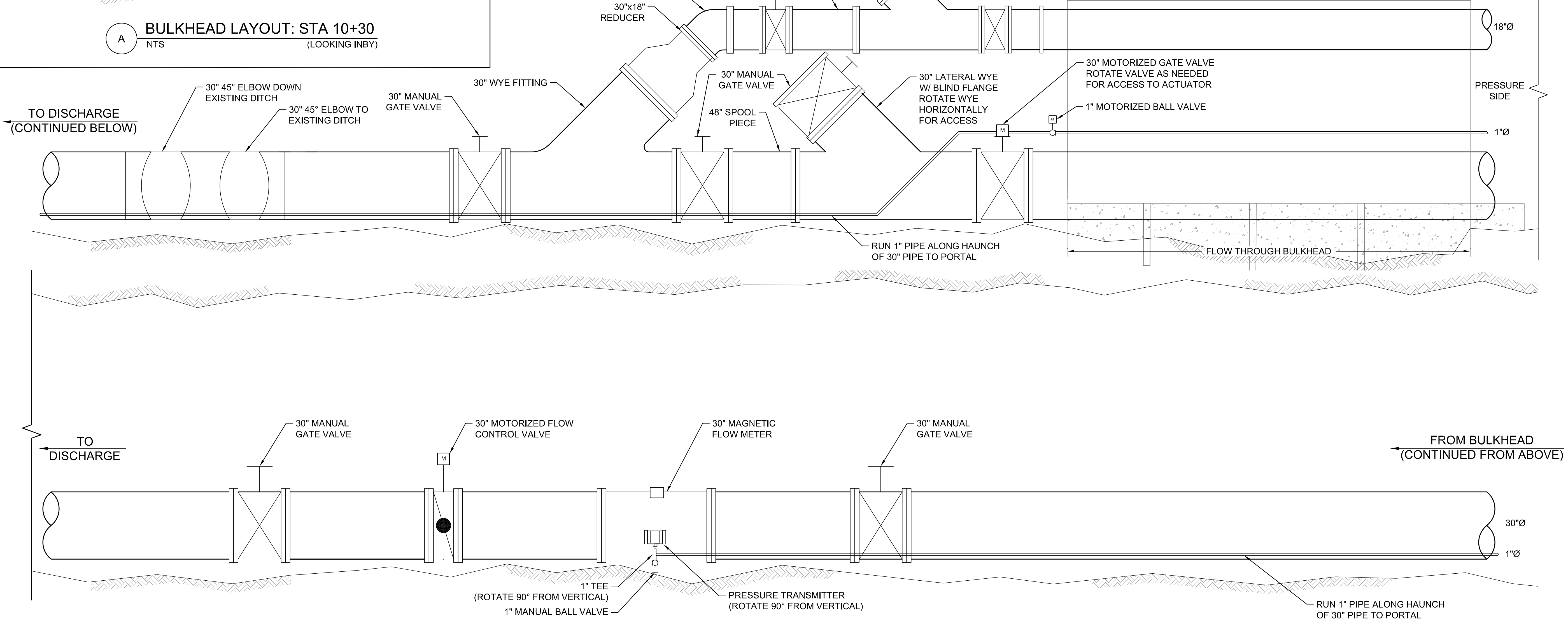
PREPARED FOR
NEWMONT

TITLE
PIPING SCHEMATIC
PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: BULKHEAD PROFILE
DRAWING C3.0
REVISION 1

O:\.18 Idarado\.17a Bulkhead Piping\Bulkhead Profile.dwg SAVED: 3/12/18 PRINTED: 3/13/18 BY: RPACELLA



A BULKHEAD LAYOUT: STA 10+30
NTS (LOOKING INBY)



B

BULKHEAD AREA PIPING LAYOUT (PROFILE VIEW)
NTS

DRAFT
FOR REVIEW ONLY

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	JAN	TRR			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

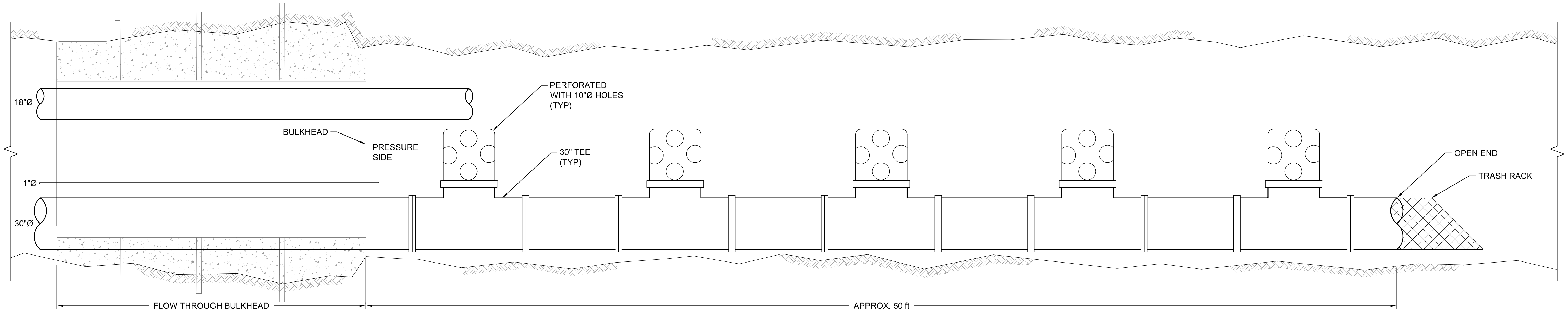
PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

TITLE
BULKHEAD AREA PIPING
PROFILE

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: BULKHEAD PROFILE
DRAWING C4.0
REVISION 1

O:\18 Idarado\.17a Bulkhead Piping\Bulkhead Profile.dwg SAVED: 3/13/18 PRINTED: 3/13/18 BY: RPACELLA



1

INTAKE DETAIL (PROFILE VIEW)
NTS

DRAFT
FOR REVIEW ONLY

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	JAN	TRR			3/12/18
△						
△						
△						
△						
△						
△						

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

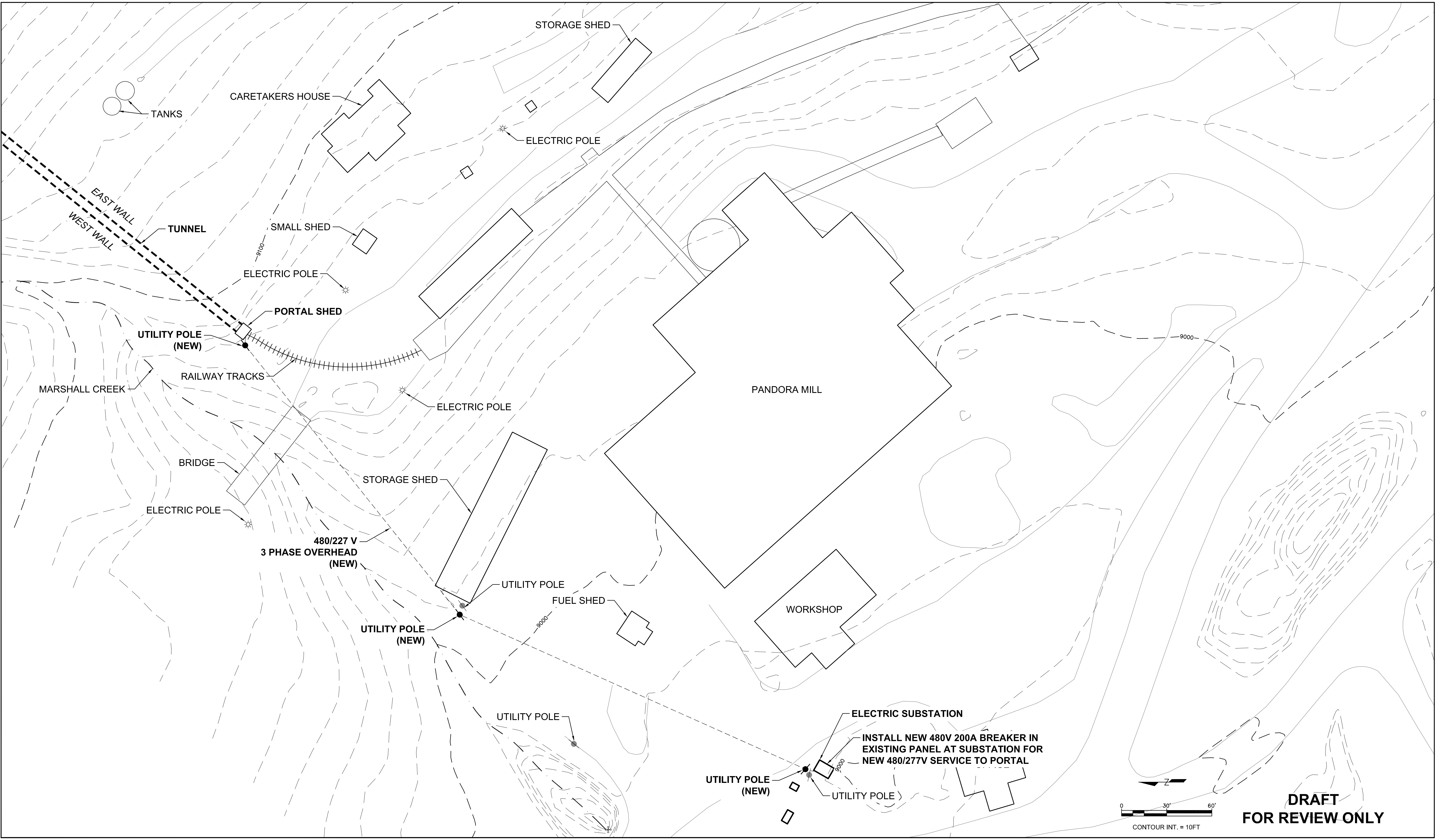
NEWMONT

TITLE

INTAKE DETAIL

				DRAWING	REVISION
PROJECT:	IDARADO	DATE:	MARCH 12, 2018	C5.0	1
SCALE:	NTS	FILE:	BULKHEAD PROFILE		

O:\.18 Idarado\.17a Bulkhead Bulkhead Piping\Bulkhead Profile.dwg SAVED: 3/13/18 PRINTED: 3/13/18 BY: TBLOCH



DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Elec Site Plan.dwg SAVED: 3/9/18 PRINTED: 3/9/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGB	JEB			3/12/18

REFERENCES
DWG No. | DRAWING TITLE

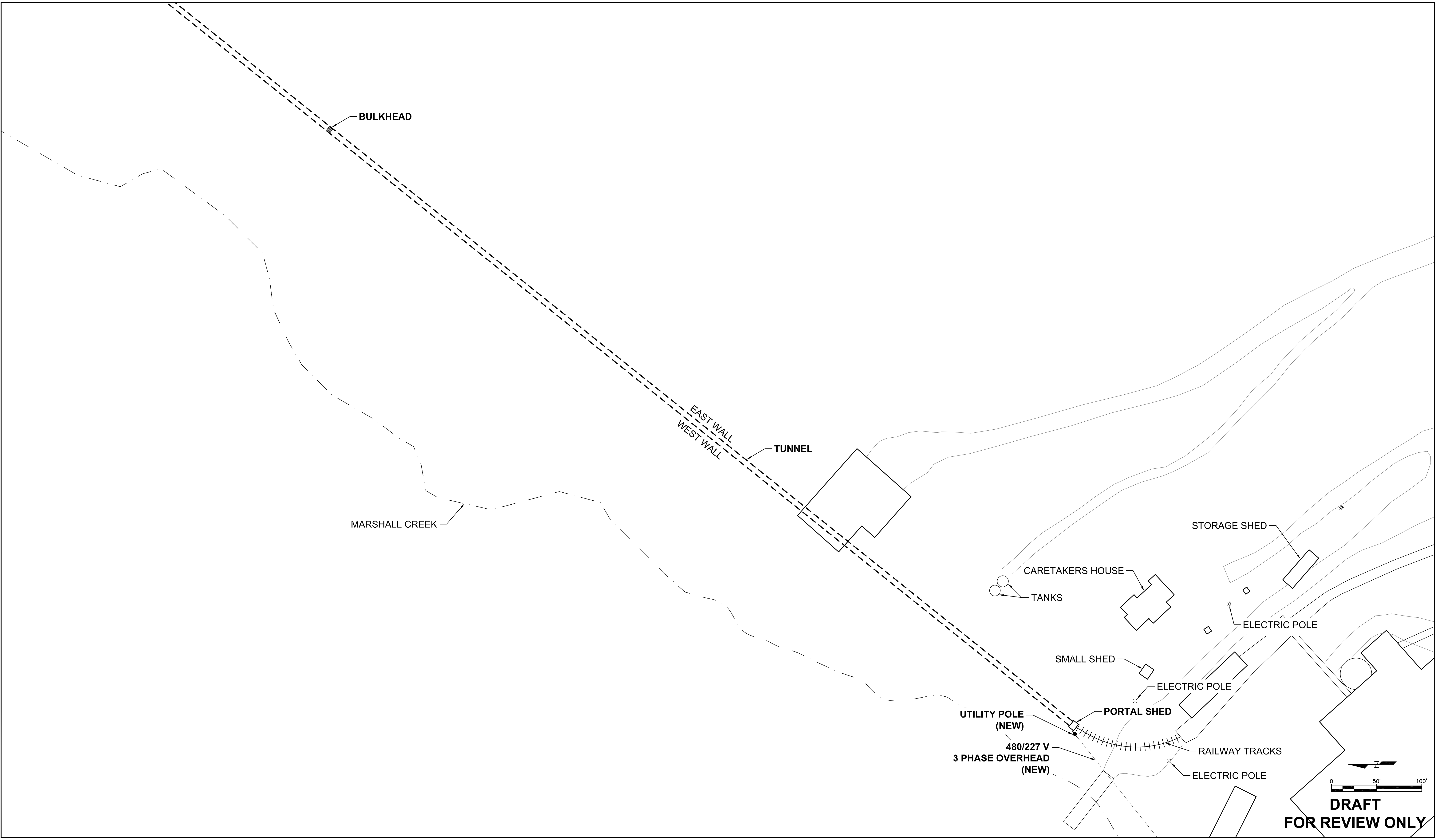
DESIGNERS
ENGINEERING RECORD | BY | DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

TITLE
ELECTRICAL SITE PLAN

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: 1" = 60'
FILE: ELEC SITE PLAN
DRAWING: E1.0
REVISION: 1



DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Elec Site Plan.dwg SAVED: 3/9/18 PRINTED: 3/9/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

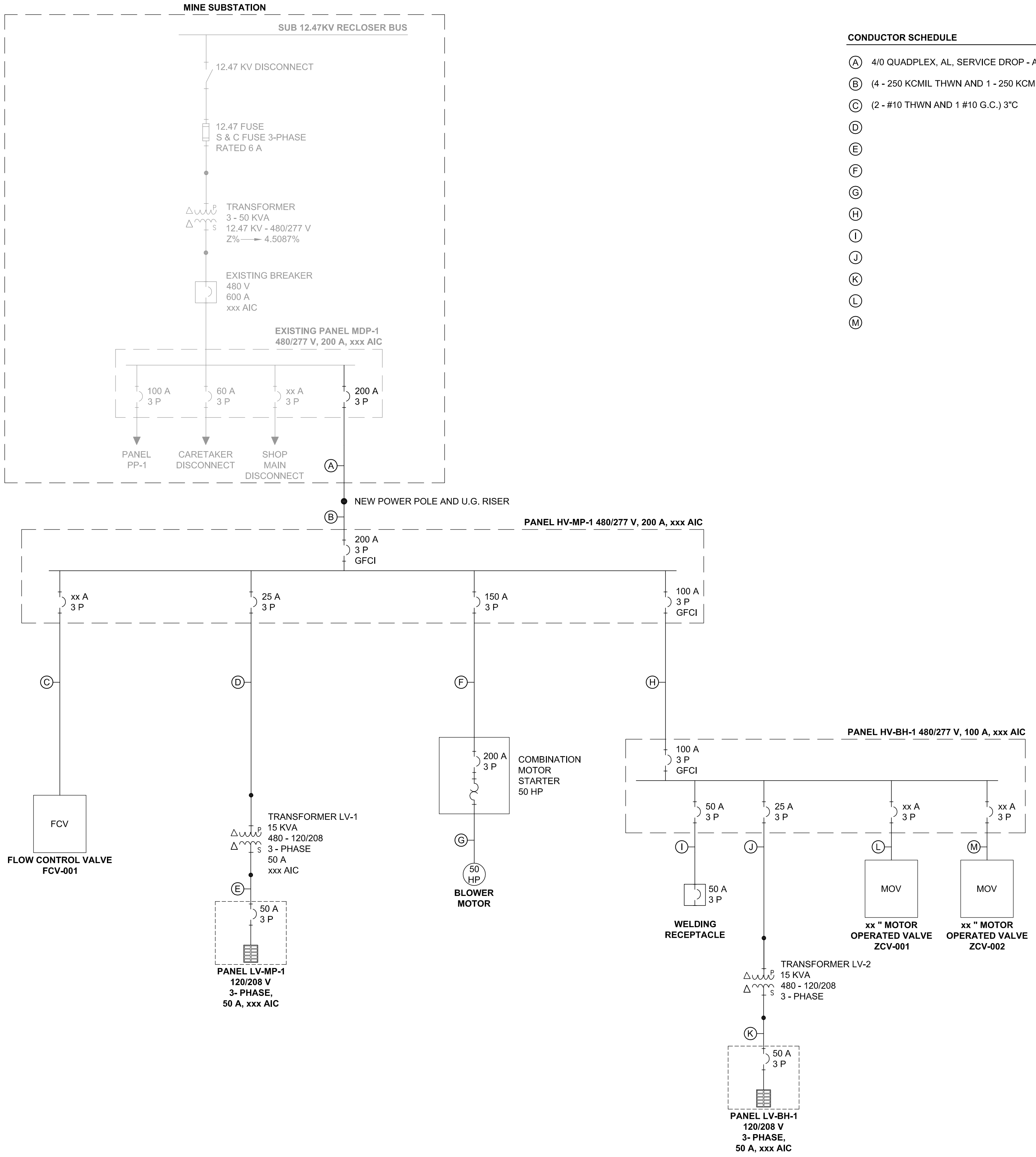
NEWMONT

TITLE

ELECTRICAL TUNNEL SITE PLAN

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: 1" = 100'
FILE: ELEC SITE PLAN
DRAWING: E2.0
REVISION: 1

NOTE:
NEED TO ADD SURGE SUPRESSION



CONDUCTOR SCHEDULE

- Ⓐ 4/0 QUADPLEX, AL, SERVICE DROP - ARIAL INSTALL
- Ⓑ (4 - 250 KCMIL THWN AND 1 - 250 KCMIL G,C,) 3"C
- Ⓒ (2 - #10 THWN AND 1 #10 G.C.) 3"C
- Ⓓ
- Ⓔ
- Ⓕ
- Ⓖ
- Ⓗ
- Ⓘ
- Ⓙ
- Ⓚ
- Ⓛ
- Ⓜ

DRAFT
FOR REVIEW ONLY

O:_18 Idarado_17a Bulkhead Piping\Elec One-Lines.dwg SAVED: 3/9/18 PRINTED: 3/9/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

NEWMONT

TITLE

MAIN DISTRIBUTION ELECTRICAL ONE-LINE

PROJECT:	IDARADO	DATE:	MARCH 12, 2018	DRAWING	REVISION
SCALE:	NTS	FILE:	ELEC ONE-LINES	E3.0	1

FLAG NOTES

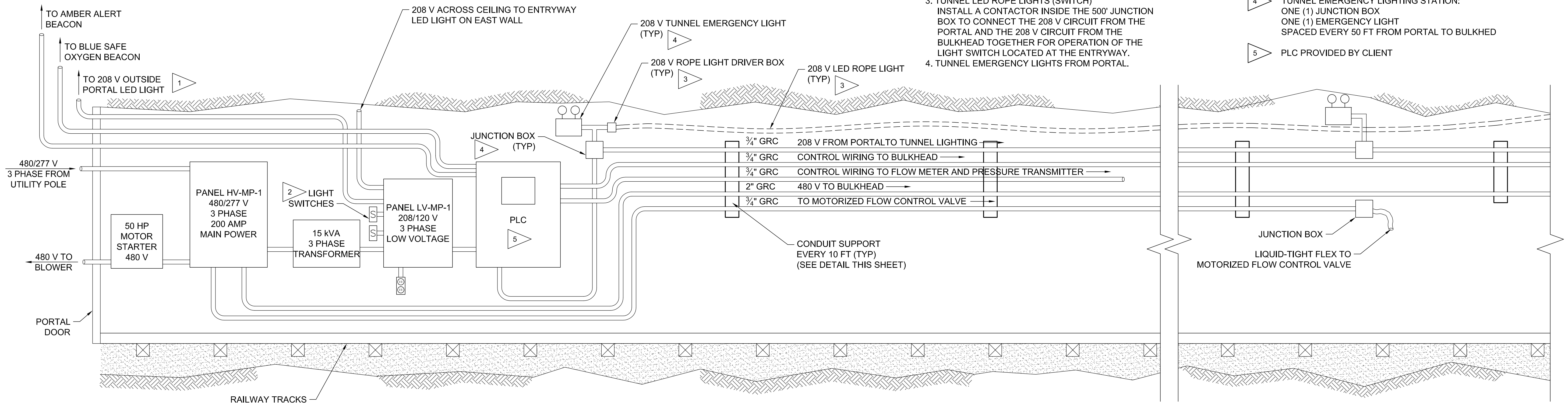
1 OUTSIDE PORTAL LED LIGHT ON A SENSOR.

2 FOUR LIGHTING CIRCUITS:
1. OUTSIDE PORTAL LED LIGHT (LIGHT SENSOR)
2. ENTRYWAY LED LIGHT (SWITCH)
3. TUNNEL LED ROPE LIGHTS (SWITCH)
INSTALL A CONTACTOR INSIDE THE 500' JUNCTION BOX TO CONNECT THE 208 V CIRCUIT FROM THE PORTAL AND THE 208 V CIRCUIT FROM THE BULKHEAD TOGETHER FOR OPERATION OF THE LIGHT SWITCH LOCATED AT THE ENTRYWAY.
4. TUNNEL EMERGENCY LIGHTS FROM PORTAL.

3 TUNNEL LIGHTING STATION:
ONE (1) ROPE LIGHT DRIVER BOX
ONE (1) LED ROPE LIGHT
SPACED EVERY 150 FT FROM PORTAL TO BULKHEAD.

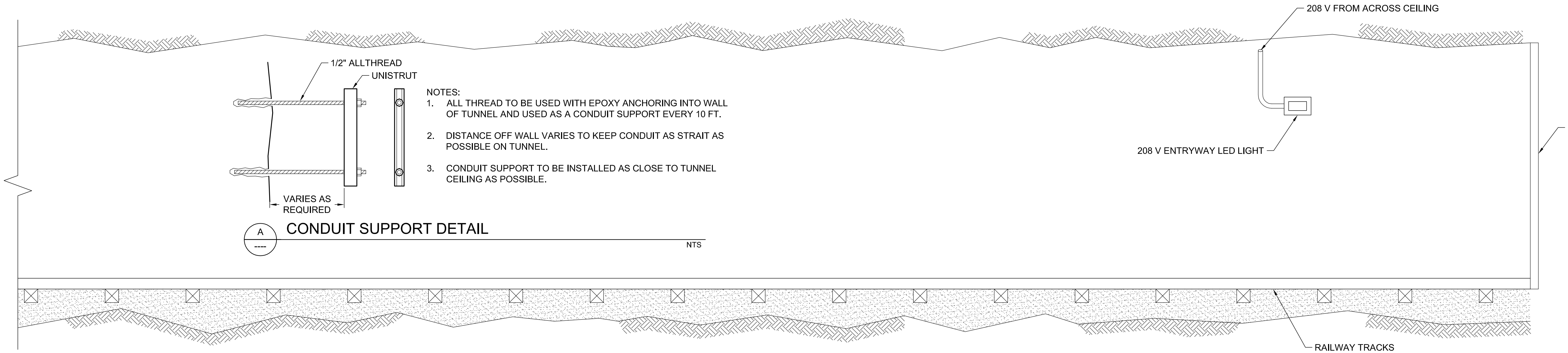
4 TUNNEL EMERGENCY LIGHTING STATION:
ONE (1) JUNCTION BOX
ONE (1) EMERGENCY LIGHT
SPACED EVERY 50 FT FROM PORTAL TO BULKHED

5 PLC PROVIDED BY CLIENT



1

PORTAL ELEVATION - WEST WALL
1/4" = 1'-0"



NOTES:
1. ALL THREAD TO BE USED WITH EPOXY ANCHORING INTO WALL OF TUNNEL AND USED AS A CONDUIT SUPPORT EVERY 10 FT.
2. DISTANCE OFF WALL VARIES TO KEEP CONDUIT AS STRAIT AS POSSIBLE ON TUNNEL.
3. CONDUIT SUPPORT TO BE INSTALLED AS CLOSE TO TUNNEL CEILING AS POSSIBLE.

A

CONDUIT SUPPORT DETAIL
NTS

2

PORTAL ELEVATION - EAST WALL
1/4" = 1'-0"

DRAFT
FOR REVIEW ONLY

O:\18_Idarado\17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

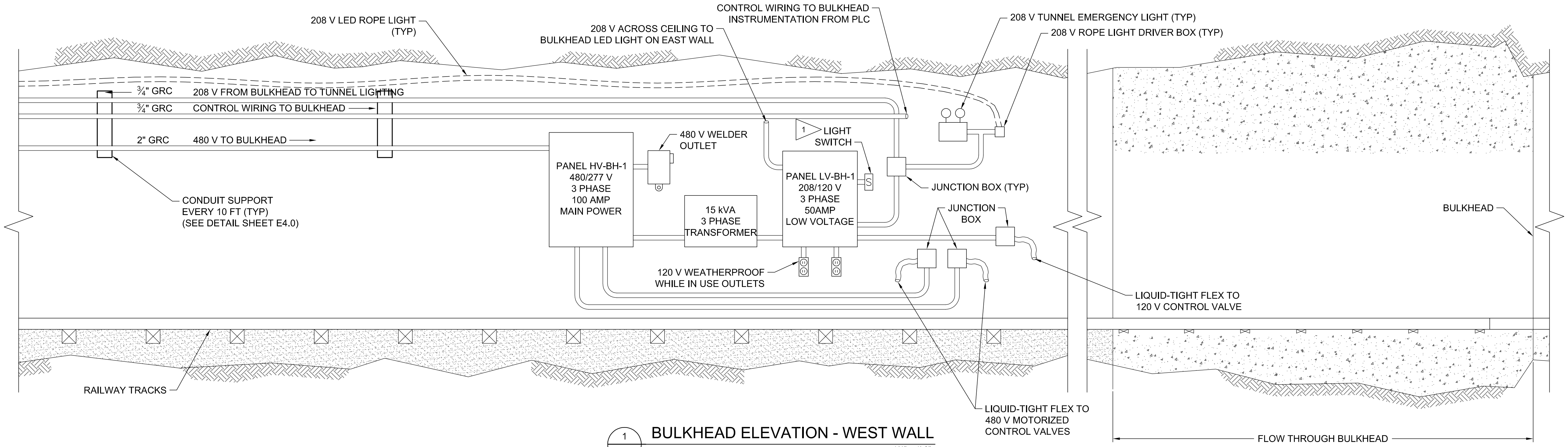
ENGINEERING RECORD	BY	DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

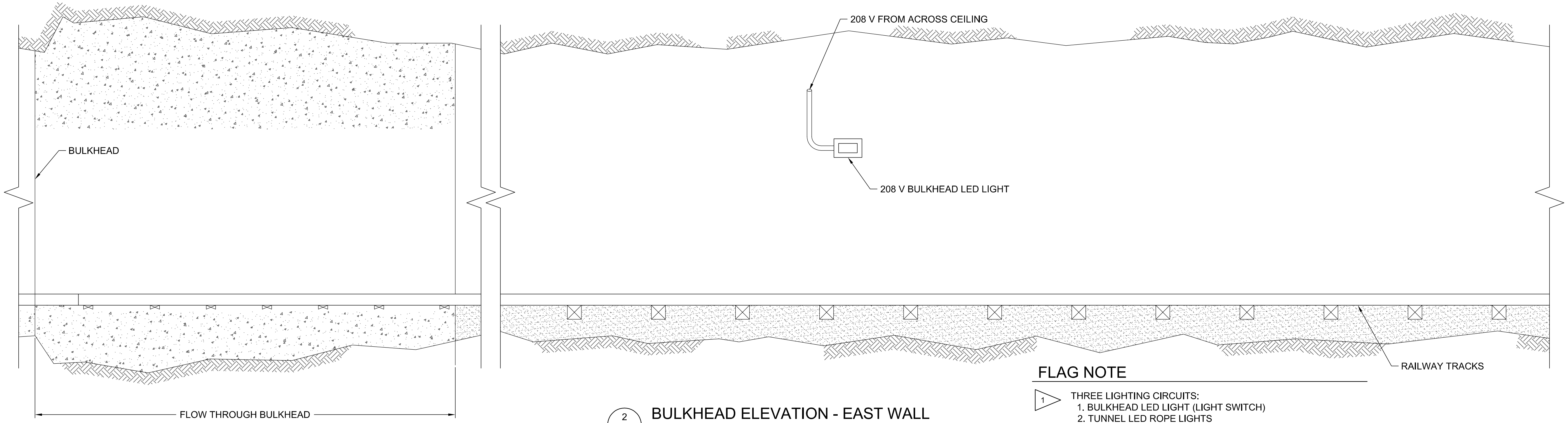
TITLE
PORTAL ELEVATIONS

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: 1/4" = 1'-0"
FILE: ELEC DETAILS
DRAWING E4.0
REVISION 1



1

BULKHEAD ELEVATION - WEST WALL
1/4" = 1'-0"



2

BULKHEAD ELEVATION - EAST WALL
1/4" = 1'-0"

FLAG NOTE

1 THREE LIGHTING CIRCUITS:

1. BULKHEAD LED LIGHT (LIGHT SWITCH)
2. TUNNEL LED ROPE LIGHTS
   INSTALL A CONTACTOR INSIDE THE 500' JUNCTION BOX TO CONNECT THE 208 V CIRCUIT FROM THE PORTAL AND THE 208 V CIRCUIT FROM THE BULKHEAD TOGETHER FOR OPERATION OF THE LIGHT SWITCH LOCATED AT THE ENTRYWAY.
3. TUNNEL EMERGENCY LIGHTS FROM BULKHEAD.

DRAFT
FOR REVIEW ONLY

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

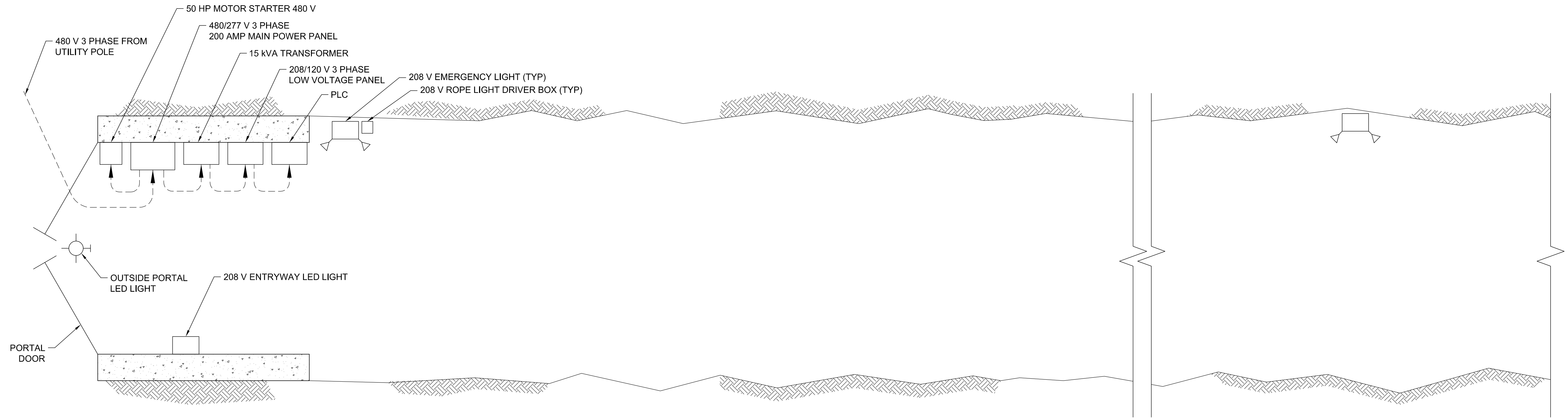
NEWMONT

TITLE

BULKHEAD ELEVATIONS

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: 1/4" = 1'-0"
FILE: ELEC DETAILS
DRAWING E5.0
REVISION 1

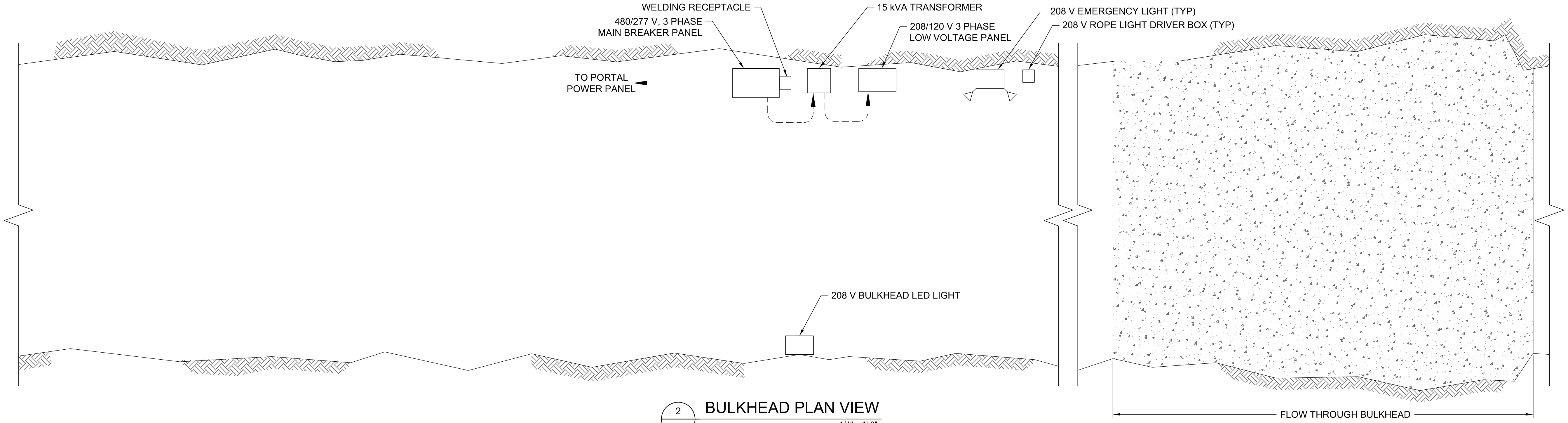
O:\.18 Idarado\.17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH



1 ----

PORTAL PLAN VIEW

1/4" = 1'-0"



2 ----

BULKHEAD PLAN VIEW

1/4" = 1'-0"

DRAFT
FOR REVIEW ONLY

O:\18 Idarado\17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR

NEWMONT

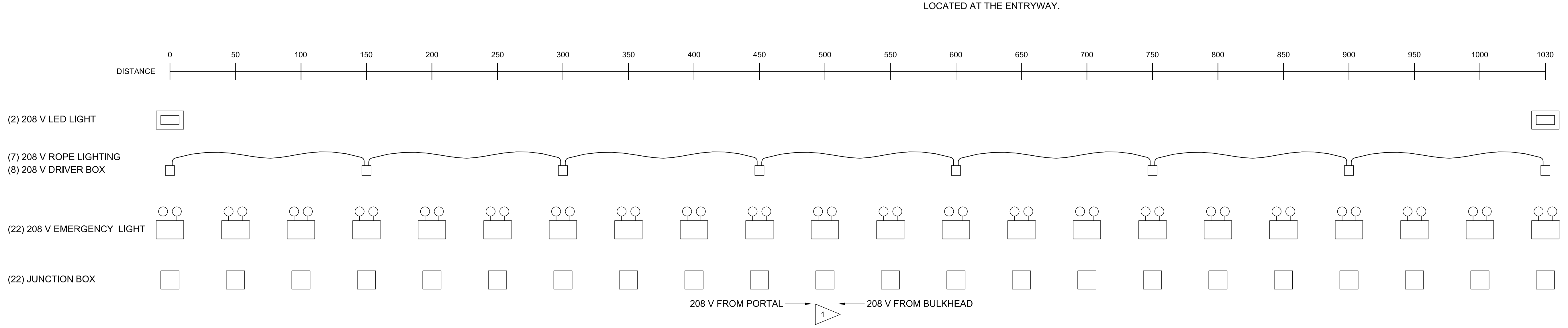
TITLE

PORTAL AND BULKHEAD - PLAN VIEW

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: 1/4" = 1'-0"
FILE: ELEC DETAILS
DRAWING E6.0
REVISION 1

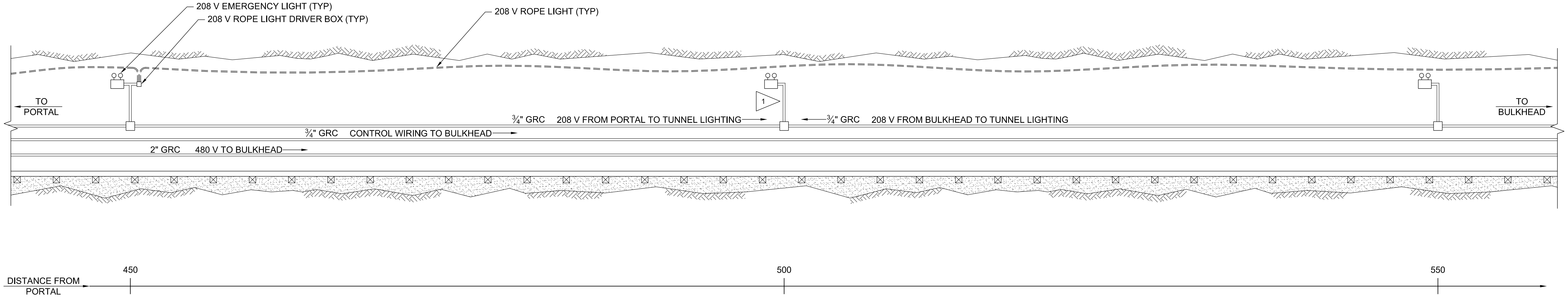
FLAG NOTE

1 INSTALL A CONTACTOR INSIDE THE 500' JUNCTION BOX TO CONNECT THE 208 V CIRCUIT FROM THE PORTAL AND THE 208 V CIRCUIT FROM THE BULKHEAD TOGETHER FOR OPERATION OF THE LIGHT SWITCH LOCATED AT THE ENTRYWAY.



LOCATION OF LIGHTING IN TUNNEL 0 - 1,030 FEET

NTS



TUNNEL ELEVATION AT 450'-550' - WEST WALL

1/8" = 1'-0"

DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

TITLE
LOCATION OF LIGHTING IN TUNNEL

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: AS SHOWN
FILE: ELEC DETAILS
DRAWING E7.0
REVISION 1

ELECTRICAL SUBSTATION 480/277 V PHASE 3 PANEL (MDP-1)

PROJECT NAME: Idarado Mine 2900 Mill Level Bulkhead
PANEL NAME: MDP-1
3/1/2018

VOLTS: 480/277 Volt
PHASE, WIRE: 3 Phase, 4 Wire
CIRCUITS: 18
MANUFACTURER:
CONDUCTOR:
AIC RATING:
LOCATION: Mine Substation
FED FROM: 12.47 Recloser Bus
MOUNTING: Surface
BUS: 400A
MAIN BREAKER AMPS: 400A
NEMA RATING: 4
AVAILABLE FAULT CURRENT:

ID	BREAKER	DESCRIPTION	V - A	CIRCUIT	PHASE	CIRCUIT	V - A	DESCRIPTION	BREAKER	ID
+	100A/3P	Trans XF2-0005		1	A	2		Shop Main Disconnect	XXA/3P	+
+				3	B	4				+
+				5	C	6				+
+	60A/3P	Caretaker Site Disconnect		7	A	8		Portal Panel HV-MP-1	200A/3P	+
+				9	B	10				+
+				11	C	12				+
+		- SPACE -		13	A	14		- SPACE -		+
+		- SPACE -		15	B	16		- SPACE -		+
+		- SPACE -		17	C	18		- SPACE -		+

CONNECTED LOAD (Dow nstream Loads Included)	TOTALS
Phase A	**0**
Phase B	**0**
Phase C	**0**
DOWNSTREAM LOADS	

LOAD SUMMARY

CATEGORY	CONNECTED	FACTOR	CALCULATED V - A	AMPS
LIGHTING	0	125%	0	0.0
GENERAL RECEPTACLE	0	100%	0	0.0
REMAINING GENERAL REC.	0	50%	0	0.0
DEDICATED RECEPTACLE	0	100%	0	0.0
MOTOR	0	100%	0	0.0
LARGEST MOTOR	0	125%	0	0.0
MISCELANEOUS	0	100%	0	0.0
HVAC	0	100%	0	0.0
ELECTRIC HEAT	0	125%	0	0.0
Total Demand:			0	0
Total Demand w ith Pow er Factor:		95%	**0**	**0**

PORTAL 480/277 V 3 PHASE PANEL (HV-MP-1)

PROJECT NAME: Idarado Mine 2900 Mill Level Bulkhead
PANEL NAME: HV-MP-1
3/1/2018

VOLTS: 480/277 Volt
PHASE, WIRE: 3 Phase, 4 Wire
CIRCUITS: 18
MANUFACTURER:
CONDUCTOR: 4-250 kcmil and 1-250 kcmil G.C
AIC RATING:
LOCATION: Mine Portal
FED FROM: MDP-1
MOUNTING: Surface
BUS: 200A
MAIN BREAKER AMPS: 200A
NEMA RATING: 4
AVAILABLE FAULT CURRENT:

ID	BREAKER	DESCRIPTION	V - A	CIRCUIT	PHASE	CIRCUIT	V - A	DESCRIPTION	BREAKER	ID
+	100A/3P	Panel HV-BH-1		1	A	2		Blower Motor	150A/3P	+
+				3	B	4				+
+				5	C	6				+
+	25A/3P	Control Valve		7	A	8		FCV-001		+
+				9	B	10			XXXA/3P	+
+				11	C	12				+
+		- SPACE -		13	A	14		- SPACE -		+
+		- SPACE -		15	B	16		- SPACE -		+
+		- SPACE -		17	C	18		- SPACE -		+

CONNECTED LOAD (Dow nstream Loads Included)	TOTALS
Phase A	**0**
Phase B	**0**
Phase C	**0**
DOWNSTREAM LOADS	

LOAD SUMMARY

CATEGORY	CONNECTED	FACTOR	CALCULATED V - A	AMPS
LIGHTING	0	125%	0	0.0
GENERAL RECEPTACLE	0	100%	0	0.0
REMAINING GENERAL REC.	0	50%	0	0.0
DEDICATED RECEPTACLE	0	100%	0	0.0
MOTOR	0	100%	0	0.0
LARGEST MOTOR	0	125%	0	0.0
MISCELANEOUS	0	100%	0	0.0
HVAC	0	100%	0	0.0
ELECTRIC HEAT	0	125%	0	0.0
Total Demand:			0	0
Total Demand w ith Pow er Factor:		95%	**0**	**0**

PORTAL 208/120 V PANEL 3 PHASE PANEL (LV-MP-1)

PROJECT NAME: Idarado Mine 2900 Mill Level Bulkhead
PANEL NAME: LV-MP-1
3/1/2018

VOLTS: 208/120 Volt
PHASE, WIRE: 3 Phase, 4 Wire
CIRCUITS: 18
MANUFACTURER:
CONDUCTOR:
AIC RATING:
LOCATION: Mine Portal
FED FROM: Trans LV-1
MOUNTING: Surface
BUS: 100A
MAIN BREAKER AMPS: 50A
NEMA RATING:
AVAILABLE FAULT CURRENT:

ID	BREAKER	DESCRIPTION	V - A	CIRCUIT	PHASE	CIRCUIT	V - A	DESCRIPTION	BREAKER	ID
+	20A/2P	Outside Portal LED Light		1	A	2		Entryway LED Light	20A/2P	+
+				3	B	4				+
+	XXA/2P	Tunnel Rope Lights From Portal		5	C	6		Tunnel Emergency Lights From Portal	XXA/2P	+
+				7	A	8				+
+	20A/1P	GFCI Receptacle		9	B	10		PLC	20A/1P	+
+		- SPACE -		11	C	12		- SPACE -		+
+		- SPACE -		13	A	14		- SPACE -		+
+		- SPACE -		15	B	16		- SPACE -		+
+		- SPACE -		17	C	18		- SPACE -		+

CONNECTED LOAD (Dow nstream Loads Included)	TOTALS
Phase A	**0**
Phase B	**0**
Phase C	**0**
DOWNSTREAM LOADS	

LOAD SUMMARY

CATEGORY	CONNECTED	FACTOR	CALCULATED V - A	AMPS
LIGHTING	0	125%	0	0.0
GENERAL RECEPTACLE	0	100%	0	0.0
REMAINING GENERAL REC.	0	50%	0	0.0
DEDICATED RECEPTACLE	0	100%	0	0.0
MOTOR	0	100%	0	0.0
LARGEST MOTOR	0	125%	0	0.0
MISCELANEOUS	0	100%	0	0.0
HVAC	0	100%	0	0.0
ELECTRIC HEAT	0	125%	0	0.0
Total Demand:			0	0
Total Demand w ith Pow er Factor:		95%	**0**	**0**

DRAFT
FOR REVIEW ONLY

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

TITLE
PANEL SCHEDULES - 1

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: ELEC DETAILS
DRAWING E8.0
REVISION 1

O:\.18 Idarado\.17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

BULKHEAD 480/277 V 3 PHASE PANEL (HV-BH-1)

PROJECT NAME: Idarado Mine 2900 Mill Level Bulkhead
PANEL NAME: HV-BH-1
3/1/2018

VOLTS: 480/277 Volt
PHASE, WIRE: 3 Phase, 4 Wire
CIRCUITS: 24
MANUFACTURER:
CONDUCTOR:
AIC RATING:
LOCATION: Bulkhead
FED FROM: HV-MP-1
MOUNTING: Surface
BUS: 125A
MAIN BREAKER AMPS: 100A
NEMA RATING:
AVAILABLE FAULT CURRENT:

ID	BREAKER	DESCRIPTION	V - A	CIRCUIT	PHASE	CIRCUIT	V - A	DESCRIPTION	BREAKER	ID
+	50A-3P	Welding Receptacle		**1**	**A**	**2**		Trans LV-2	25A-3P	+
+				**3**	**B**	**4**				+
+				**5**	**C**	**6**				+
+	XXA-3P	30-inch Motorized Valve		**7**	**A**	**8**		18-inch Motorized Valve	XXA-3P	+
+				**9**	**B**	**10**				+
+				**11**	**C**	**12**				+
+		- SPACE -		**13**	**A**	**14**		- SPACE -		+
+		- SPACE -		**15**	**B**	**16**		- SPACE -		+
+		- SPACE -		**17**	**C**	**18**		- SPACE -		+
+		- SPACE -		**19**	**A**	**20**		- SPACE -		+
+		- SPACE -		**21**	**B**	**22**		- SPACE -		+
+		- SPACE -		**23**	**C**	**24**		- SPACE -		+

CONNECTED LOAD (Dow nstream Loads Included)	TOTALS
Phase A	**0**
Phase B	**0**
Phase C	**0**
DOWNSTREAM LOADS	

LOAD SUMMARY				
CATEGORY	**CONNECTED**	**FACTOR**	**CALCULATED V - A**	**AMPS**
LIGHTING	0	125%	0	0.0
GENERAL RECEPTACLE	0	100%	0	0.0
REMAINING GENERAL REC.	0	50%	0	0.0
DEDICATED RECEPTACLE	0	100%	0	0.0
MOTOR	0	100%	0	0.0
LARGEST MOTOR	0	125%	0	0.0
MISCELANEOUS	0	100%	0	0.0
HVAC	0	100%	0	0.0
ELECTRIC HEAT	0	125%	0	0.0
Total Demand:			0	0
Total Demand w ith Pow er Factor:		95%	**0**	**0**

BULKHEAD 208/120 V 3 PHASE PANEL (LV-BH-1)

PROJECT NAME: Idarado Mine 2900 Mill Level Bulkhead
PANEL NAME: LV-BH-1
3/1/2018

VOLTS: 208/120 Volt
PHASE, WIRE: 3 Phase, 4 Wire
CIRCUITS: 18
MANUFACTURER:
CONDUCTOR:
AIC RATING:
LOCATION: Bulkhead
FED FROM: Trans LV-2
MOUNTING: Surface
BUS: 100A
MAIN BREAKER AMPS: 50A
NEMA RATING:
AVAILABLE FAULT CURRENT:

ID	BREAKER	DESCRIPTION	V - A	CIRCUIT	PHASE	CIRCUIT	V - A	DESCRIPTION	BREAKER	ID
+	XXA/2P	Tunnel Rope Lights From Bulkhead		**1**	**A**	**2**		Tunnel Emergency Lights From Bulkhead	XXA/2P	+
+				**3**	**B**	**4**				+
+	20A/2P	Bulkhead LED Light		**5**	**C**	**6**		GFCI Receptacles	20A/1P	+
+				**7**	**A**	**8**		Bulkhead SOV	20A/1P	+
+		- SPACE -		**9**	**B**	**10**		- SPACE -		+
+		- SPACE -		**11**	**C**	**12**		- SPACE -		+
+		- SPACE -		**13**	**A**	**14**		- SPACE -		+
+		- SPACE -		**15**	**B**	**16**		- SPACE -		+
+		- SPACE -		**17**	**C**	**18**		- SPACE -		+

CONNECTED LOAD (Dow nstream Loads Included)	TOTALS
Phase A	**0**
Phase B	**0**
Phase C	**0**
DOWNSTREAM LOADS	

LOAD SUMMARY				
CATEGORY	**CONNECTED**	**FACTOR**	**CALCULATED V - A**	**AMPS**
LIGHTING	0	125%	0	0.0
GENERAL RECEPTACLE	0	100%	0	0.0
REMAINING GENERAL REC.	0	50%	0	0.0
DEDICATED RECEPTACLE	0	100%	0	0.0
MOTOR	0	100%	0	0.0
LARGEST MOTOR	0	125%	0	0.0
MISCELANEOUS	0	100%	0	0.0
HVAC	0	100%	0	0.0
ELECTRIC HEAT	0	125%	0	0.0
Total Demand:			0	0
Total Demand w ith Pow er Factor:		95%	**0**	**0**

DRAFT
FOR REVIEW ONLY

O:\18 Idarado\17a Bulkhead Piping\Elec Details.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

TITLE
PANEL SCHEDULES - 2

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: ELEC DETAILS
DRAWING: E9.0
REVISION: 1

LIGHT FIXTURE SCHEDULE

TYPE	DESCRIPTION	MANUFACTURER	CATALOG NUMBER	MOUNTING	VOLTAGE	NOTES	SUB QUANTITY	TOTAL QUANTITY
A	208 V OUTSIDE PORTAL LED LIGHT	---	---	---	208 V	---	1	1
B	208 V ENTRYWAY LED LIGHT	---	---	---	208 V	---	1	2
C	208 V BULKHEAD LED LIGHT	---	---	---	208 V	---	1	
D	208 V ROPE LIGHT DRIVER BOX	---	---	---	208 V	---	8	8
E	208 V LED ROPE LIGHT	---	---	---	208 V	---	7	7
F	208 V EMERGENCY LIGHT	---	---	---	208 V	---	22	22

PRELIMINARY PENDING
AREA CONDITION REVIEW

CONDUIT MOUNTING DETAILS

DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Elec Details.dwg SAVED: 3/9/18 PRINTED: 3/9/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
1	80% DESIGN REVIEW COMPILED DRAFT	RGD	JEB		3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

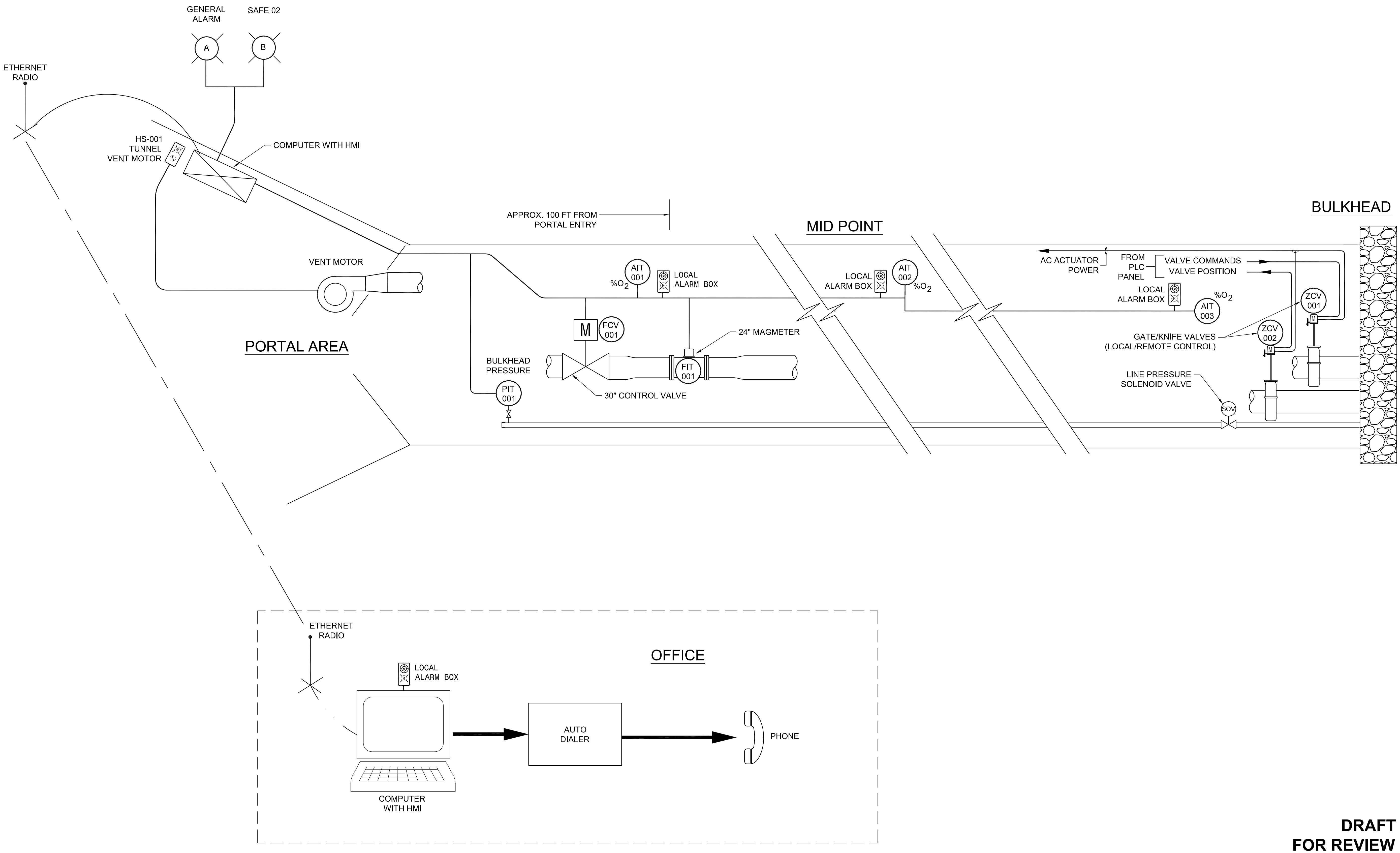
PREPARED FOR

NEWMONT

TITLE

LIGHT FIXTURE SCHEDULE

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: ELEC DETAILS
DRAWING: E10.0
REVISION: 1



DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Controls.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	JJM	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE
INITIAL I AND C LAYOUT	JJM	3/5/18

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

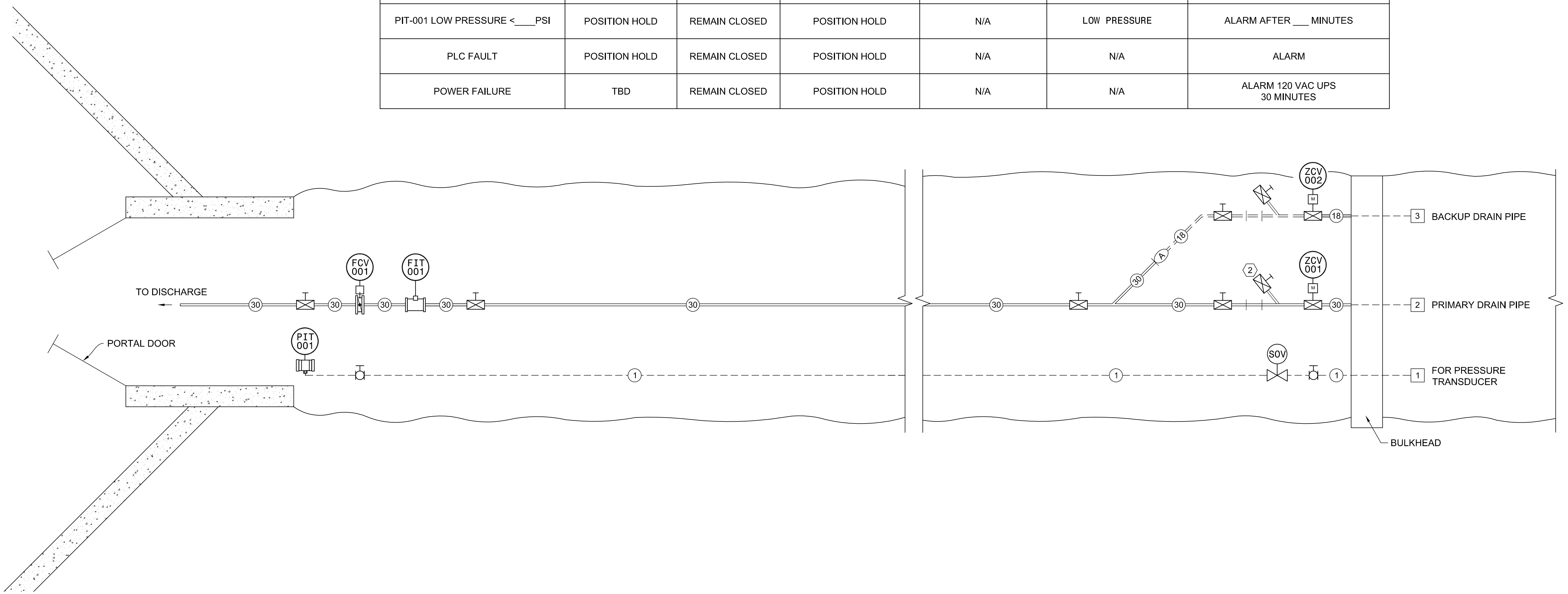
PREPARED FOR
NEWMONT

TITLE
INSTRUMENT AND CONTROL
FUNCTIONAL DESCRIPTION

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: CONTROLS
DRAWING CP1.0
REVISION 1

INSTRUMENT AND CONTROLS MATRIX

HMI COMMAND / EVENT	ZCV-001	ZCV-002	FCV-001	FIT-001	PIT-001	EXTERIOR FLASHER / CALLOUT
PERMISSIVE START UP	0-___ SEC FULL OPEN	REMAIN CLOSED	NORMAL FLOW SET PT. __ GPM	0-12,500 GPM MAINTAIN __ GPM	0-1000 PSI RANGE NORMAL OPERATING ___ PSI	
PERMISSIVE SHUTDOWN	0-___ SEC FULL CLOSE	REMAIN CLOSED	DELAY CLOSED PER ZCV-001	N/A	N/A	
ZCV-001 FAIL TO OPEN	FAIL TO OPEN	REMAIN CLOSED	REMAIN CLOSED	NO FLOW CONDITION	N/A	ALARM AFTER ___ MINUTES
FCV-001 FAIL TO OPEN	0-___ SEC FULL CLOSE	REMAIN CLOSED	FAIL TO OPEN	NO FLOW CONDITION	N/A	ALARM AFTER ___ MINUTES
FIT-001 LOW FLOW AFTER ___ MIN	0-___ SEC FULL CLOSE	REMAIN CLOSED	POSITION HOLD	LOW FLOW AFTER ___ MIN	N/A	ALARM AFTER ___ MINUTES
FIT-001 FAULT AFTER ___ MIN	POSITION HOLD	REMAIN CLOSED	POSITION HOLD	FAULT	N/A	ALARM AFTER ___ MINUTES
FIT-001 HIGH FLOW AFTER ___ MIN	0-___ SEC FULL CLOSE	REMAIN CLOSED	CLOSE VALVE	HIGH FLOW AFTER ___ MIN	N/A	ALARM AFTER ___ MINUTES
PIT-001 HIGH PRESSURE >____PSI	0-___ SEC FULL CLOSE	REMAIN CLOSED	CLOSE VALVE	N/A	HIGH PRESSURE	ALARM AFTER ___ MINUTES
PIT-001 LOW PRESSURE <____PSI	POSITION HOLD	REMAIN CLOSED	POSITION HOLD	N/A	LOW PRESSURE	ALARM AFTER ___ MINUTES
PLC FAULT	POSITION HOLD	REMAIN CLOSED	POSITION HOLD	N/A	N/A	ALARM
POWER FAILURE	TBD	REMAIN CLOSED	POSITION HOLD	N/A	N/A	ALARM 120 VAC UPS 30 MINUTES



DRAFT
FOR REVIEW ONLY

O:\.18 Idarado\.17a Bulkhead Piping\Controls.dwg SAVED: 3/12/18 PRINTED: 3/12/18 BY: TBLOCH

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
1	80% DESIGN REVIEW COMPILED DRAFT	JJM	JEB			3/12/18

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

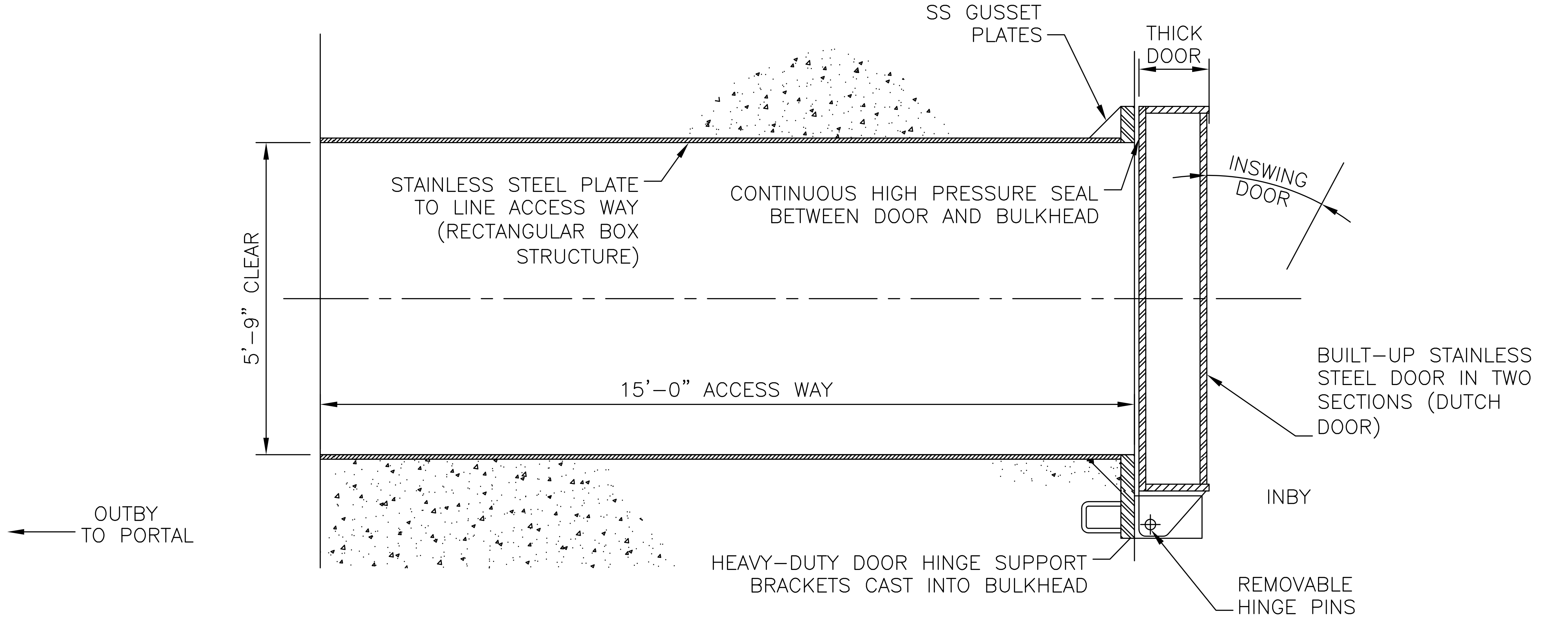
ENGINEERING RECORD	BY	DATE
FUNCTIONAL DESCRIPTION I & C	JJM	3/5/18

PREPARED BY
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, CO 80525
(970) 488-3111

PREPARED FOR
NEWMONT

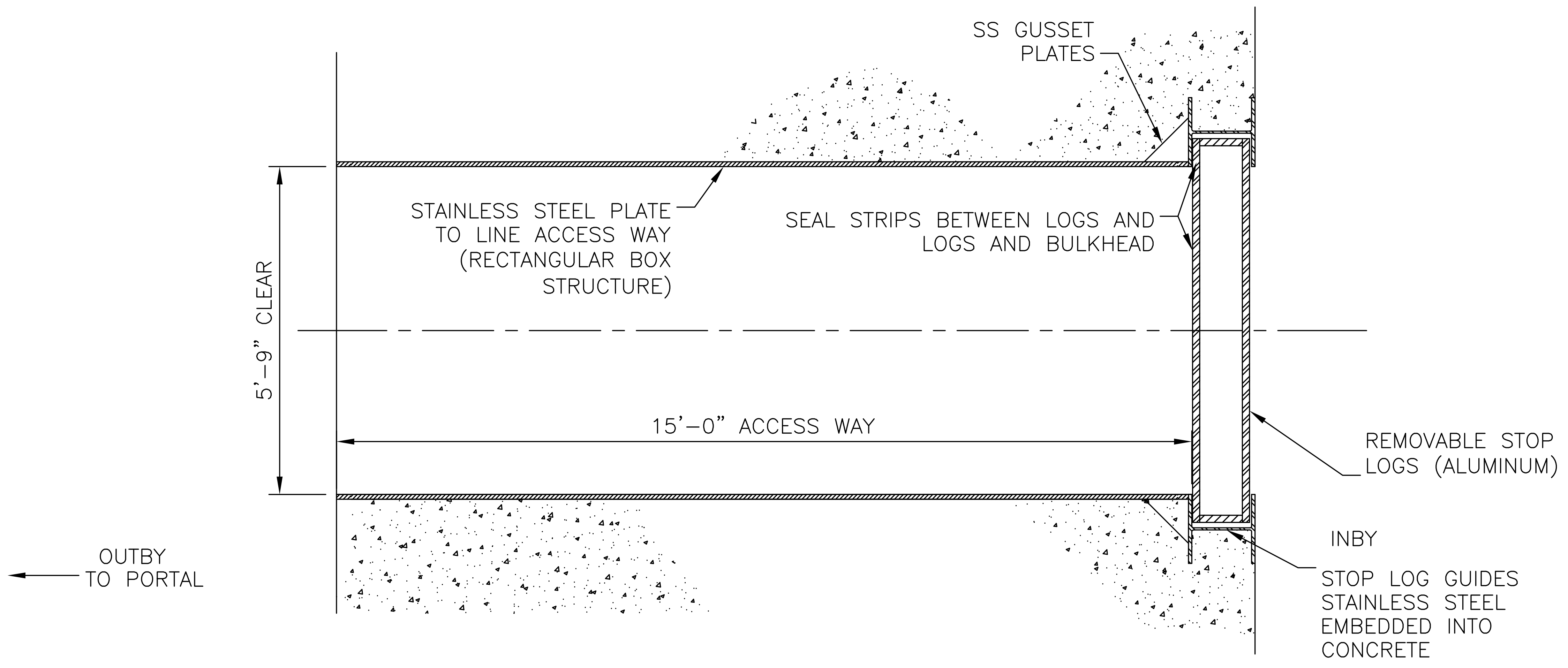
TITLE
INSTRUMENT AND CONTROL
FUNCTIONAL DESCRIPTION

PROJECT: IDARADO
DATE: MARCH 12, 2018
SCALE: NTS
FILE: CONTROLS
DRAWING CP2.0
REVISION 1



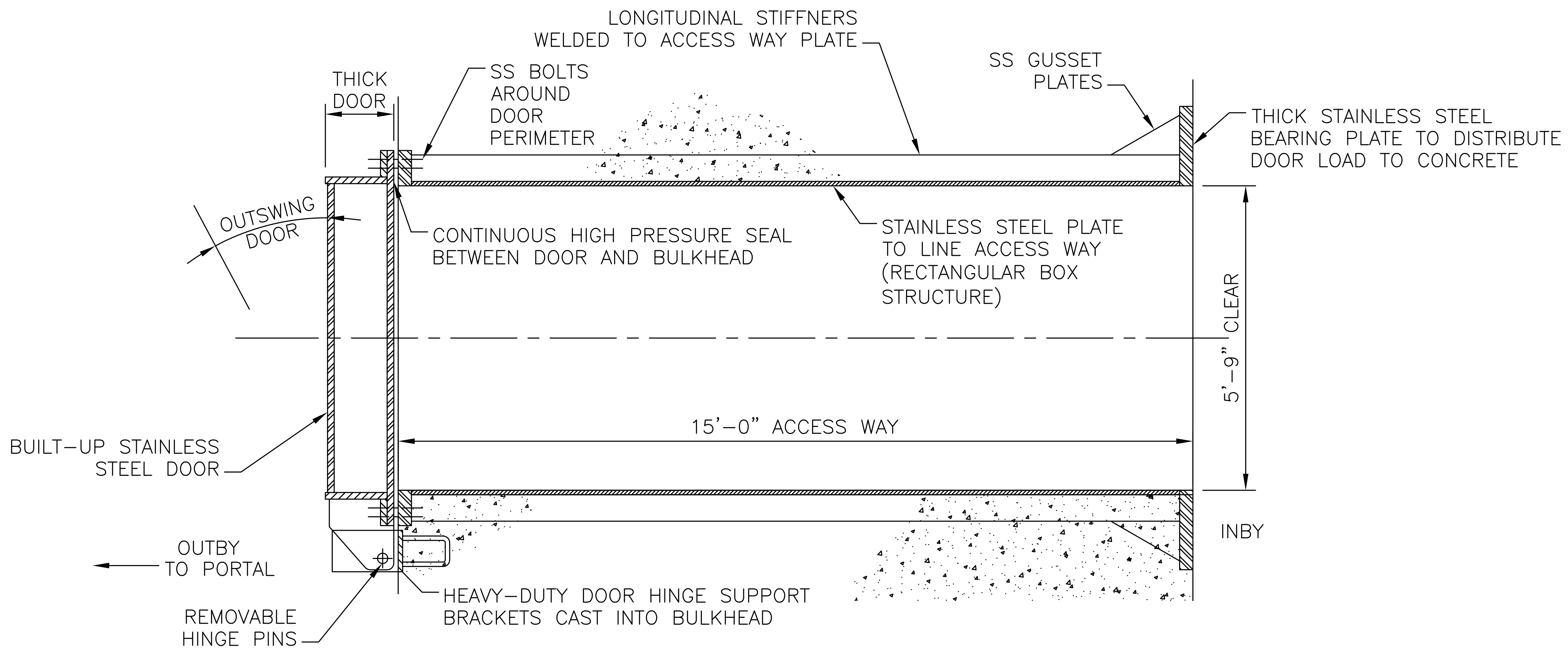
PLAN: ACCESS WAY AND DOOR – INSWING OPTION

SCALE: 1/2" = 1'-0"



PLAN: ACCESS WAY AND DOOR – STOP LOG OPTION

SCALE: 1/2" = 1'-0"



PLAN: ACCESS WAY AND DOOR – OUTSWING OPTION

SCALE: 1/2" = 1'-0"

C:\Users\kbrau\Documents\L-7 Services\Idarado Mine Bulkhead\Idarado Blkhd A.dwg SAVED:3/13/18 PRINTED:3/13/18 BY:KBRAU

REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED	DATE
△					
△					
△					
△					
△					
△					
△					

REFERENCES

DWG No.	DRAWING TITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE

PREPARED BY

L-7 SERVICES LLC
P.O. BOX 1387
GOLDEN, CO 80402

PREPARED FOR

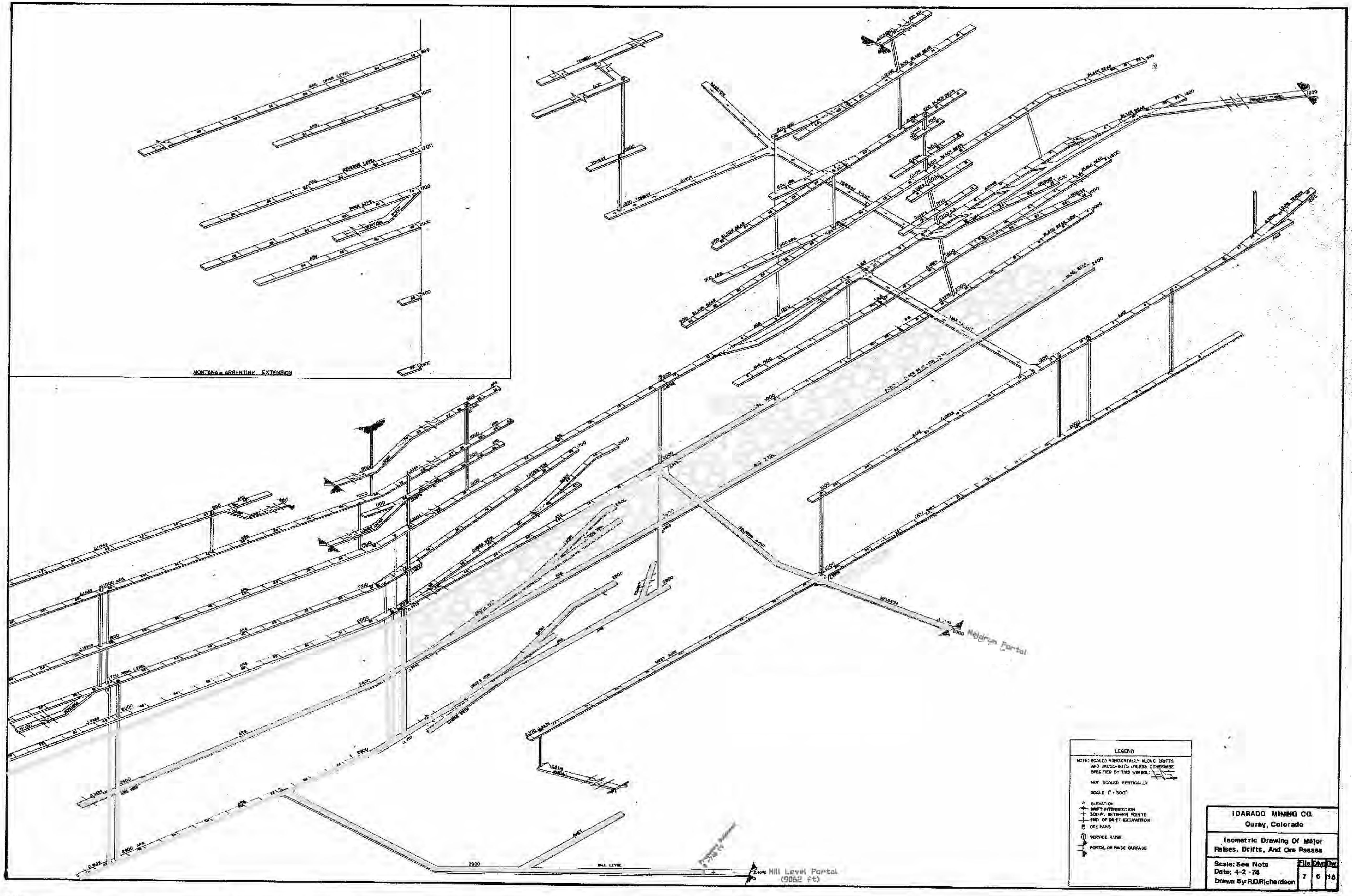
NEWMONT

TITLE

MILL LEVEL BULKHEAD ACCESS WAY AND DOOR

PROJECT: IDARADO
DATE: MARCH 2018
SCALE: AS SHOWN
FILE: IDARADO BLKHD A
DRAWING: S1
REVISION: △

Appendix B
Idarado Isometric Drawing with Proposed Bulkhead



REVISIONS

No.	DESCRIPTION	BY	CHKD.	APPROVED		DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE
A	DESCRIPTION	BY	CHKD	APP1	APP2	DATE

REFERENCES

DWG No.	DRAWING TITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE
DWGNO	DWGTITLE

DESIGNERS

ENGINEERING RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE
RECORD	BY	DATE

PREPARED BY

Monadnock Mineral Services, LLC
Robert A. Larson CPG-PLS
342 7th Ave. Box 85
Ouray, CO 81427
970-325-4600 (O)
970-318-1430 (M)
bob@mmsouray.com

PREPARED FOR

NEWMONT

TITLE

Idarado Isometric With Proposed Bulkhead

PROJECT: Idarado
DATE: 3-6-18
DRAWING
REVISION △
SCALE: ~1"=75'
FILE:

Appendix C
Available Mine Storage Evaluation

Monadnock Mineral Services, L.L.C.

February 9, 2017

Mark Levin
MES Mining
P.O. Box 1511
Idaho Springs, CO 80452

Re: Technical Memorandum – Idarado Mill Level Drainage

Dear Mark,

It is being proposed to construct a bulkhead inside the Mill Level workings of the Idarado Mine, approximately 740 ft inside the portal, as per the information you have provided. The following data and calculations are to estimate the volume of water that could be backed-up or stored in the Idarado Mine, from 2900 Mill Level up to the 2000 Level workings. Water would discharge out the Meldrum Portal if allowed to fill up to the 2000 Level. The Mill Level Portal is at an elevation of 9062 ft and the Meldrum Portal is at an elevation of 9943 ft.

Plan maps of the workings were used to determine the approximate volume of the various crosscuts and drifts on the 2900 Level, 2400 Level, up to the 2000 Level, from where the Meldrum can be accessed. Linear distances of these workings were measured from historical maps of the workings. It is assumed that most of these workings are 9 ft high by 9 ft wide. These cubic feet volumes were multiplied by 7.48 gallons/cubic ft to determine the estimated gallons of water. A plan map of the 2400 Level outlined the replacement ore bodies (ROB) so that an area could be determined for those particular stopes. The remaining pillars were subtracted from the calculated areas. The height of the ROB's was assumed to be 9 ft so this volume was again multiplied by 7.48 to determine the estimated gallons of water in these stopes.

Historic longitudinal sections of the Argentine-Montana Veins, Cross Vein and Basin Vein stopes were used to calculate the estimated volumes of these shrink-stopes. An average width of 6 ft was used for the Argentine and Basin veins but an average width of 20 ft was used for the very wide Cross Vein workings. The attached spreadsheet summarizes these calculations and provides the following estimates:

• Crosscuts and Drifts	24.7 million gallons
• Stopes	221.5 million gallons
Total	**246.2 million gallons**

Not knowing whether the stopes are entirely open, if there have been cave-ins or sluffs, or if the stopes were used for waste rock storage, the following provides further estimates:

• If 70% of the calculated volume remains open	**172.3 million gallons**
• If 50% of the calculated volume remains open	**123.1 million gallons**

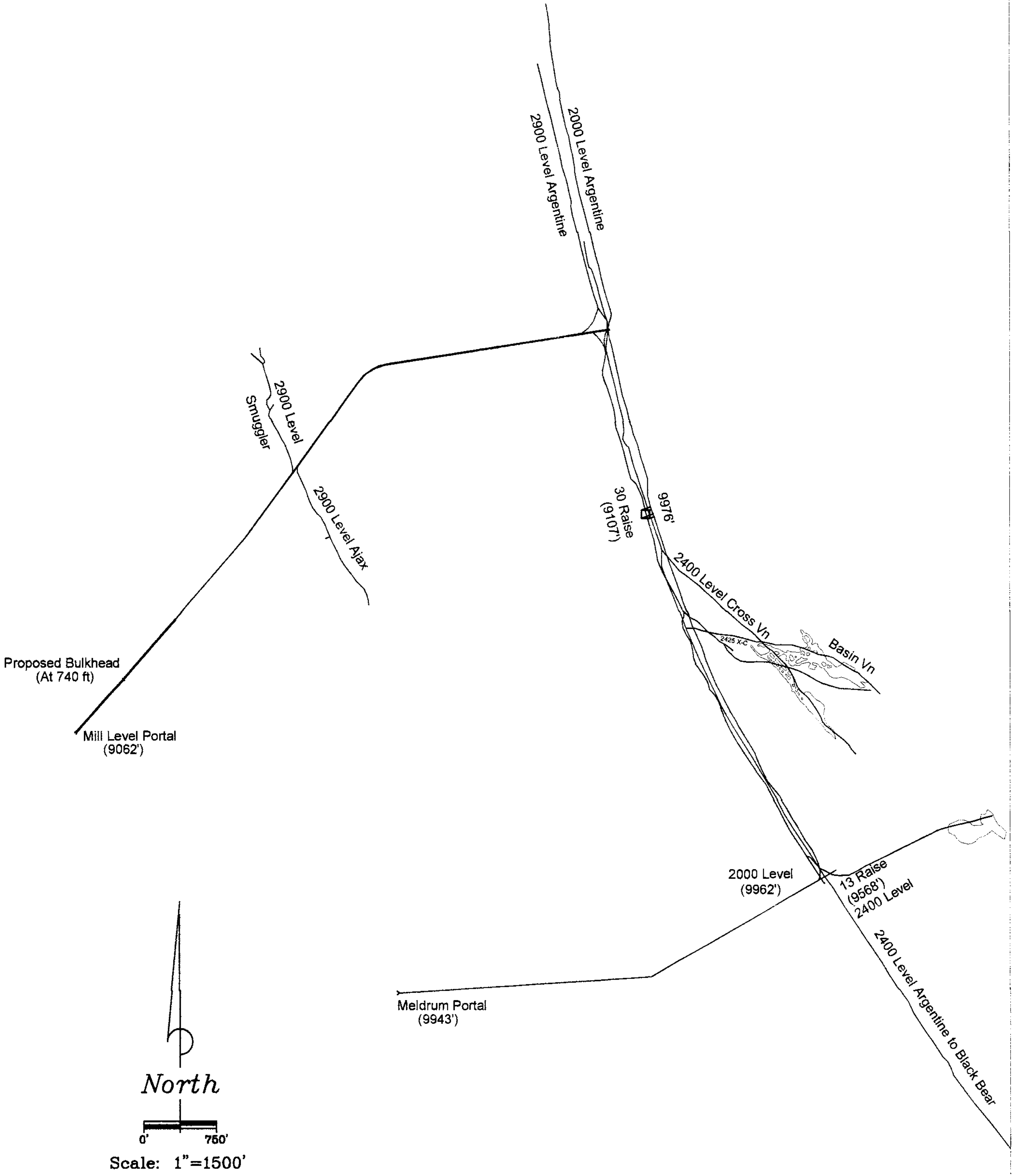
Respectfully submitted,

Robert A. Larson

Robert A. Larson, CPG-PLS
Monadnock Mineral Services, LLC

American Institute of Professional Geologists
Certificate Number 4682
AIPG
2-09-17
ROBERT A. LARSON

Idarado Workings
Volume Estimates for Water Storage

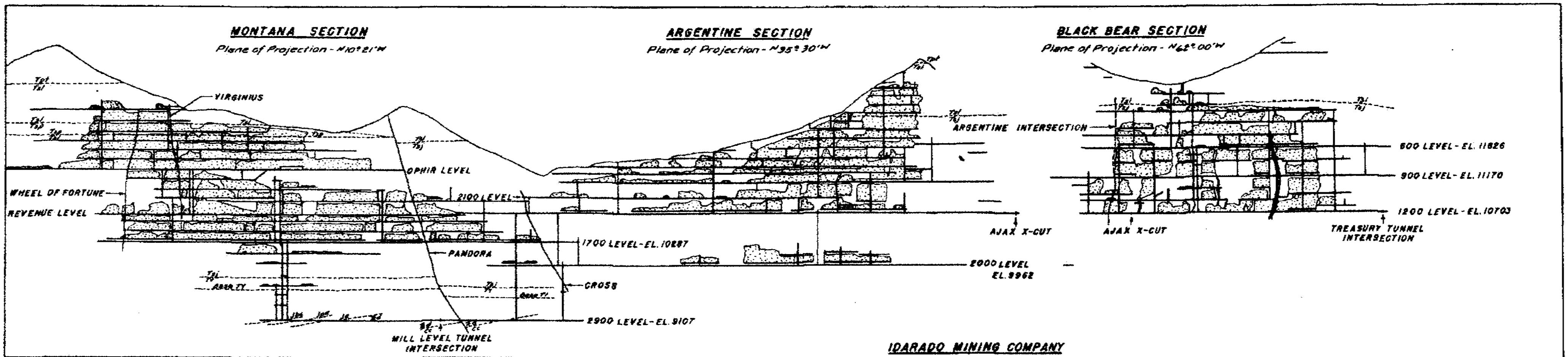


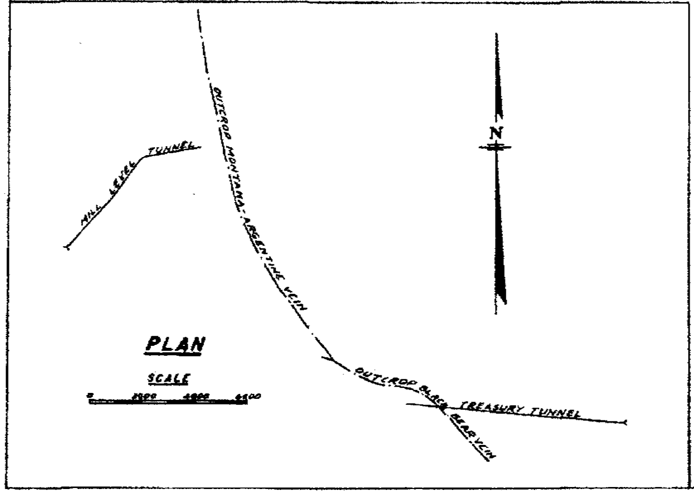
Idarado Volume Estimates

Workings	Distance (ft)	WxH	Volume (cubic feet)	Million Gallons (MG))
2900 Mill Level to Argentine	6620'	9'X9'	536,220	4.0
Ajax (South)	1690'	9'X9'	136,890	1.0
Smuggler (North)	1630'	9'X9'	132,030	1.0
Argentine (South) to Cross Vr	3110'	9'X9'	251,910	1.9
Argentine Beyond Cross Vn	3225'	9'X9'	261,225	2.0
Cross Vein to Basin Vein	650'	9'X9'	52,650	0.4
Basin Vein	1670'	9'X9'	135,270	1.0
Tomboy Crosscut	2125'	9'X9'	172,125	1.3
Argentine (North)	3365'	9'X9'	272,565	2.0
2400 Level Argentine N & S	3335'	9'X9'	270,135	2.0
Cross Vein to Basin Vein	1400'	9'X9'	113,400	0.8
Basin Vein	1394'	9'X9'	112,914	0.8
Argentine Beyond Cross Vn	9897'	9'X9'	801,657	6.0
2425 X-C	800'	9'X9'	64,800	0.5
				24.7

Stopes	Area (sq.ft.)	Width	Volume (cubic feet)	Million Gallons (MG))
Argentine	1,615,736	6'	9,694,416	72.5
Cross Vein - Wider Structure	845,649	20'	16,912,980	126.5
Basin Vein	170,377	6'	1,022,262	7.6
ROB Stopes	221,235	9' Hgt	1,991,115	14.9
				221.5

Total Calculated Gallons	**246.2**
If 70% Remains Open	**172.3**
If 50% Remains Open	**123.1**





IDARADO MINING COMPANY

LONGITUDINAL SECTION OF THE BLACK BEAR & MONTANA-ARGENTINE VEINS

SCALE

900 0 900 1800 2700 3600

LEGEND

Tpt - Treasure Mountain quartz latite } Potosi Group
Tsl - Hornblende latite and rhyolite } Picayune Group
Tsp - Pyroxene andesite } Picayune Group
Tsj - San Juan tuff
Tt - Telluride conglomerate
Jsc - Bilk Creek sandstone } Morrison Formation
Jpe - Pony Express limestone } Morrison Formation
Je - Entrada sandstone
Ꞧd - Dolores Formation
Cc - Cutler Formation
▰ - Rhyolite dike

Drawn by: J.W.S.

LEGEND

NOTE: SCALED HORIZONTALLY ALONG DRIFTS AND CROSS-CUTS UNLESS OTHERWISE SPECIFIED BY THIS SYMBOL:

NOT SCALED VERTICALLY

SCALE 1" = 300'

- △ ELEVATION
- DRIFT INTERSECTION
- + 300 FT. BETWEEN POINTS
- END OF DRIFT EXCAVATION
- ORE PASS
- SERVICE RAISE
- PORTAL OR RAISE SURFACE

IDARADO MINING CO.
Ouray, Colorado

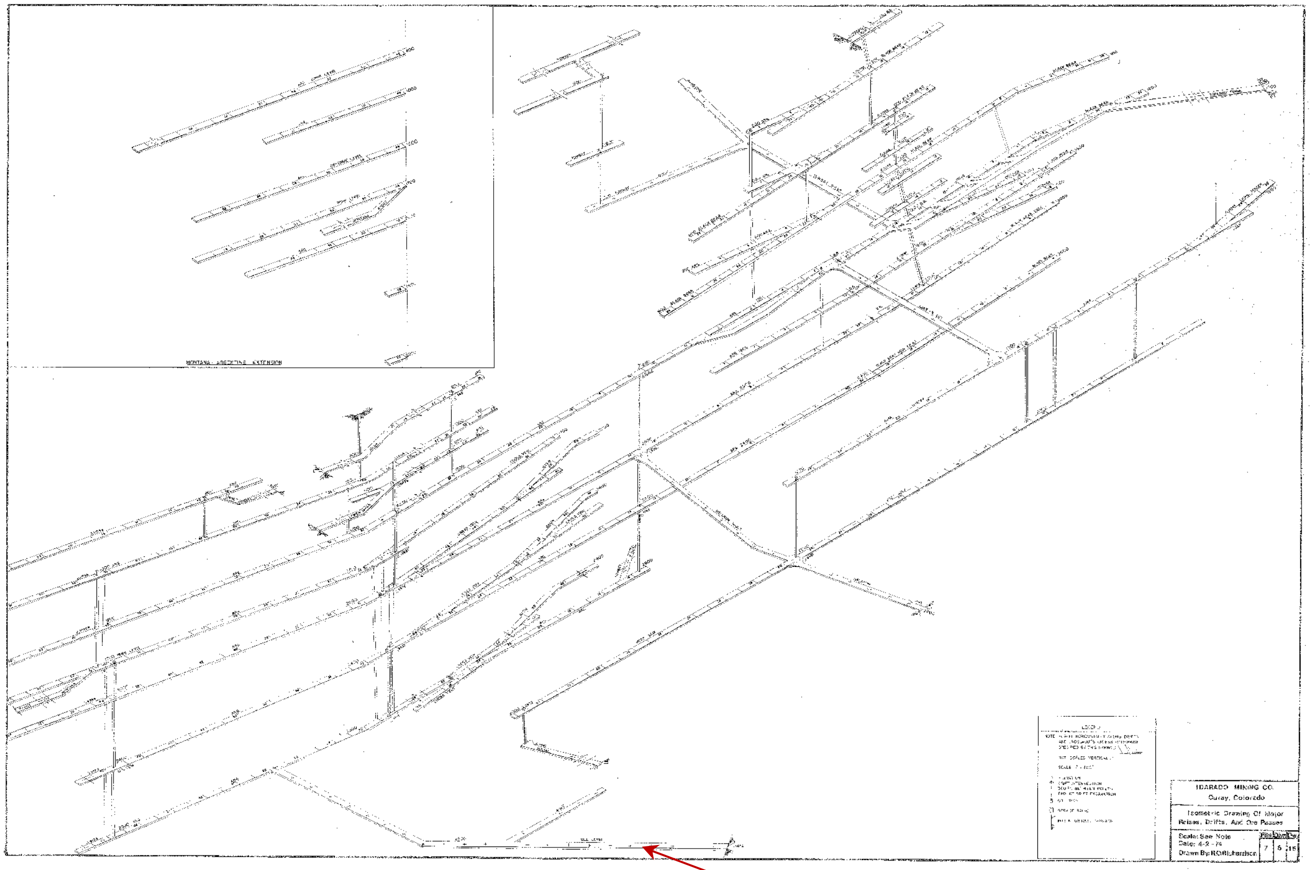
Isometric Drawing Of Major Raises, Drifts, And Ore Passes

	File	Divn	Dw
Scale: See Note Date: 4-2 -74 Drawn By: R.O.Richardson	7	6	15

Appendix D
Geotechnical Overview and Laboratory Rock Test Results

Introduction:

This written to provide an overview of the site geology, the geotechnical explorations performed, and the impact of the geology on the Idarado bulkhead design. The proposed bulkhead at the Idarado Mine will be located in the Mill Level 2900 drift. The Mill Level adit is the lowest level of a series of adits and shafts that comprise an extensive mine complex as shown below.



Approx. Bulkhead Location in Mill Level Adit

Figure 1: Idarado Mine Complex

General Geology:

The bulkhead will be constructed within the sedimentary Cutler Formation which consists of sandstones, siltstones, shales, conglomerates, and claystones deposited during the Permian geologic period. Outcrop exposures of the Cutler Formation are plentiful in the Telluride valley and reveal relatively uniform horizontal beds of sedimentary rock layers. Local exposures near the Mill Level portal indicate that the adit is excavated in fine grained red sandstone/siltstone with a well-cemented conglomerate approximately 10 feet above the adit back. The majority of the Mill Level adit is excavated in the Cutler Formation and the bulkhead locations considered to date have all been within the Cutler Formation. The Cutler Formation forms the basal unit for the Telluride valley and is one of the thicker formations present. Above the Cutler Formation is the Dolores Formation which has similar sedimentary rock types (shales, siltstones, sandstones, conglomerates, and limestones) as the Cutler Formation and is difficult to distinguish visually in the valley outcrops. The contact between the two is formations is unconformable indicating a period of non-deposition with a likely irregular and undulating interface due to erosional processes. At the Mill Level Portal, the contact with the Dolores Formation is approximately at El. 9400, roughly 340 feet above the adit. A general cross-section of the Telluride valley is shown below with the Cutler Formation being the thick blue unit at the base of the valley. For reference, the stratigraphic sequence going upwards consists of the Cutler Formation, Dolores Formation (TRd), Entrada Sandstone (Je), Wanakah Formation (Jw), Morrison Formation (Jm), Telluride Conglomerate (Tt), and the San Juan Formation (Tsj).

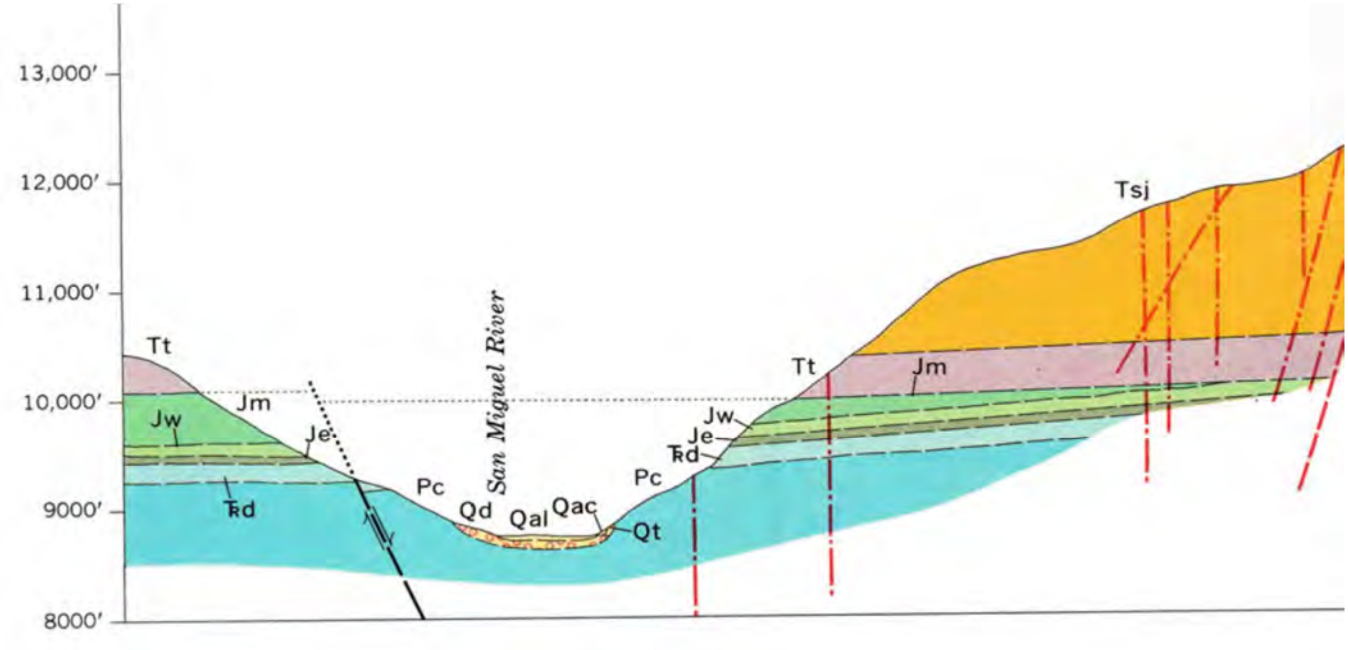
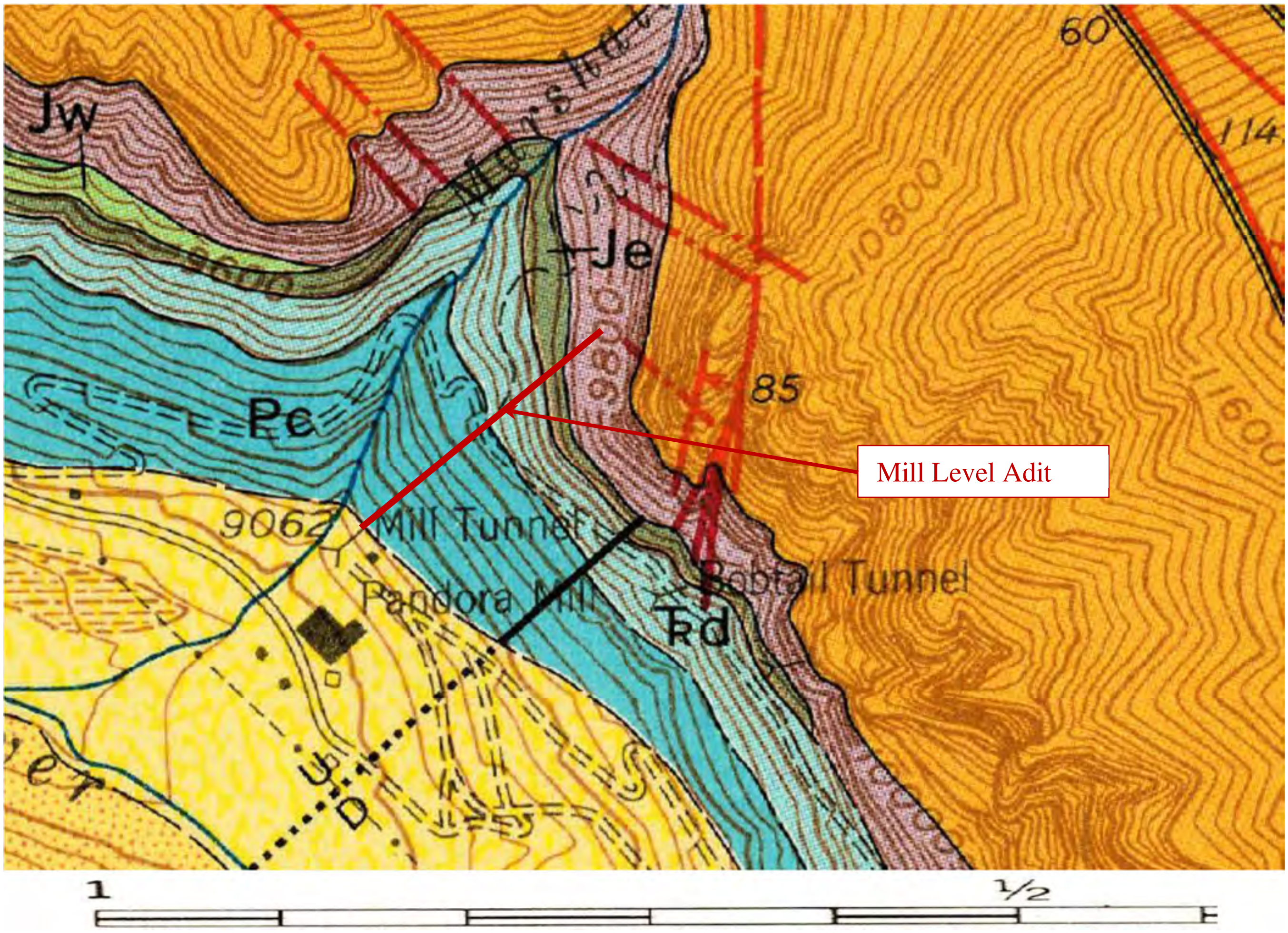


Figure 2: General Statigraphy of Telluride Valley (per USGS Geologic Map of the Telluride Quadrangle (1966))

Per the USGS Telluride Quadrangle in the vicinity of the Mill Level adit (shown below), these stratigraphic units are present, although some are locally absent to the southeast of Marshall Creek (Wanakah and Morrison Formatins. Based on the strata elevations depicted on the USGS Telluride quadrangle, the top of the Cutler Formation has an apparent dip of approximately 1.6° inby (to N41E; parallel to adit orientation) across the valley and a steeper apparent dip of 4.3 degrees measured further away on the Bear Creek outcrop. The apparent dip of the strata was measured on a prominent rock layer on the southern rib of the Mill Level adit near Sta. 16+00 with a dip angle of 8° inby relative to horizontal; this measurement was inby the large shear zone where vertical offset of the rock strata was observed and is considered to be representative of the strata dip beyond Sta. 13+80. Clearly there is some variation to the strata dip in this region.

0



(Scale in Miles)

Figure 3: Mill Level Adit (modified from USGS Geologic Map of the Telluride Quadrangle (1966))

Also indicated on the USGS geologic map is the presence of a near parallel fault to the Mill Level adit approximately 600 feet to the southeast. A review of the mine maps for the Mill Level workings did not identify any major fault zone inby that would correlate with this fault and therefore, it does not appear that the fault presents any specific considerations for the bulkhead siting or operation. It is noted that the overall region is intersected by a network of faults and structural discontinuities (some with mineralized veins) and the bulkhead location has intentionally been sited to avoided proximity to major intersecting seams, shears, or faults in the adit.

Site Geology:

Per the mine map for the 2900 Mill Level adit (shown below), the portal elevation is at EL. 9062 with the Ajax Dyke-Vein listing an EL. 9080.5 and a distance of approximately 3500 feet resulting in an approximate slope of 0.005 ft/ft. The strike of the Mill Level adit near the portal is approximately N41°E based on the existing maps.

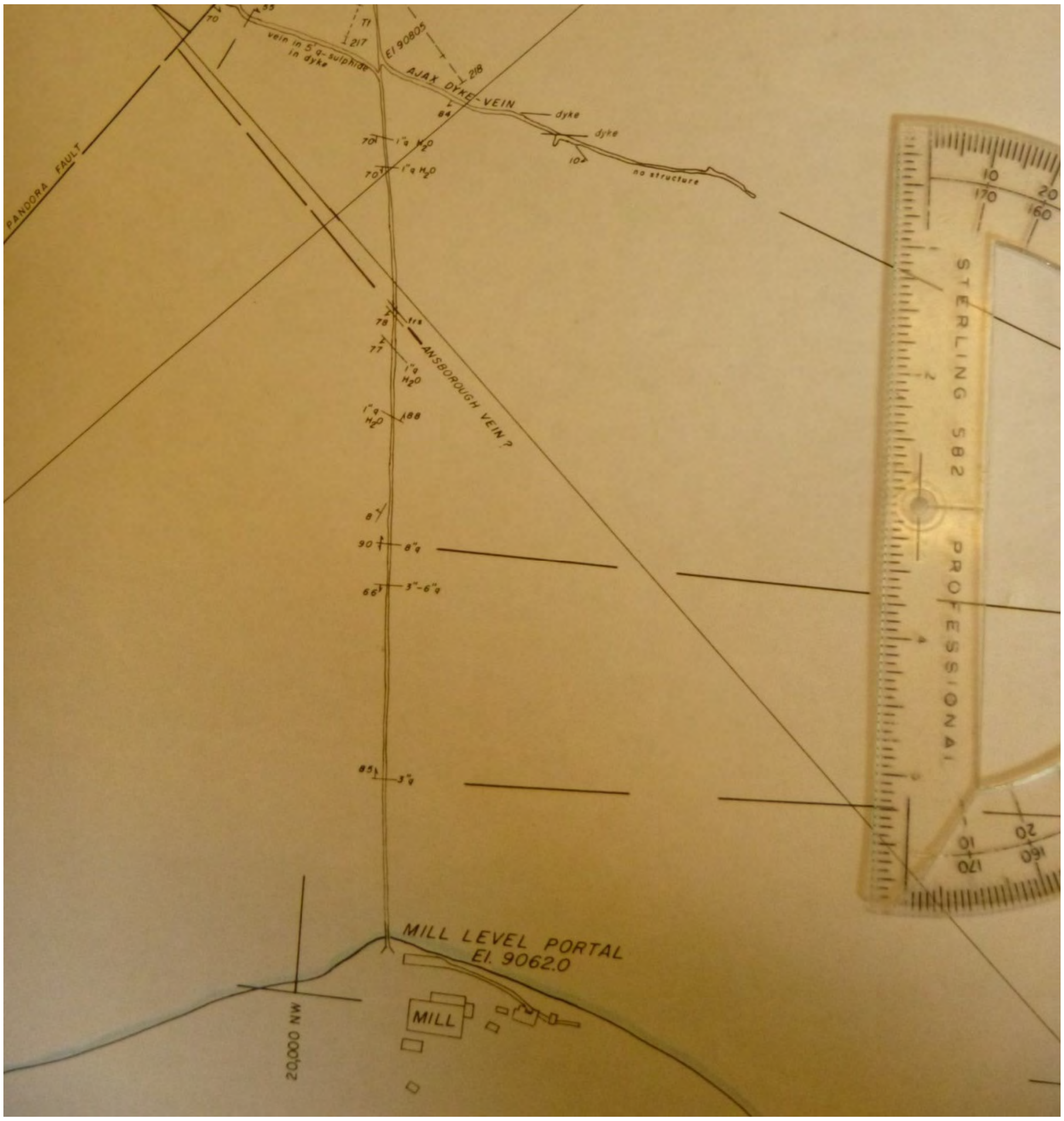


Figure 4: **Idarado 2900 Mill Level Adit Mine Map (1"=500 lf on ruler shown)**

It is important to note that the mine map lists very few geologic features (veins, shears, faults) for the adit near the portal. This is in contrast to the areas further inby (particularly near mined areas) where the frequency of the features identified increases significantly. Although the majority of the Mill Level Adit rock surfaces are obscured by a thin coating of shotcrete (flashcrete), major discontinuities were not observed and majority of the adit within the initial 1200 feet appears to be relatively uniform with gradually dipping sedimentary beds. Where features were noted during site visits, they also were listed on the mine map. Per the mine map shown above, the few features listed include:

Sta. 5+50:	3" seam/vein with quartz dipping 85° inby
Sta. 11+75:	3" to 6" seam/vein with quartz dipping 66° outby
Sta. 13+50:	8" seam/vein with quartz vertical dip

The latter two were recently observed (January 2018) and were also sources of groundwater inflow into the mine. The initial siting criteria for the bulkhead was based on attaining adequate vertical rock cover to counteract potential hydrostatic pressure and an initial bulkhead location was targeted at Sta. 7+32 (later refined construction stationing indicates Sta. 7+71). A geotechnical drilling program (discussed in subsequent section) was performed at this initial bulkhead location. The proximity to the Marshall Creek presented issues with potential lateral hydrojacking of the rock slope under the maximum pressure and the target bulkhead locations was revised to be a minimum 9+75 feet inby from the portal.

During the adit rehabilitation effort in January 2018, reconnaissance of the Mill Adit was conducted to identify a potential location for the bulkhead inby of Sta. 9+75. Adit conditions nearest to Sta. 9+75 were deemed undesirable due to a large amount of existing rock support in the back, significant vertical adit height, drummy rock conditions in the back, and an unfavorable local widening of the adit. A suitable potential bulkhead location was identified slightly inby in the vicinity of Sta. 10+30 which presented more favorable adit dimensions and less rock support of the back. Local removal of the shotcrete was performed on the back and ribs to expose the rock and revealed that the rock conditions in the back were somewhat less desirable than hoped, with thin bedded, open joints, and readily scalable sandstone. Sounding of the back with a scaling bar indicated that the overhead rock is consistently drummy throughout this area, while the sounding of the ribs indicated tight rock (albeit thinly bedded). Additional scaling of the back and rock bolting revealed that the thinly bedded zone extends approximately 12” to 18” above the adit before a more competent rock layer is encountered.

Alternative bulkhead sites were investigated on January 18th, 2018, with several comparable bulkhead sites identified, but with the same drummy sounding back conditions as Sta. 10+30. The nearest alternative site was located at Sta. 12+10 with a sound back and a natural keyway, however there was a near vertical seam with water seeps immediately outby this location. Another alternative location was identified near Sta. 13+00 with minimal rock support and a sound back, but relatively close to a major shear with considerable water inflow at approximate Sta. 13+80. It is anticipated that either of these sites could be utilized, but consideration would need to be given to the effect that the permeable near vertical seams may have on the bulkhead and if supplemental grouting would be needed.

Given that the bulkhead will require some rock excavation to create an adequate taper for pressure transfer, the thin bedded rock conditions near the back at Sta. 10+30 may not necessarily be a significant issue and the lack of significant vertical seams in the area is certainly a benefit. This 10+30 location represents the current targert bulkhead location with the understanding that additional rock removal in the back will be needed as part of bulkhead construction. This location is approximately 260 feet from the location of the underground boring program and represents a strata shift (based on a minimum 1.6° apparent dip and adit gradient of 0.005 ft/ft) of approximately 8.4 vertical feet at the back. Therefore, very little (maximum of 1.6 feet) of the 10 vertical feet core interval collected before is applicable to the current bulkhead location and accordingly a second geotechnical drilling program has been performed to confirm rock conditions at the 10+30 site.

Geotechnical Investigations:

During the initial site visit in July 2015, a rock sample from the portal was collected which had a similar appearance to the rock in the vicinity of the potential bulkhead location. Subsequent laboratory testing indicates that the unconfined compressive strength (UCS) of the portal rock sample is relatively strong with UCS results of 22,190 psi and 23,320 psi for two orthogonal rock cores through the sample.

Figure 5: Portal Rock Block Sample 1A

A subsequent rock coring program was conducted at the initial bulkhead location (approximate Sta. 7+32; 7+71 current stationing) on August 15th, 16th, and 17th, 2016 consisting of four core holes extending away from the adit a minimum of 10 feet. The drilling was completed by San Juan Drilling with support from MES. Due to clearance issues with the drilling rig, the two vertical borings had to be inclined relative to vertical. The following lists the exploratory borehole locations and orientations:

Borehole	Location	Hole Orientation	Total Drilling Depth
D-1	Sta. 7+32 Invert	Inclined Downwards 69.5° from horizontal	13 feet
U-1	Sta. 7+32 Back	Inclined Upwards 74° from horizontal	13 feet
E-1	Sta. 7+32 Right Side (inby)	Horizontal	13 feet
W-1	Sta. 7+32 Left Side (inby)	Horizontal	10 feet

Figure 6: Drilling Operations for Exploratory Borehole D-1

Boring logs and core photos for the four exploratory holes have been included in Appendix C and D respectively. The typical rock at the bulkhead location consists of a red fine grained sandstone with occasional lenses of medium to coarse grain sandstone. Full core recoveries (or close to full) were able to be collected and RQD (rock quality designation) ranged from 58% to 100%, with the majority of the rock core in the excellent range (>90%).

Figure 7: Typical Rock Core (from Borehole U-1 0' to 10' depth)

Laboratory testing was performed on the core samples by Advanced Terra Testing in Lakewood, CO. Both unconfined compressive strength tests and direct shear tests were conducted. Unconfined compressive strength samples were selected from each borehole to represent the range of geotechnical variation (i.e. grain size gradation and visual appearance) encountered in the rock cores. The direct shear tests were performed on select relatively undisturbed natural fractures to simulate potential sliding along existing discontinuities. The results of the laboratory testing are summarized below:

Rock Sample	Boring	Depth	Test Results
U-1B	U-1	6'-7'	Direct Shear (ASTM 5607): cohesion c= 10.9 psi; friction angle φ = 19.2°; density γ = 172.1 pcf
D-1A	D-1	9.5'-10'	Unconfined Compressive Strength: UCS = 9,160 psi; density γ = 163.1pcf
W-1A	W-1	2'-2.5'	Unconfined Compressive Strength: UCS = 5,020 psi; density γ = 172.2pcf; Elastic modulus E = $9.19\text{x}10^6$ psi; Poisson's ratio = 0.201;
U-1A	U-1	8.25'-9.5'	Unconfined Compressive Strength: UCS = 14,160 psi; density γ = 173.0 pcf; Elastic modulus E = $4.41\text{x}10^6$ psi; Poisson's ratio = 0.225

Recently the second boring program was completed and confirmed uniform rock conditions surrounding the bulkhead. The program was similar to the first drilling program (four holes extending 10 feet away from adit), but also included rock permeability tests to provide an indication of the seepage potential of the bulkhead. Currently, the rock cores have not been reviewed in detail and the packer test data have not been fully processed, but initial observations appear to indicate that the 10+30 is a suitable location for the bulkhead. Rock testing is planned for select core samples to confirm the rock strength assumption (comparable to concrete strength) utilized for design of the bulkhead.

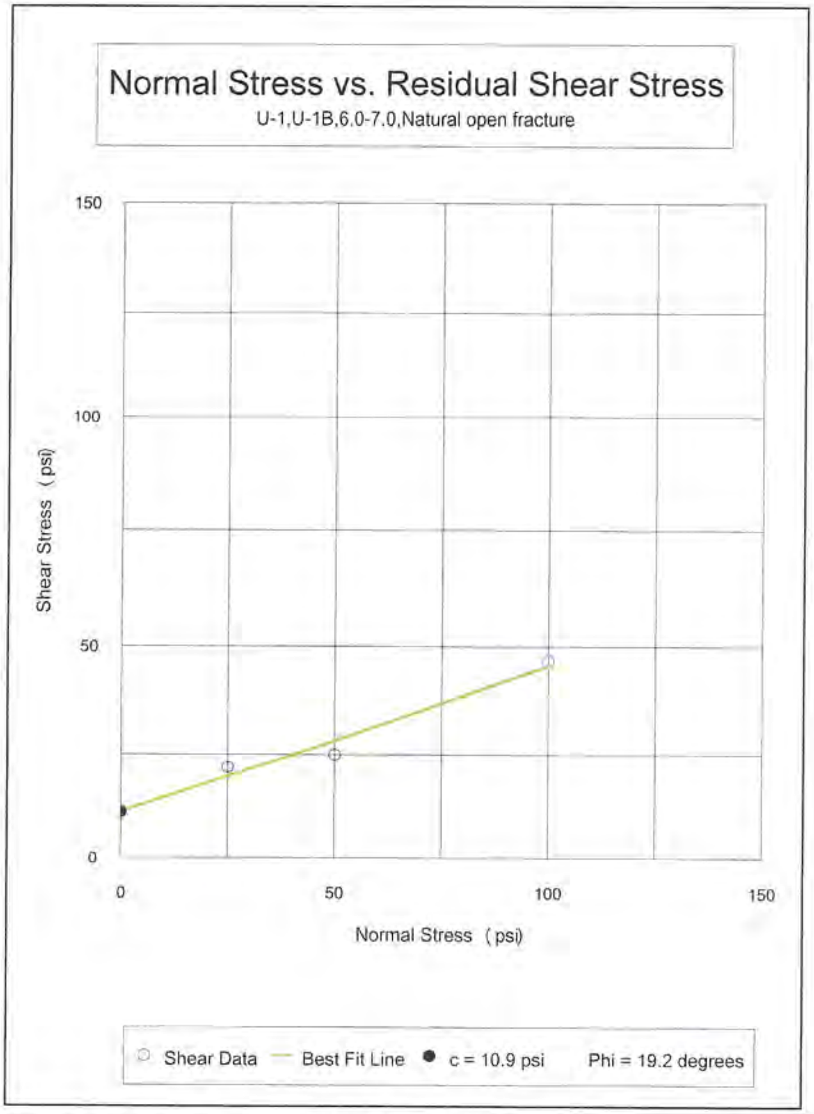
DIRECT SHEAR

ASTM D 5607

DIRECT SHEAR
* ASTM D 5607

CLIENT	L-7 Services	JOB NO.	2845-04
BORING NO.	U-1	DATE SAMPLED	
DEPTH (ft.)	6.0-7.0	DATE TESTED	9/18/16 HN
SAMPLE NO.	U-1B	PROJECT	Idarado Mill Level
ROCK TYPE		JOINT TYPE	Natural open fracture
Diameter (in)	1.993	Mass (g)	694.50
Length (in)	4.928	Wet Density (pcf)	172.1
Shear Area (in^2)	3.262	Shear Length (in)	0.199

NORMAL STRESS (psi)	: STRESS (psi)	RESIDUAL SHEAR STRESS (psi)
25		21.8
50		25.0
100		46.8

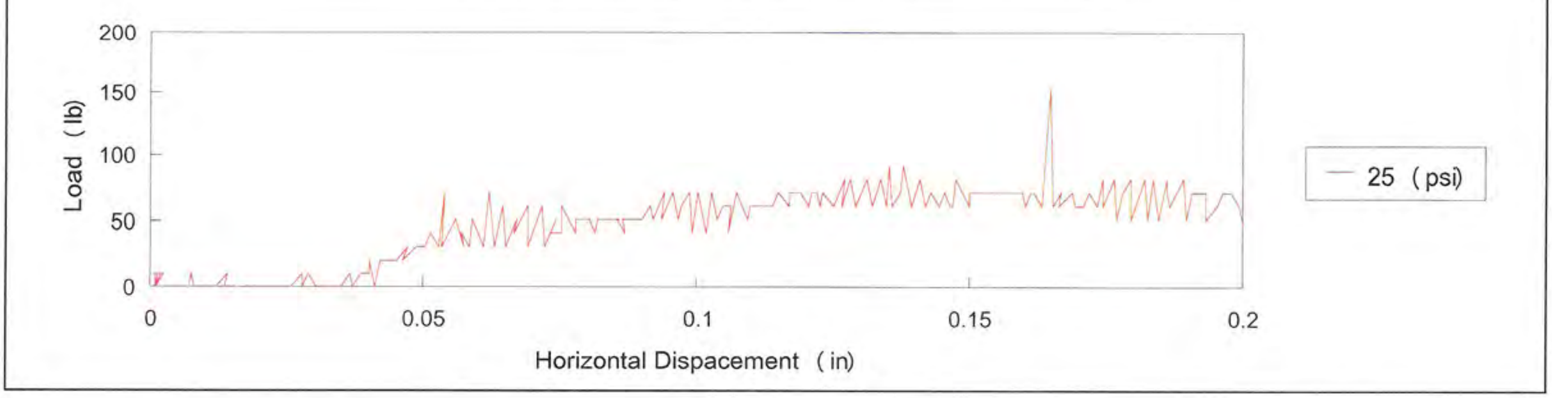


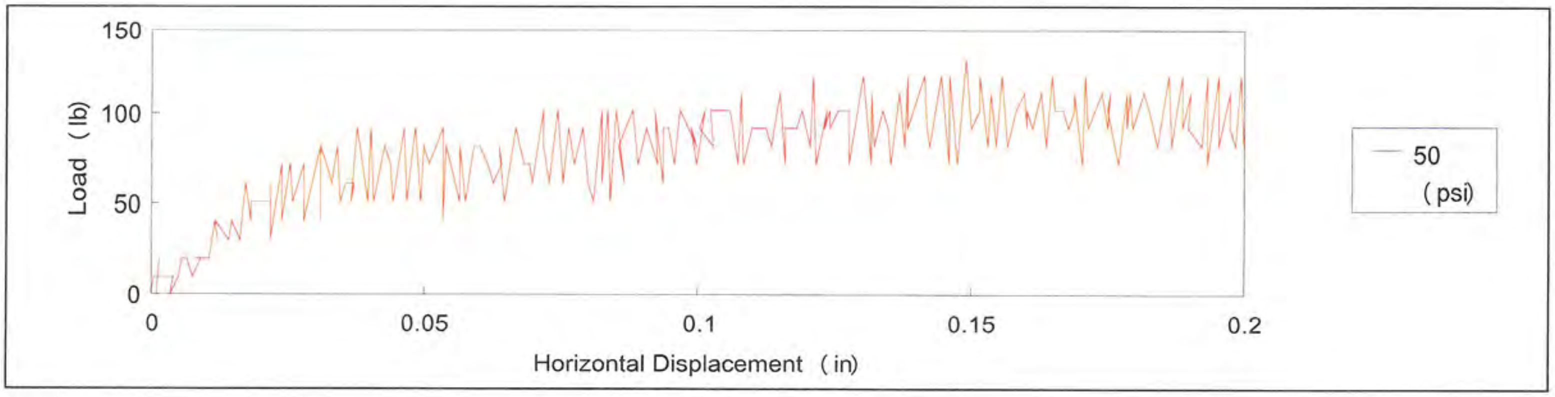
Notes and Comments: * Due to client's request, whole sample and its molds has beed soaked prior to the test in water, and also at each run water sprayed on shear area.
Uneven shear area.

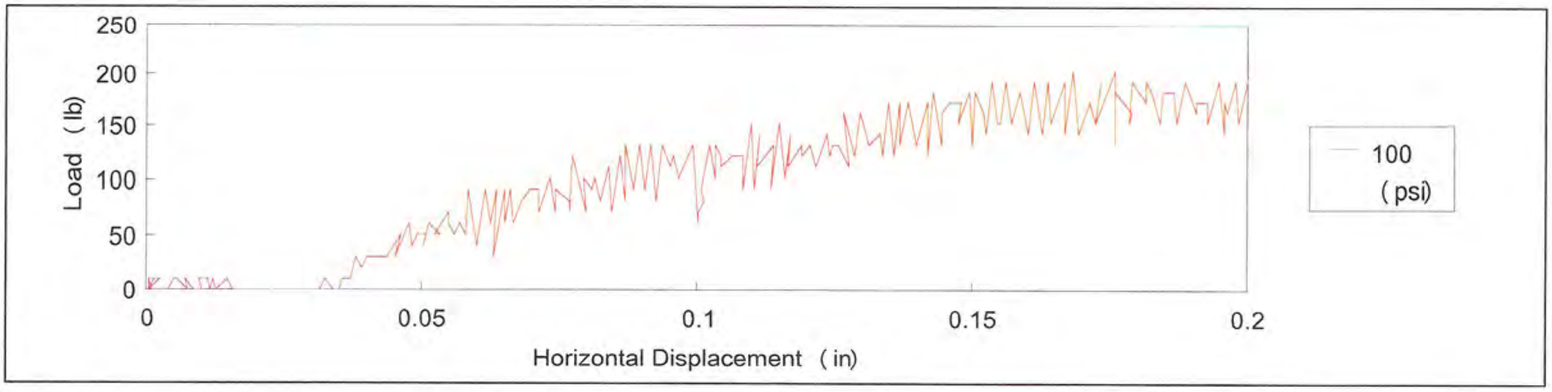
Data entered by: HN Date: 09/18/2016
Data checked by: CJ Date: 09/19/2016
File Name: DS4

Shear Load Vs. Horizontal Displacement

U-1,U-1B,6.0-7.0,Natural open fracture

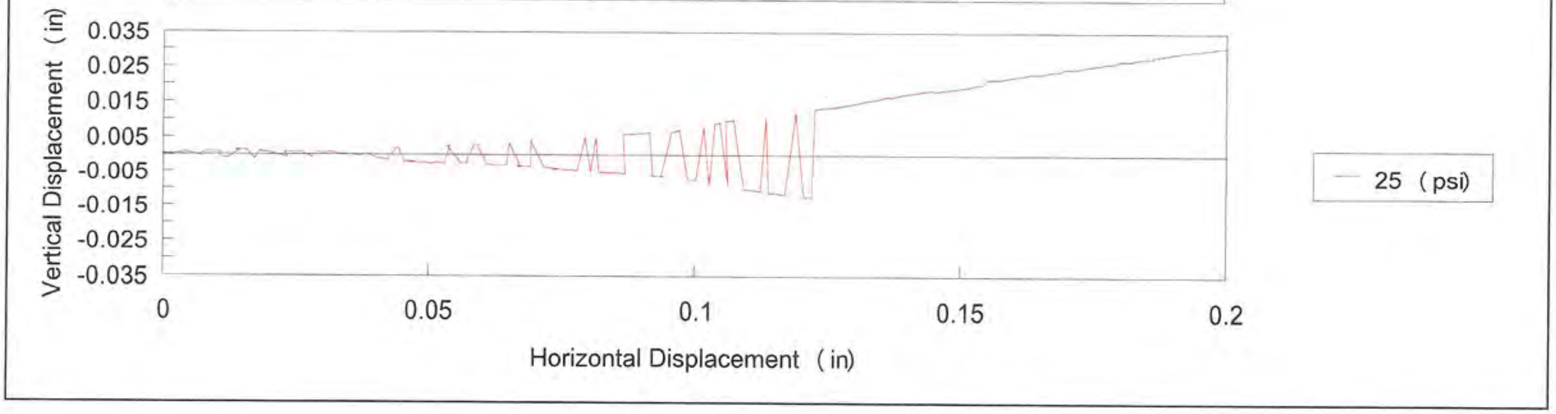


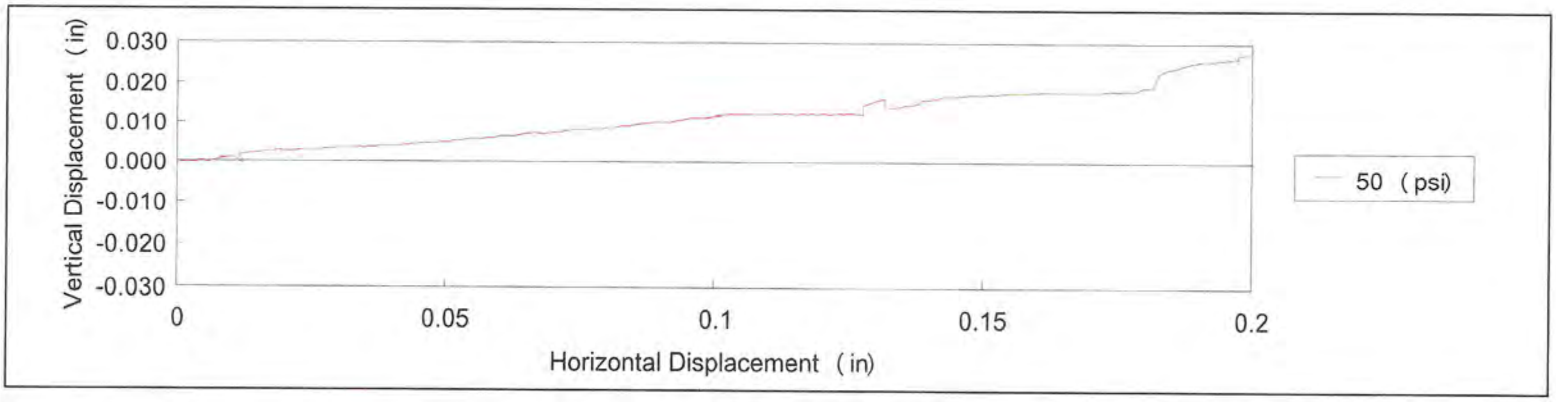


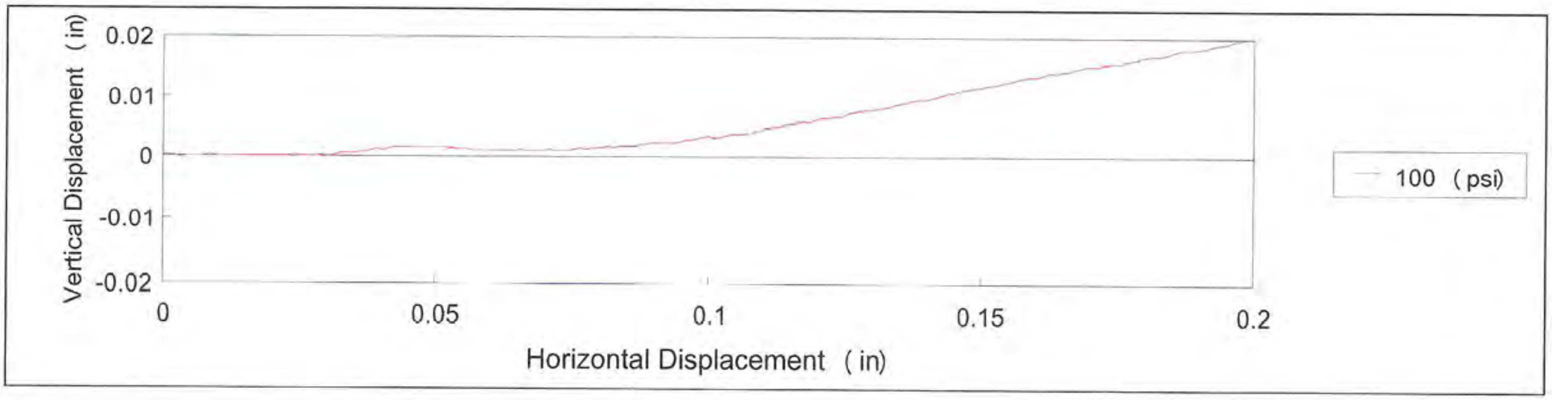


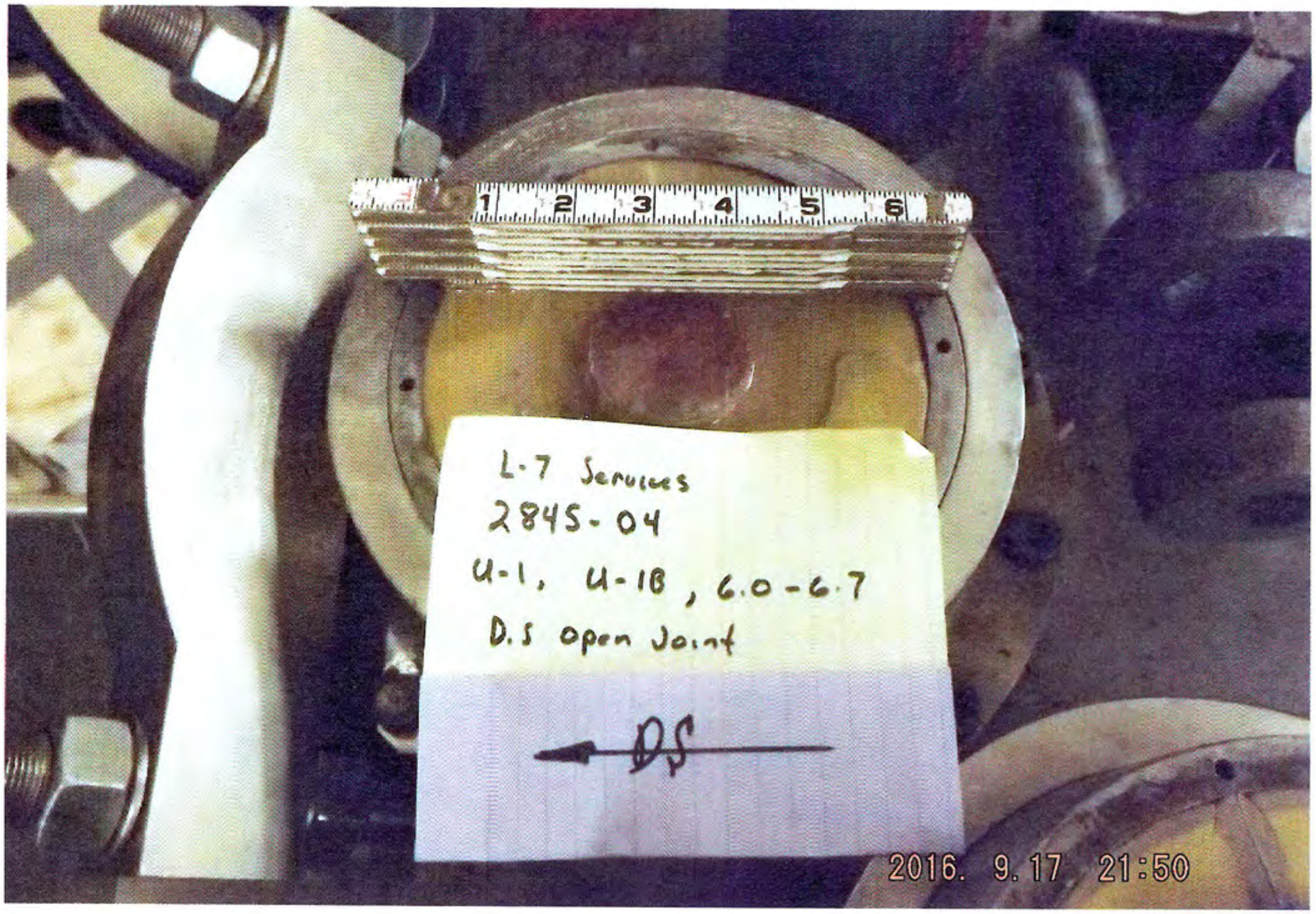
Vertical Displacement Vs. Horizontal Displacement

U-1,U-1B,6.0-7.0,Natural open fracture

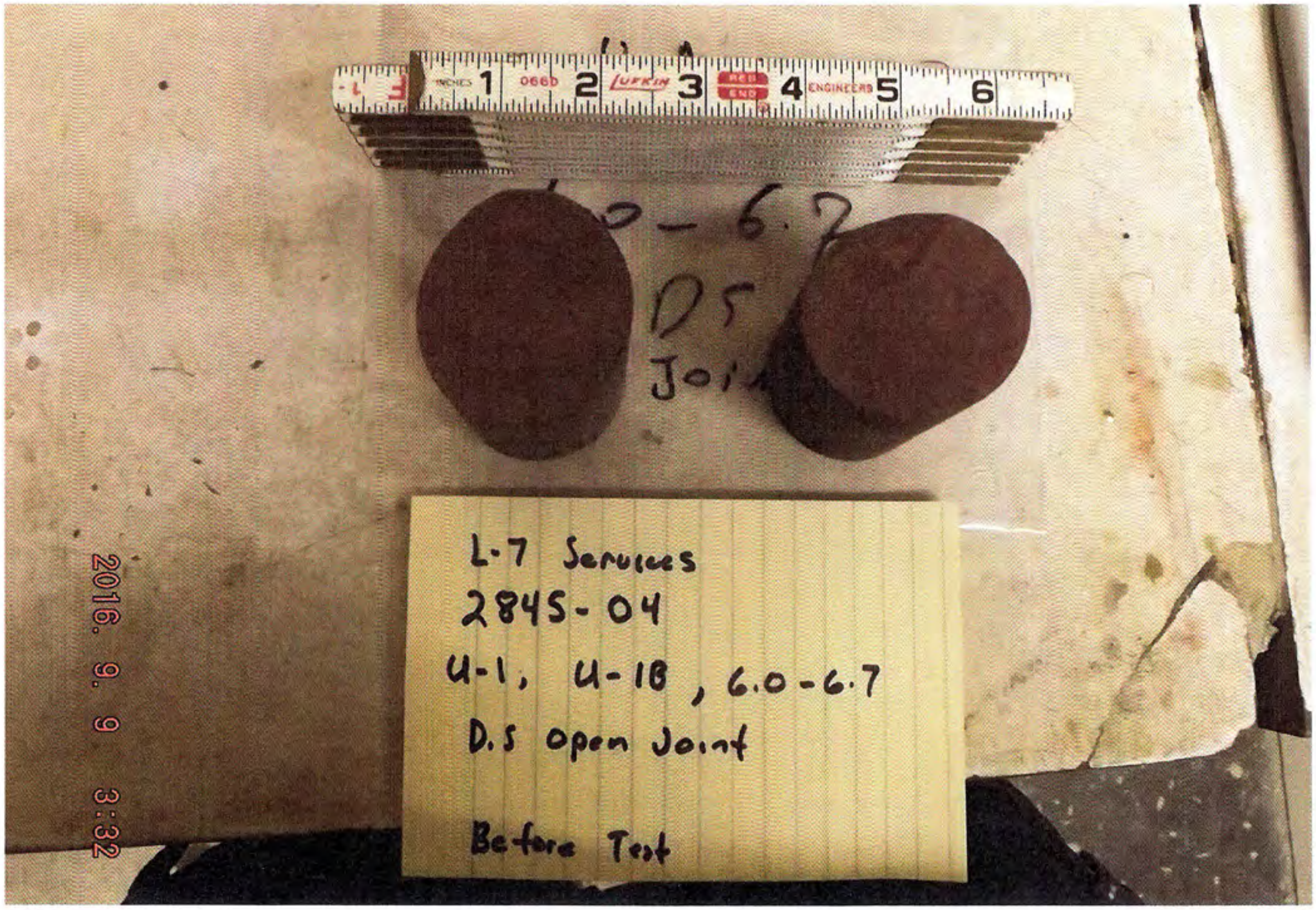








Q:\Client Data File\2845\4\PICTURE\DSCF7577



Q:\Client Data File\2845\4\PICTURE\DSCF7487

Unconfined Compressive Strength

ASTM D7012 Method C

UNCONFINED COMPRESSIVE STRENGTH
ASTM D 7012; Method C (Previously ASTM D 2938)

CLIENT: L-7 Services LLC

JOB NO.: 2845-04

LOCATION:

DATE TESTED: 9/02/16 HN

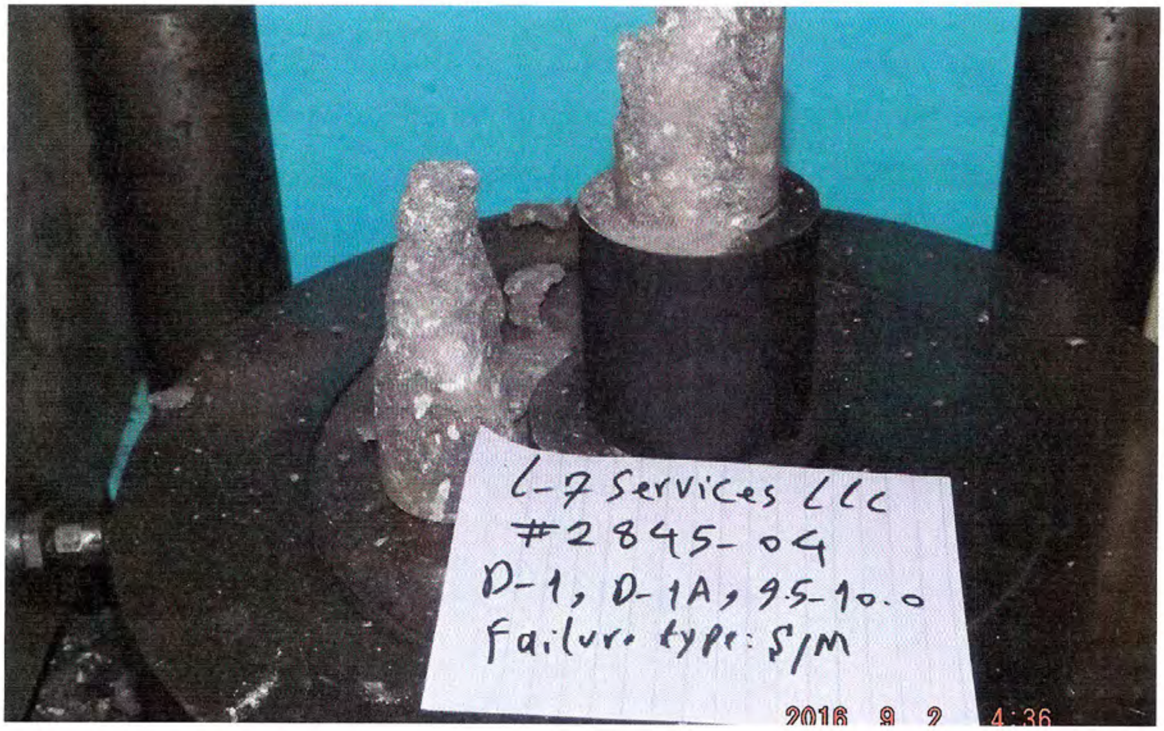
PROJECT: Idarado Mill Level

Specimen ID Boring, Sample, Depth (ft.)	Diameter (in.)	Length (in.)	Mass (gms)	Wet Density (pcf)	Failure Load (lb)	Failure Types *	Compressive Strength (psi)
D-1, D-1A, 9.5-10.0	1.990	4.144	551.9	163.1	28,493	S/M	9,160

Notes and Comments: * Failure types S: Shear Failure, M: Matrix Failure, F: Failure due to Fracture/Bedding, V: Void Failure, C: Combination

Data Entered By: HN Date: 09/02/2016
Data Checked By: Cw Date: 09/06/2016
Filename: UCS4

ADVANCED TERRA TESTING



Q:\Client Data File\2046\124\PICTURE\DSCF7475

Unconfined Compressive Strength

With Stress/Strain Measurements

ASTM D7012, Method D

UNCONFINED COMPRESSIVE STRENGTH
With Stress / Strain Measurements
ASTM D 7012, method D (previously ASTM D 3148)

CLIENT: L7 Services LLC

JOB NO.: 2845-04

LOCATION:

DATE TESTED: 9/2/16 HN

PROJECT: Idarado Mill Level

PAGE : 1 of 1

Specimen ID Boring, Sample, Depth (ft.)	Diameter (in.)	Length (in.)	Mass (gms)	Wet Density (pcf)	Failure Load (lb)	Failure Type *	Compressive Strength (psi)	Young's Modulus (X10^6 psi)	Poisson's Ratio
W-1, W-1A, 2.0-2.5	1.990	4.129	580.40	172.2	15,617	F/S	5,020	9.19	0.201
U-1, U-1A, 8.25-9.50	1.990	4.293	606.30	173.0	45,427	S/F	14,610	4.41	0.225

Notes and Comments: * Failure type

S: Shear Failure, M: Matrix Failure, F/V: Fracture, Bedding/Void Failure, C: Combination

Data Entered By: HN Date: 09/02/2016

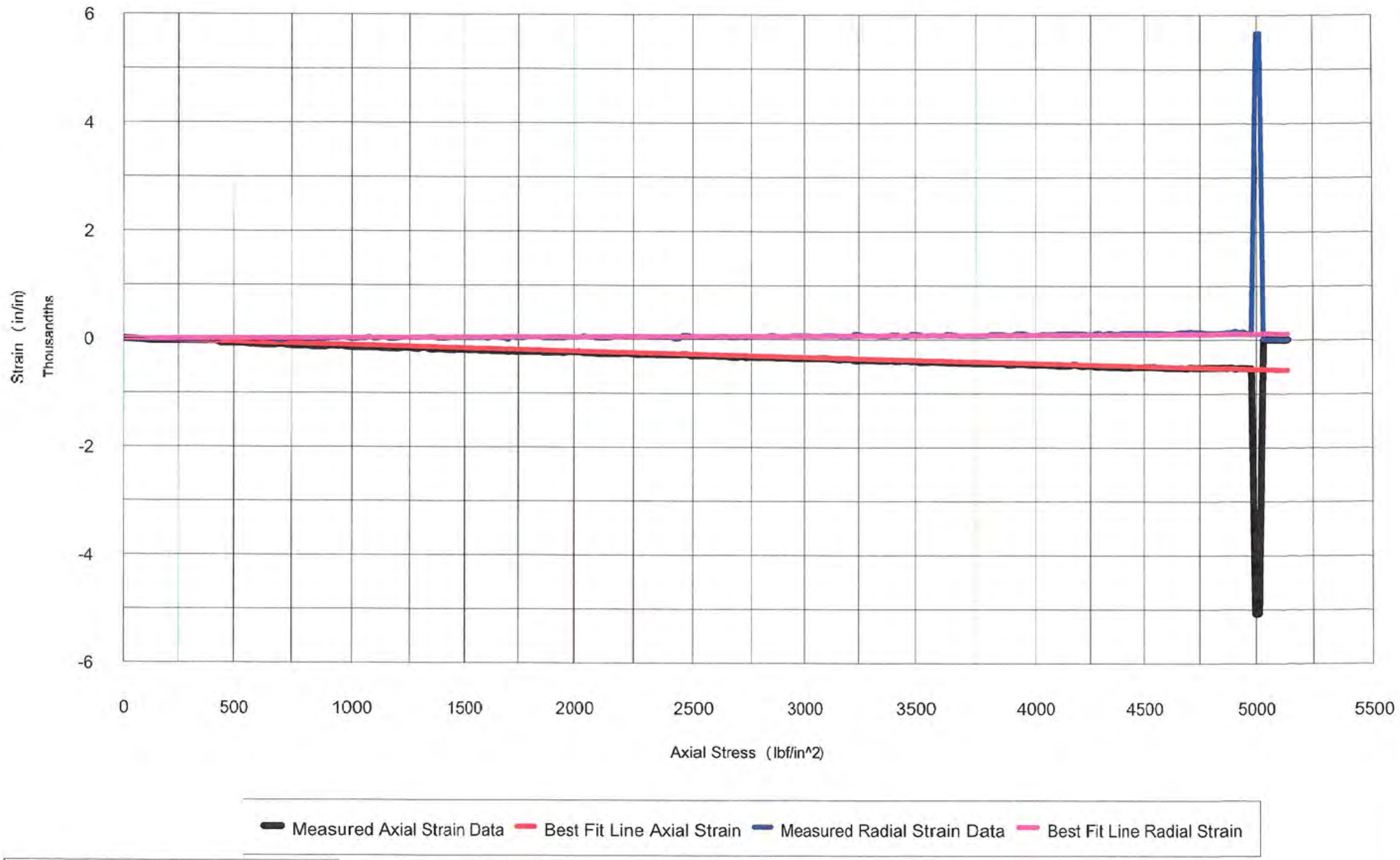
Data checked by: CJ Date: 09/06/2016

Filename: UCS-SS4

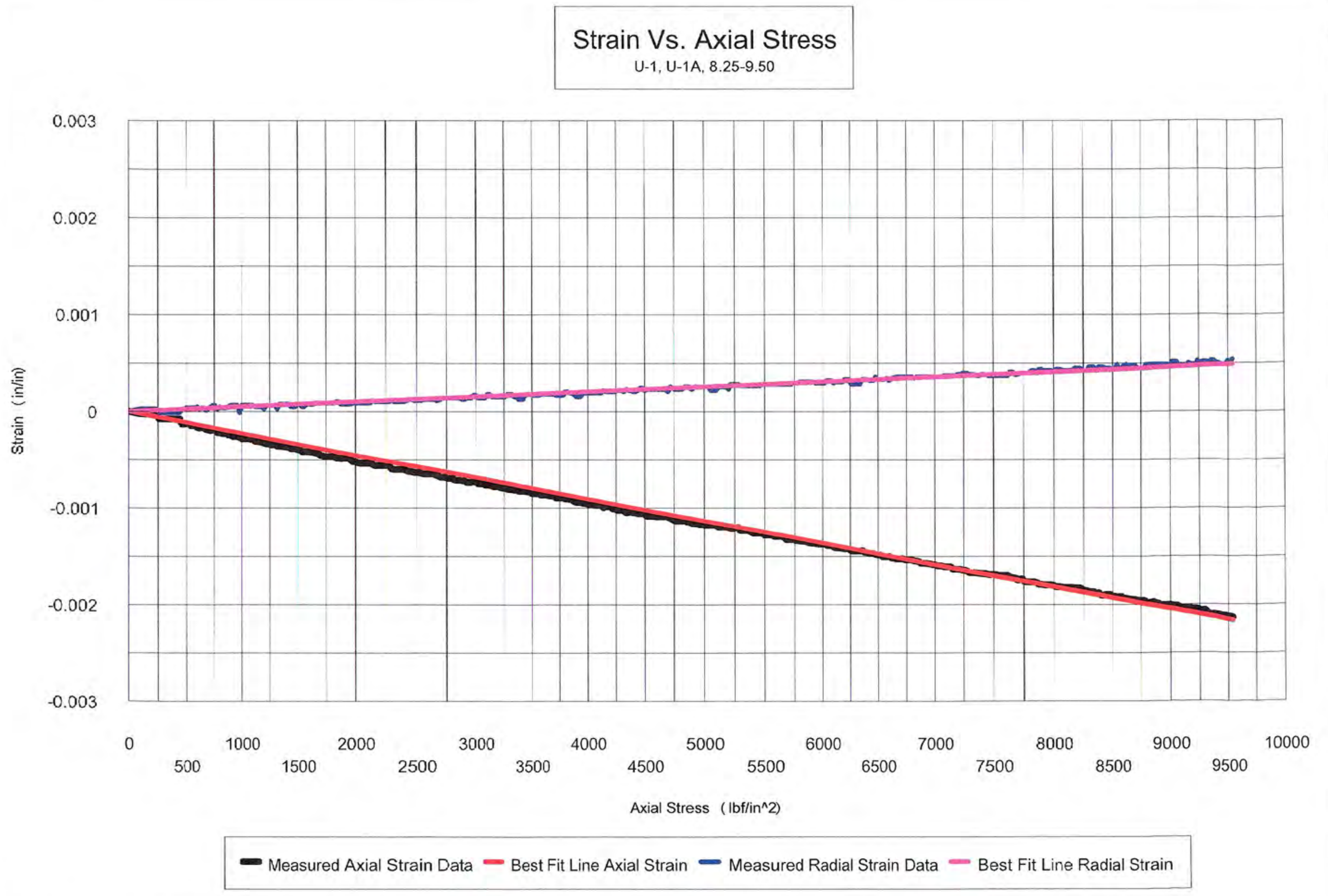
ADVANCED TERRA TESTING

Strain Vs. Axial Stress

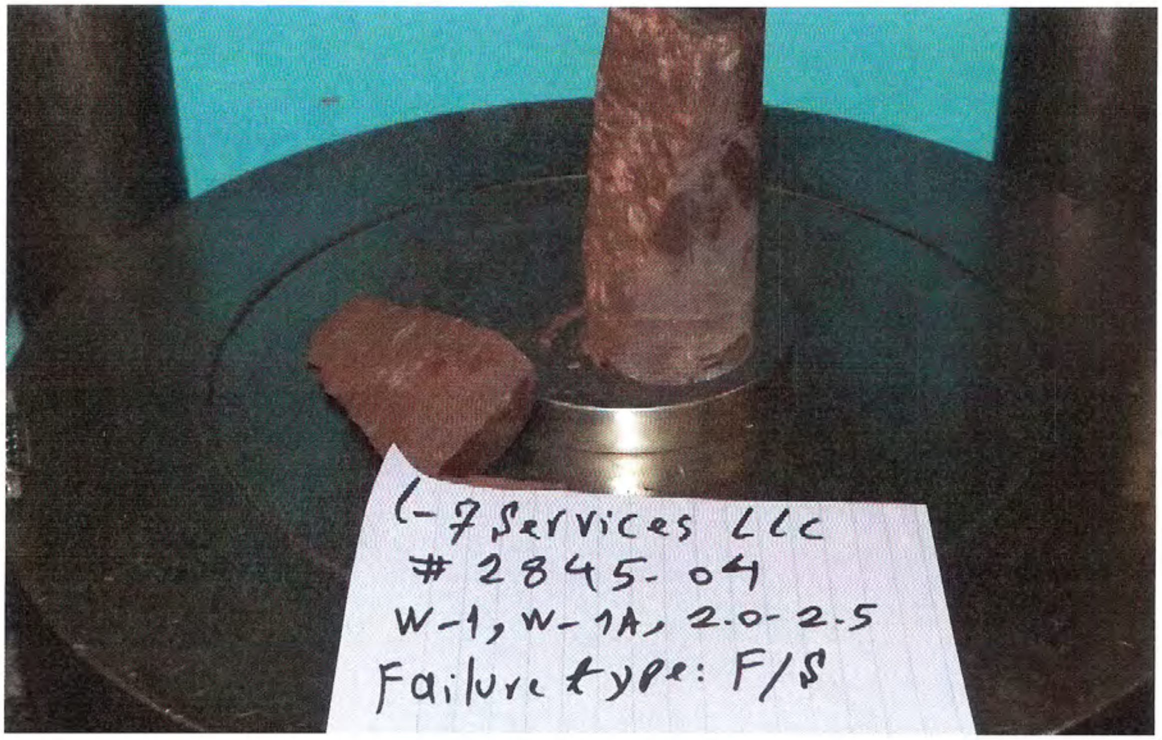
W-1, W-1A, 2.0-2.5



Young's Modulus X (10^6 psi) : 9.19
Poisson's Ratio: 0.201



Young's Modulus X (10^6 psi) : 4.41
Poisson's Ratio: 0.225



Q:\Client Data File\2046\124\PICTURE\DSCF7476

Q:\Client Data File\2046\124\PICTURE\DSCF7477

Appendix E
Rock Core Logs

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit - Station 7+32

ROCK CORE LOGGING FORM

BOREHOLE No.: W-1
Sheet 1 of 1

Drilling Company:	Drilling Rig:	Location: West Rib	Azimuth:	Flush: —	Start Date:
Drillers (day/night):	Drilling Method:	Surveyed Northing:	Inclination: Horiz.	DTW: —	Finish Date:
Drillers Helpers(day/night):	Core Diameter:	Surveyed Easting:	Casing Depth:	Water Table: —	Logged by:
Field Representitive (day/night):	Bit Type:	Surveyed Elevation:	Total Depth: 10'		

Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
0	1/1	100	83% (50")	>10		R4		SANDSTONE, fine - v. fine grained, dull red-maroon; generally massive with possible vertical laminations in core (or horiz. in ground). Matrix has visible quartz and possible mica. Weathering is fresh overall, w/ strength strong - very strong. Occasional coarse sand grains visible. No infilling along discontinuities.	1	25	J	O	—		St Ir	VR				
									2	20	J	O	—		St	R				
									3	15	J	N	—		St	R				
1				∅	W1 ↓	R5 ↓			4	10	J	N	—		W	R				
2				∅					5	0 · 90	MB								SAMPLE W-1A	
3				∅																
4				∅																
5	2/1	100 %	100% (60")	∅	W1 ↓	R5 ↓			6	0 · 5	MB									
6				1					7	85	J	VN	—		Ir	Sr				
7				1					8	10	J	VN	—		Ir Wa	Sr				
8				∅																
9				∅																
10																			— BOH. 10' —	

DISCONTINUITY TYPE
- F - Fault
- J - Joint (Discontinuity)
- Fz - Fractrue Zone
- S - Shear
- Sz - Shear Zone
- V - Vein
- Fo - Foliation
- B - Bedding Joint
- MB - Mechanical Break
- BZ - Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Fe - Iron Oxide
- Gy - Gypsum
- Py - Pyrite
- Qz - Quartz
- Sd - Sand
- No - None
- O - Other

INFILLING AMOUNT
- Clean (No)
- Stained (Su)
- Spotty (Sp)
- Partial Filled (Pa)
- Filled (Fi)
- Cemented (Cm)

SHAPE
- Wa - Wavy
- Pl - Planer
- St - Stepped
- Ir - Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	> 2 m
Wide (W)	61 cm - 2 m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	< 2 cm

WEATHERING
- Fresh (W1)
- Slightly (W2)
- Moderately (W3)
- Highly (W4)
- Decomposed or Completely (W5)
- Residual Soil (W6)

STRENGTH
- R0 Extremely weak
- R1 Very weak
- R2 Weak
- R3 Moderately strong
- R4 Strong
- R5 Very Strong
- R6 Extremely strong

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit 25Station 7+32.

ROCK CORE LOGGING FORM

BOREHOLE No.: E-1
Sheet 1 of 2:

Drilling Company:	Drilling Rig:	Location: East Rib	Azimuth:	Flush: —	Start Date:
Drillers (day/night):	Drilling Method:	Surveyed Northing:	Inclination: Horiz	DTW: —	Finish Date:
Drillers Helpers(day/night):	Core Diameter:	Surveyed Easting:	Casing Depth:	Water Table: —	Logged by:
Field Representitive (day/night):	Bit Type:	Surveyed Elevation:	Total Depth: 13'		

Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
0				>10	W3	R3		0-1" SANDSTONE - coarse, gray. dipping 15° in core. 1"- 9" as above w/ laminated bedding, slightly weathered. 9"- 25" as above w/ nearly vert. fractures & v. thin bedding 25" - 13' SANDSTONE - dull red - maroon, fine - v. fine grained, beds & laminations visible at high angle to core (so almost horiz in situ), some quartz-rich interbeds visible. no infilling in discontinuities identified.			15 15	J J				W ST	SR R				
1				3	W2	R4					65	B				ST	R				
2				2	W1	R5					55 10	J				ST	VR				
3				1							55 5-15	B/J J				ST ST	R R				
4	1/1	96%	90%	1							5	J				PL	S				
5				1							10	J				PL	SR				
6		(92")	(86")	Ø																	
7				1							10	J				Pl	SR				
8											5 40	J J	O O			Pl PL	SR SR				
9	2/2										45	J	T			PL	SR				
10											0	MB									

DISCONTINUITY TYPE
F - Fault
J - Joint (Discontinuity)
Fz - Fractrue Zone
S - Shear
Sz - Shear Zone
V - Vein
Fo - Foliation
B - Bedding Joint
MB - Mechanical Break
BZ Broken Zone

APERATURE	
Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
Cl - Clay
Ca - Calcite
Ch - Chlorite
Fe - Iron Oxide
Gy - Gypsum
Py - Pyrite
Qz - Quartz
Sd - Sand
No - None
O - Other

INFILLING AMOUNT
Clean (No)
Stained (Su)
Spotty (Sp)
Partial Filled (Pa)
Filled (Fi)
Cemented (Cm)

SHAPE
Wa - Wavy
Pl - Planer
St - Stepped
Ir - Irregular

ROUGHNESS	
Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING	
Extremely Wide (EW)	>2m
Wide (W)	61 cm - 2m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	<2 cm

WEATHERING
Fresh (W1)
Slightly (W2)
Moderately (W3)
Highly (W4)
Decomposed or Completely (W5)
Residual Soil (W6)

STRENGTH
R0 Extremely weak
R1 Very weak
R2 Weak
R3 Moderately strong
R4 Strong
R5 Very Strong
R6 Extremely strong

Client: Newmont Mining & Environmental Services Task: Idarado Mine Bulkhead Project Location: Mill Level Adit ~ Station 7+32	**ROCK CORE LOGGING FORM**	BOREHOLE No.: E-1 Sheet 2 of 2

Drilling Company:	Drilling Rig:	Location: East Rib	Azimuth:	Flush: ~	Start Date:
Drillers (day/night):	Drilling Method:	Surveyed Northing:	Inclination: Horiz.	DTW: —	Finish Date:
Drillers Helpers(day/night):	Core Diameter:	Surveyed Easting:	Casing Depth:	Water Table: ~	Logged by:
Field Representitive (day/night):	Bit Type:	Surveyed Elevation:	Total Depth: 13'		

Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	DISCONTINUITY DATA Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
10								Cont - SANDSTONE - As above -													
11	2/2	100% (60")	100% (60")																		
12												MB									
											5	MB?									
13								BOH 13'													
14																					
15																					
16																					
17																					
18																					
19																					
20																					

DISCONTINUITY TYPE

F	- Fault
J	- Joint (Discontinuity)
Fz	- Fractrue Zone
S	- Shear
Sz	- Shear Zone
V	- Vein
Fo	- Foliation
B	- Bedding Joint
MB	- Mechanical Break
BZ	- Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE

Cl	- Clay
Ca	- Calcite
Ch	- Chlorite
Fe	- Iron Oxide
Gy	- Gypsum
Py	- Pyrite
Qz	- Quartz
Sd	- Sand
No	- None
O	- Other

INFILLING AMOUNT

Clean (No)
Stained (Su)
Spotty (Sp)
Partial Filled (Pa)
Filled (Fl)
Cemented (Cm)

SHAPE

Wa	- Wavy
Pl	- Planer
St	- Stepped
Ir	- Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	>2m
Wide (W)	61 cm - 2m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	< 2 cm

WEATHERING

Fresh (W1)
Slightly (W2)
Moderately (W3)
Highly (W4)
Decomposed or Completely (W5)
Residual Soil (W6)

STRENGTH

R0 Extremely weak
R1 Very weak
R2 Weak
R3 Moderately strong
R4 Strong
R5 Very Strong
R6 Extremely strong

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit ~ Station 7+32

ROCK CORE LOGGING FORM

BOREHOLE No.: U-1
Sheet 1 of 2

Drilling Company:	Drilling Rig:	Location: Back	Azimuth:	Flush: –	Start Date:
Drillers (day/night):	Drilling Method:	Surveyed Northing:	Inclination: 14° off Hor	DTW: –	Finish Date:
Drillers Helpers(day/night):	Core Diameter:	Surveyed Easting:	Casing Depth:	Water Table: –	Logged by:
Field Representitive (day/night):	Bit Type:	Surveyed Elevation:	Total Depth: 13'		

Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
0				5	W1 ↓	RS ↓		SANDSTONE - dull red-maroon, v.fine - fine grained, occassionally alt. beds w/ fine-med grained, generally dipping approx 10-15° in core (generally flatlying in situ ?). Quartz and mica visible in matrix. weathering is fresh, strength is strong - very strong. No infilling along discon. visible.		1	15	J	O			W	Se				
										2	25	J	O			W	R				
1				Ø																	
2	1/1	100% (60")	92% (55")	Ø																	
3				2						3	5	J	W			St	R				
										4	5	J	N			W	R				
4				1						5	10	J	W			St	R				
5				1	W1 ↓	RS ↓				6		MB				W	R				
6				1						7	10	J	N			W	R			SAMPLE U-1B	
7	2/1	100% (60")	94% (565")	2						8	•	MB									
										9	10	J	N		–	St	R				
8				Ø																	
9										10	10	J	O		–	W	Se			SAMPLE U-1A	
										11	10	J	O		–	W	Se				
10																					

DISCONTINUITY TYPE
F - Fault
J - Joint (Discontinuity)
Fz - Fractrue Zone
S - Shear
Sz - Shear Zone
V Vein
Fo - Foliation
B - Bedding Joint
MB - Mechanical Break
BZ - Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
Cl - Clay
Ca - Calcite
Ch - Chlorite
Fe - Iron Oxide
Gy - Gypsum
Py - Pyrite
Qz - Quartz
Sd - Sand
No - None
O - Other

INFILLING AMOUNT
Clean (No)
Stained (Su)
Spotty (Sp)
Partial Filled (Pa)
Filled (Fi)
Cemented (Cm)

SHAPE
Wa - Wavy
Pl - Planer
St - Stepped
Ir - Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	>2m
Wide (W)	61 cm - 2m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	<2 cm

WEATHERING
Fresh (W1)
Slightly (W2)
Moderately (W3)
Highly (W4)
Decomposed or Completely (W5)
Residual Soil (W6)

STRENGTH
R0 Extremely weak
R1 Very weak
R2 Weak
R3 Moderately strong
R4 Strong
R5 Very Strong
R6 Extremely strong

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit ~Station 7+32

ROCK CORE LOGGING FORM

BOREHOLE No.: U-1
Sheet 2 of 2 :

Drilling Company:
Drillers (day/night):
Drillers Helpers(day/night):
Field Representitive (day/night):
Drilling Rig:
Drilling Method:
Core Diameter:
Bit Type:
Location: Back
Surveyed Northing:
Surveyed Easting:
Surveyed Elevation:
Azimuth:
Inclination: 74 off Hor
Casing Depth:
Total Depth: 13'
Flush:
DTW:
Water Table:
Start Date:
Finish Date:
Logged by:

									DISCONTINUITY DATA												
Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
10				Ø	W1 ↓	R5 ↓		Cont - SANDSTONE - as above w/ alt. v fine & fine beds dipping 10-15° in core except occasional siltstone interbeds, thin and dipping w/ sandstone beds.													
11	3/2	100%	93%	3						12 13 14	10 15	J J J	0 0 6			ST PL PL	SR S S				
12		(42")	(39")	Ø																	
13								BOH 13'													
14																					
15																					
16																					
17																					
18																					
19																					
20																					

DISCONTINUITY TYPE
F - Fault
J - Joint (Discontinuity)
Fz - Fractrue Zone
S - Shear
Sz - Shear Zone
V - Vein
Fo - Foliation
B - Bedding Joint
MB - Mechanical Break
BZ - Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
Cl - Clay
Ca - Calcite
Ch - Chlorite
Fe - Iron Oxide
Gy - Gypsum
Py - Pyrite
Qz - Quartz
Sd - Sand
No - None
O - Other

INFILLING AMOUNT
Clean (No)
Stained (Su)
Spotty (Sp)
Partial Filled (Pa)
Filled (Fi)
Cemented (Cm)

SHAPE
Wa - Wavy
Pl - Planer
St - Stepped
Ir - Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperitics are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	>2m
Wide (W)	61 cm - 2m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	<2 cm

WEATHERING
Fresh (W1)
Slightly (W2)
Moderately (W3)
Highly (W4)
Decomposed or Completely (W5)
Residual Soil (W6)

STRENGTH
R0 Extremely weak
R1 Very weak
R2 Weak
R3 Moderately strong
R4 Strong
R5 Very Strong
R6 Extremely strong

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit ~ Station 7+32

ROCK CORE LOGGING FORM

BOREHOLE No.: D-1
Sheet 1 of 2

Drilling Company:	Drilling Rig:	Location: Invert	Azimuth:	Flush: —
Drillers (day/night):	Drilling Method:	Surveyed Northing:	Inclination: 69.5 off [illegible]	DTW: —
Drillers Helpers(day/night):	Core Diameter:	Surveyed Easting:	Casing Depth:	Water Table: —
Field Representitive (day/night):	Bit Type:	Surveyed Elevation:	Total Depth: 13'	
Start Date:	Finish Date:	Logged by:		

Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
0					W2	R4		- 2" wood 2"-6" SANDSTONE Slightly weath strong													
				5 10	W1	R5		SANDSTONE - dull red, gray & maroon interbeds, coarsends from v. fine to fine at 1' depth, w/ salt & pepper appear. of bedding due to quartz layers.													
1	1/1	100% (36")	58% (21")	3							20 5	J J				ST W	R R				
2											10	J				ST	R				
				1							10	J				W	SR				
3				Ø	W1	R5		3'11" grades to medium grained SANDSTONE laminated to bedded 0-5° dip in core													
4				Ø																	
5				Ø																	
6	2/1	100% (60")	100% (60")	0																	
7				1							10	J				W	SR				
8	3/1	100% (60")	100% (60")	Ø	W1	R5		8'6"-9'2" bed - SANDSTONE. coarse quartz rich bed, dipping approx 10° in core. contact is clear and abrupt.													
9				Ø				9'2"-11'5" SANDSTONE w/ quartz breccia., bedded cont												SAMPLE D-1A	
10																					

DISCONTINUITY TYPE
- F - Fault
- J - Joint (Discontinuity)
- Fz - Fractrue Zone
- S - Shear
- Sz - Shear Zone
- V - Vein
- Fo - Foliation
- B - Bedding Joint
- MB - Mechanical Break
- BZ - Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Fe - Iron Oxide
- Gy - Gypsum
- Py - Pyrite
- Qz - Quartz
- Sd - Sand
- No - None
- O - Other

INFILLING AMOUNT
- Clean (No)
- Stained (Su)
- Spotty (Sp)
- Partial Filled (Pa)
- Filled (Fi)
- Cemented (Cm)

SHAPE
- Wa - Wavy
- Pl - Planer
- St - Stepped
- Ir - Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	>2 m
Wide (W)	61 cm - 2 m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	<2 cm

WEATHERING
- Fresh (W1)
- Slightly (W2)
- Moderately (W3)
- Highly (W4)
- Decomposed or Completely (W5)
- Residual Soil (W6)

STRENGTH
- R0 Extremely weak
- R1 Very weak
- R2 Weak
- R3 Moderately strong
- R4 Strong
- R5 Very Strong
- R6 Extremely strong

Client: Newmont Mining & Environmental Services
Task: Idarado Mine Bulkhead
Project Location: Mill Level Adit ~Station 7+32

ROCK CORE LOGGING FORM

BOREHOLE No.: D-1
Sheet 2 of 2 :

Drilling Company:
Drillers (day/night):
Drillers Helpers(day/night):
Field Representitive (day/night):

Drilling Rig:
Drilling Method:
Core Diameter:
Bit Type:

Location: invert
Surveyed Northing:
Surveyed Easting:
Surveyed Elevation:

Azimuth:
Inclination: 69.5° off horiz.
Casing Depth:
Total Depth: 13'

Flush:
DTW:
Water Table:

Start Date:
Finish Date:
Logged by:

									DISCONTINUITY DATA												
Depth / Elevation	Run/Box Number	Recovery (%)	RQD (%)	Fracture / ft	Weathering Index	Strength Index	Lithology / Symbol	Description	Graphic	Disc. Number	Dip / Core Axis	Type of Disc.	Width	Type of Infilling	Amount of Infilling	Surface Shape	Roughness	Spacing	Permiability	Remarks	Well Details
10	3/2	100% (60")	100% (60")	Ø	W1 ↓	R5 ↓		cont - 9'2" - 11'5" - SANDSTONE w/ quartz breccia pieces in matrix, beds dip approx 10-15° in core													
11				Ø				11'5" - 12'8" - SANDSTONE - coarse - very coarse angular clasts													
12				Ø				12'8" - BOH - SANDSTONE med grained, finely bedded dipping 15-20° in core.													
13								BOH 13'													
14																					
15																					
16																					
17																					
18																					
19																					
20																					

DISCONTINUITY TYPE
F - Fault
J - Joint (Discontinuity)
Fz - Fractrue Zone
S - Shear
Sz - Shear Zone
V - Vein
Fo - Foliation
B - Bedding Joint
MB - Mechanical Break
BZ - Broken Zone

APERATURE

Tight (T)	0
Very Narrow (Vn)	<1.3 mm (<0.05")
Narrow (N)	1.3 - 2.5 mm (0.05 - 0.1")
Open (O)	2.5 - 12.7 mm (0.1 - 0.5")
Wide (W)	>12.7 mm (>0.5")

INFILLING TYPE
Cl - Clay
Ca - Calcite
Ch - Chlorite
Fe - Iron Oxide
Gy - Gypsum
Py - Pyrite
Qz - Quartz
Sd - Sand
No - None
O - Other

INFILLING AMOUNT
Clean (No)
Stained (Su)
Spotty (Sp)
Partial Filled (Pa)
Filled (Fi)
Cemented (Cm)

SHAPE
Wa - Wavy
Pl - Planer
St - Stepped
Ir - Irregular

ROUGHNESS

Slickensided (Slk)	Visual evidence of polishing, striations
Smooth (S)	Surface appears and feels smooth
Slightly rough (Sr)	Asperities are distinguishable and can be felt
Rough (R)	Asperities are clearly visible, some ridges evident, suface feels abrasive
Very rough (Vr)	Near-vertical ridges occur on surface

DISCONTINUITY SPACING

Extremely Wide (EW)	> 2 m
Wide (W)	61 cm - 2 m
Moderate (M)	21 - 60 cm
Close (C)	6 - 21 cm
Very Close (VC)	2 - 6 cm
Extremely Close (Ex)	< 2 cm

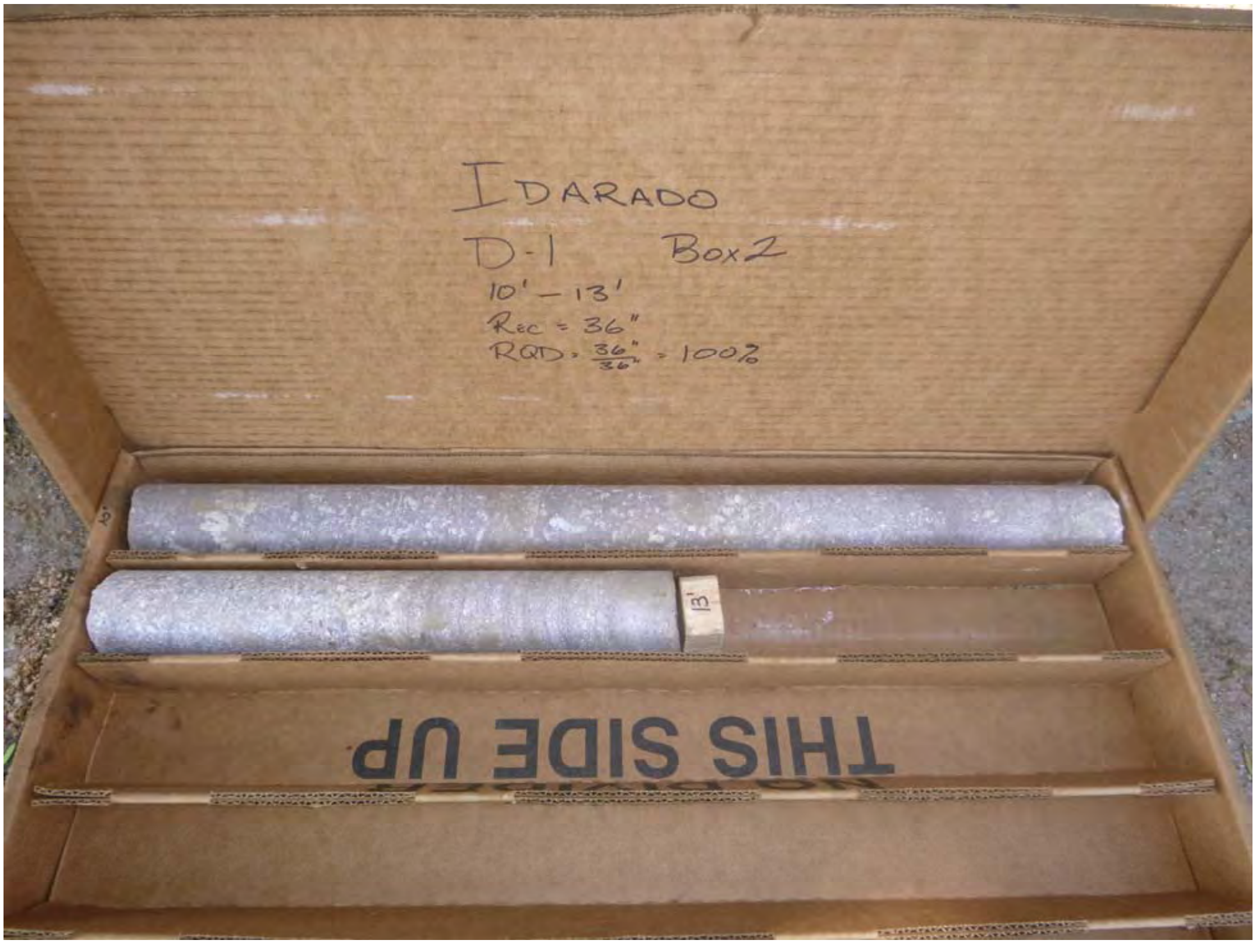
WEATHERING
Fresh (W1)
Slightly (W2)
Moderately (W3)
Highly (W4)
Decomposed or Completely (W5)
Residual Soil (W6)

STRENGTH
R0 Extremely weak
R1 Very weak
R2 Weak
R3 Moderately strong
R4 Strong
R5 Very Strong
R6 Extremely strong

Appendix F
Rock Core Photos


W-1 Box 1
0' — 10'
Recovery = 120"
RQD = 110"/120" = 92%
HQ DIVIDER


IDARADO
D-1 0'-10' θ=69.5°
Rec = 120"
RQD = 104"/120" = 87%
8'
10'


IDARADO
D-1 Box2
10'–13'
Rec = 36"
RQD = 36"/36" = 100%
13'
THIS SIDE UP


IDARADO
E-1 Box 1
0'–8'
Rec = 96"
RQD = 86"/96" = 90%
8'


IDARADO
E-1 Box 2
8' - 13'
Rec = 60"
RQD = 60"/60" = 100%
THIS SIDE UP
13'


IDARADO
U-1 Box 1
0' - 9.5' θ = 74°
Rec = ~~120"~~ 114"
RQD = 112"/114" = 98%
5'
WWW.COREBOX.COM


IDARADO
U-1 Box 2 θ = 74°
9.5' - 13'
Rec = 42'
RQD = 39"/42" = 93%
9.5'
10'
13'
HQ DIVIDER


U-1B
U-1

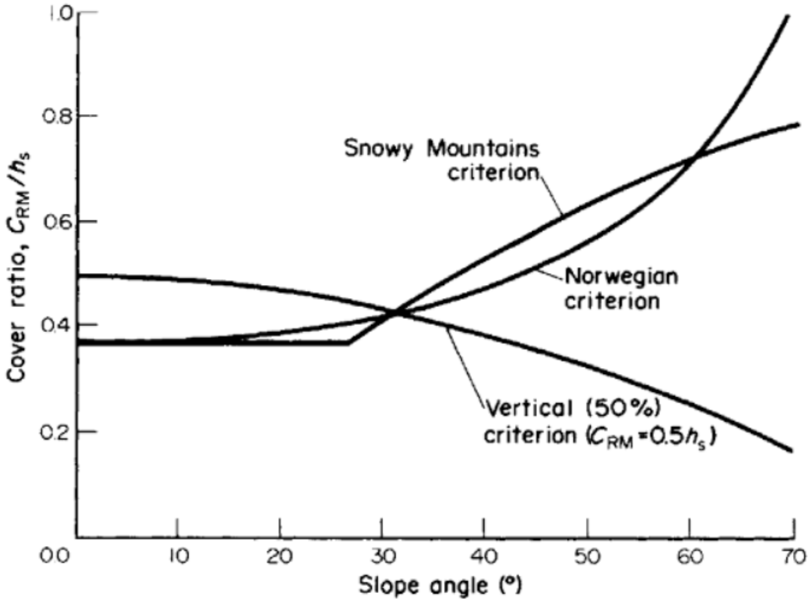
Appendix G
Lateral Confinement Evaluation and Bulkhead Preliminary Design Calculations

Overview:

During a 2017 site visit, concerns were expressed about the proximity of the Marshall Creek ravine to the Mill Level adit and the potential for lateral hydrojacking. Lateral confinement was checked utilizing the Snowy Mountain Confinement criteria for unlined pressure tunnels with a safety factor 1.3.

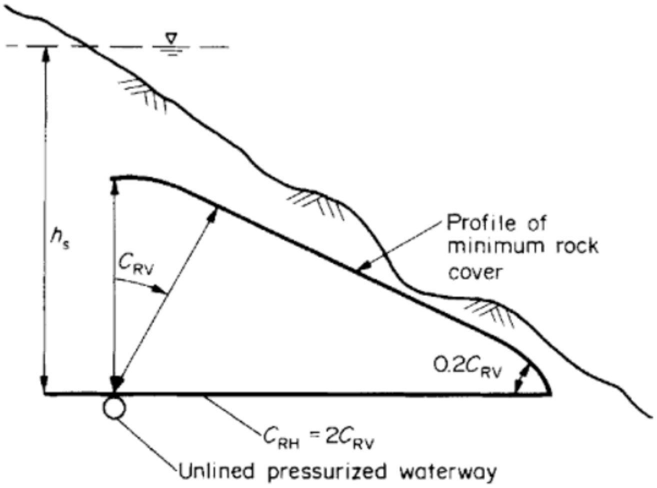
Lateral Confinement Evaluation:

The Snowy Mountain criteria provided a rational basis for rock cover regardless of the position of the tunnel relative to the ravine and the inclination of the slopes. It was noted that the common Norwegian Rock Cover Criteria for unlined pressure tunnels tends to diverge for steep slopes (slope angles in excess of 70 degrees) and provide unrealistic rock cover requirements (approaches infinity for vertical rock slopes). A comparison of the Snowy Mountain criteria and the Norwegian Rock Cover criterial is presented in Brekke and Ripley's paper *Design of Pressure Tunnels and Shafts* (1993) shown below. The other advantage that the Snowy Mountain Criteria provides is that the minimum rock cover limits are presented relative to the adit itself, rather than tied to the slope angle. The Mill Level adit presents an unusual scenario for the Norwegian criteria since the adit at the bulkhead location is located below the bottom of the ravine and laterally there is continuous rock present and the steep slopes do not create a direct perpendicular path to the adit as presented in the criteria. Attempts to apply the Norwegian Criteria with adjustments for the decreased hydrostatic head with increased elevation were unsuccessful due to the steep slope angles present (greater than 70 degrees).



Comparison of vertical, Snowy Mountains and Norwegian criteria for sloping topography

Figure 1: Comparison of Snowy Mountain and Norwegian Rock Cover Criteria with Increase Slope Angle (per Brekke & Ripley 1993)



Snowy Mountains criterion for confinement. C_{RV} = vertical rock cover (= $h_S\gamma_w/\gamma_R$), C_{RH} = horizontal rock cover, h_S = static head, γ_W = unit weight of water, γ_R = unit of weight of rock

Figure 2: Snowy Mountain Rock Cover Criteria (per Brekke & Ripley 1993)

By providing a minimum lateral confinement distance of $2C_{RV}$, the Snowy Mountain criteria basically indicates that no special lateral provisions are needed for slope angles less than 26 degrees (relative to horizontal) beyond the necessary vertical rock confinement at the tunnel location. For slopes steeper than 26 degrees, a lateral confinement of twice the minimum vertical confinement should be provided to achieve a safety factor 1.0. Following the recommendations for the Norwegian criteria, a safety factor of 1.3 has been applied to provide additional confinement to resist hydrojacking of the rock.

The detailed topographic data collected by the recent drone survey has been utilized to identify the critical slope orientations and to represent the surface topography. Critical cross-sections corresponding to the steepest overall slopes have been identified and cross-sections developed. The cut lines for these cross-sections are shown below for both the original bulkhead target location (Sta. 7+32; Critical Cross Section A) and for a revised bulkhead location at approximately Sta. 9+75 (Critical Cross Sections B and C).

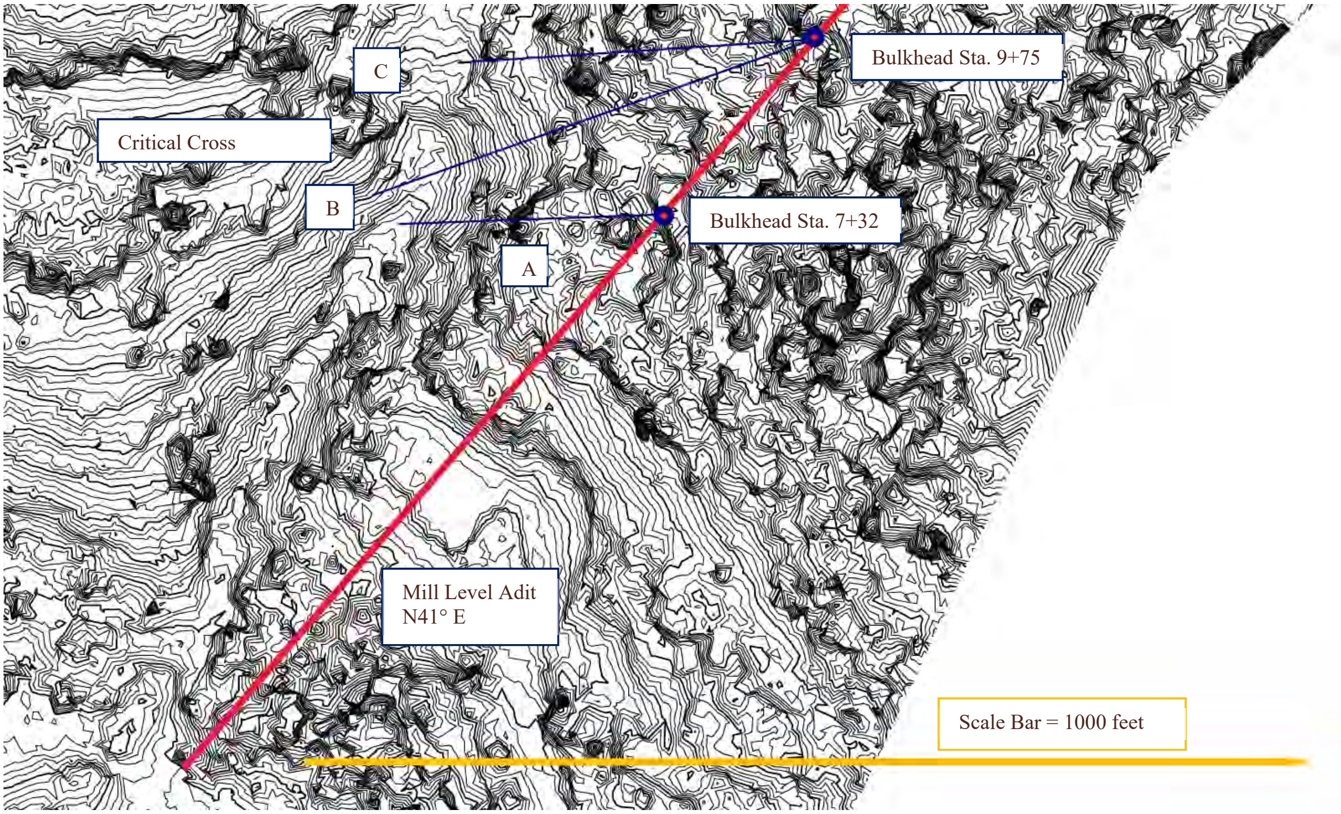


Figure 3: Detailed Topographic Map with Critical Section Cuts (modified from DragonFly Topo (2017))

Topographic data points utilized to develop the three critical cross sections are as follows:

Cross Section A		Cross Section B		Cross Section C	
Distance (ft)	**Elevation (ft)**	**Distance (ft)**	**Elevation (ft)**	**Distance (ft)**	**Elevation (ft)**
0 (adit)	9720	0 (adit)	10,050	0	10,050
17	9700	21	10,050	337	9550
50	9700	32	10,000	375 (crk)	9530
142	9650	67	9950	425	9550
150	9600	112	9900		
167	9550	158	9850		
181	9500	205	9800		
196	9450	225	9750		
225	9400	242	9700		
246	9350	258	9650		
270 (crk)	9320	292	9600		
296	9350	317	9550		
		342	9500		
		365	9450		
		380	9400		
		425 (crk)	9370		
		475	9400		

The Mill Level Adit has a listed invert elevation of 9062 at the portal and has been represented as a 10’x10’ adit with a slope of 0.005 (Inv. El = 9065.7 at Sta. 7+32; Inv. El. = 9066.9 at Sta. 9+75). The full 900 vertical feet of potential hydrostatic head was utilized for the lateral rock confinement calculations. Per the Snowy Mountain Criteria shown in Figure 2 (above):

Vertical Rock Cover: $C_{RV} = H_s(\gamma_w)/(\gamma_r) = (900vf)(62.4\ pcf)/(160\ pcf) = 351$ feet (safety factor 1.0)
$C_{RV} = (1.3)(351\ ft) = 456.3$ feet (w/ SF=1.3)

Horizontal Rock Cover: $C_{RH} = 2C_{RV} = 2(351\ feet) = 702$ feet (safety factor 1.0)
$C_{RH} = 1.3(702\ ft) = 912.6$ feet (w/ SF=1.3)

At Sta. 7+32 where the bulkhead was initially sited, the updated topography indicates that a safety factor close to 1.0 is achieved with the Snowy Mountain criteria. To provide the desired 1.3 safety factor, the bulkhead needs to be located at approximately Sta. 9+75 or further inby.

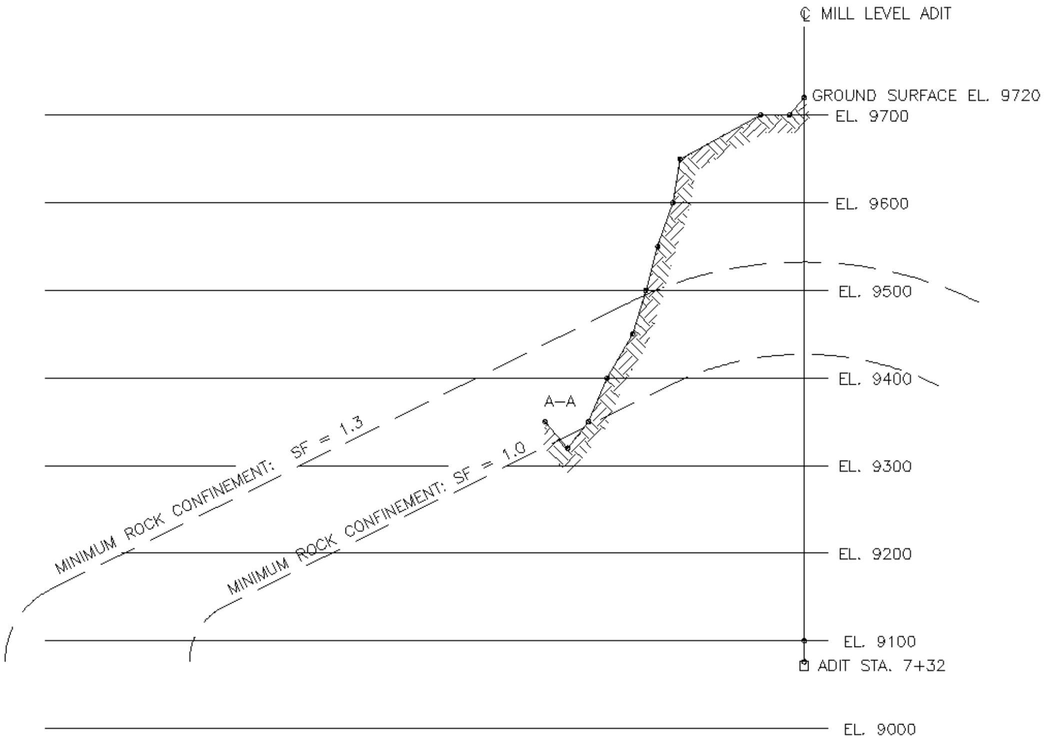


Figure 4: Snowy Mountain Rock Confinement Criteria for Bulkhead at Sta. 7+32

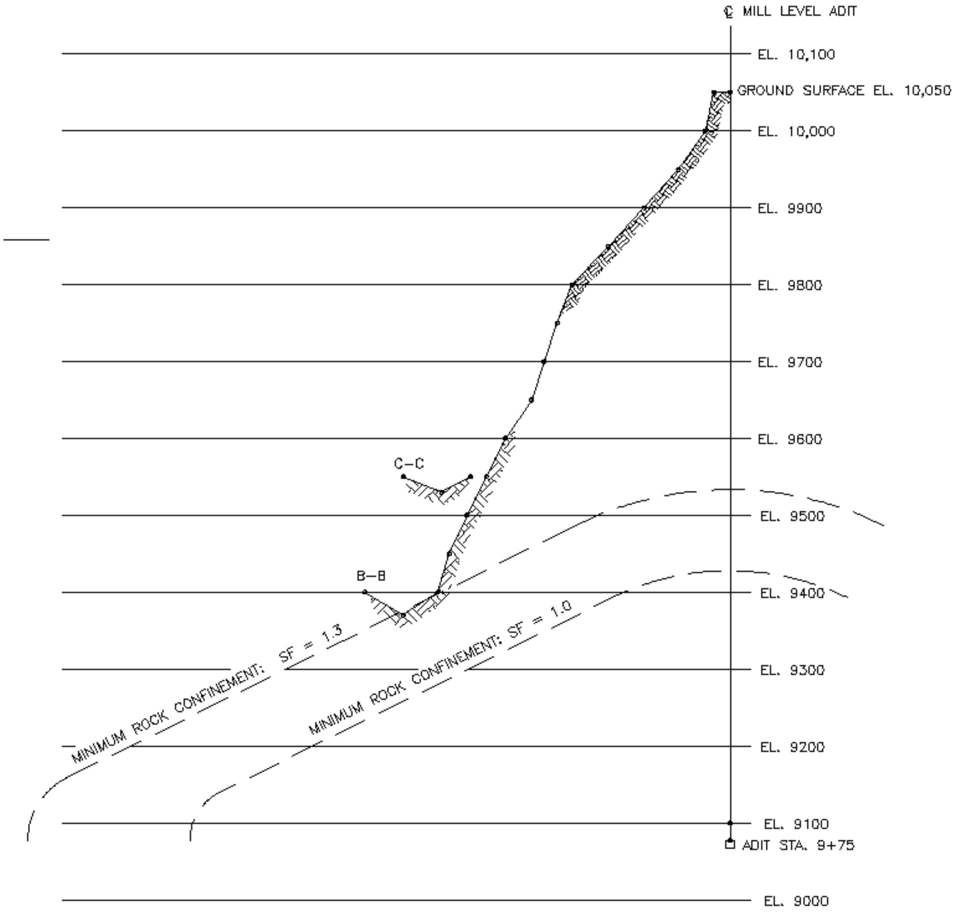


Figure 5: Snowy Mountain Rock Confinement Criteria for Bulkhead at Sta. 9+75

Bulkhead Relocation Options:

During the adit rehabilitation effort in January 2018, reconnaissance of the Mill Adit was conducted to identify a potential location for the bulkhead inby of Sta. 9+75. Adit conditions nearest to Sta. 9+75 were deemed undesirable due to a large amount of existing rock support in the back, significant vertical adit height, drummy rock conditions in the back, and an unfavorable local widening of the adit. A suitable potential bulkhead location was identified slightly inby in the vicinity of Sta. 10+30 which presented more favorable adit dimensions and less rock support of the back. Local removal of the shotcrete was performed on the back and ribs to expose the rock and revealed that the rock conditions in the back were somewhat less desirable than hoped, with thin bedded, open joints, and readily scalable sandstone. Sounding of the back with a scaling bar indicated that the overhead rock is consistently drummy throughout this area, while the sounding of the ribs indicated tight rock (albeit thinly bedded). Additional scaling of the back and rock bolting revealed that the thinly bedded zone extends approximately 12” to 18” above the adit before a more competent rock layer is encountered.

Alternative bulkhead sites were investigated on January 18th, 2018, with several comparable bulkhead sites identified, but with the same drummy sounding back conditions as Sta. 10+30. The nearest alternative site was located at Sta. 12+10 with a sound back and a natural keyway, however there was a near vertical seam with water seeps immediately outby this location. Another alternative location was identified near Sta. 13+00 with minimal rock support and a sound back, but relatively close to a major shear with considerable water inflow at approximate Sta. 13+80. It is anticipated that either of these sites could be utilized, but consideration would need to be given to the effect that the permeable near vertical seams may have on the bulkhead and if supplemental grouting would be needed.

Given that the bulkhead will require some rock excavation to create an adequate taper for pressure transfer, the thin bedded rock conditions near the back at Sta. 10+30 does not necessarily be a significant issue and the lack of significant vertical seams in the area is certainly a benefit. For the purposes of the 80% design submittal, the bulkhead location is recommended to remain at Sta. 10+30 with the understanding that additional rock removal in the back will be needed as part of bulkhead construction. Additionally, for rock reaction calculations, the resistance provided by the back has been conservatively ignored. This location is approximately 260 feet from the location of the underground boring program and represents a strata shift (based on a minimum 1.6° apparent dip and adit gradient of 0.005 ft/ft) of approximately 8.4 vertical feet at the back. Therefore, very little (maximum of 1.6 feet) of the 10 vertical feet core interval collected before is applicable to the current bulkhead location and consideration should be given to performing additional exploration.

Conclusions:

Based on the proximity to Marshall Creek and the steep topography, the bulkhead will need to be relocated further inby (Sta. 9+75 or beyond) to attain the recommended safety factor for lateral hydrojacking of the rock. A suitable bulkhead location was identified in the field at Sta. 10+30 and a geotechnical investigation program will be conducted to confirm adequate geotechnical conditions for the pressure bulkhead.

Idarado Mine Flow Through Bulkhead
Pressure Bulkhead Design
2900 Level Preliminary Design

Computed: KB 7/3/2015

Sheet: 1 of 5

Design underground pressure bulkhead utilizing design methodology presented in J.F. Abel "*Bulkhead Design for Acid Mine Drainage*" (in Proceedings of Western United States Mining-Impacted Watersheds, Denver, CO (1998))

Input:
10 ft b = adit width
10 ft h = adit height
900 ft D = hydrostatic head acting on bulkhead (to adit invert)
4000 psi $f'c$ = concrete compressive strength (28 day)
200 psi fr_s = minimum rock shear strength (intact rock)
160 pcf γ_r = unit weight of rock
10 ft L_1 = selected bulkhead length
3.5 in c_c = depth to reinforcment center from tensile face
60,000 psi Fy = yield strength of reinforcement
0.188 g PGA = peak ground acceleration due to maximum seismic event
300 ft S_1 = line-of-sight distance on pressure side of bulkhead

Hydraulic Pressure Gradient

Calculate minimum bulkhead length to satisfy allowable hydraulic pressure gradient:

Maximum hydrostatic pressure: $\rho = D(\gamma_w) =$ 56,160 psf = 390.0 psi

For an ungrouted pressure plug, allowable pressure gradient of 5 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{ungrouted} = \rho/(5\ psi/lf) =$ 78.0 lf

For a contact grouted pressure plug, allowable pressure gradient of 40 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{contact} = \rho/(40\ psi/lf) =$ 9.8 lf

Perimeter Shear Strength

Verify adequate perimeter shear strength:

Concrete ultimate shear strength (per ACI 318 11.3.1.1.)
$f'_s = 2(f'c)^{0.5} =$ 126 psi

Minimum rock shear strength: $fr_s =$ 200 psi

Since, the shear strength of the concrete is less than the rock shear strength, concrete shear controls.
Critical shear strength: $fs_{critical} =$ 126.5 psi

Minimum bulkhead length for perimeter shear: $L_{shear} = \rho(h)(b)/(2(h+b)fs_{critical}) =$ 7.7 feet

Minimum Bulkhead Depth

Calculate minimum rock cover to avoid rock hydrofracing due to hyrdrostatic pressure in the adit.

Breakdown pressure for hydrofracing: $B_p = T_s + 3S_{min} - S_{max} - P_f$

Assume: $T_s = 0$ tensile strength of rock due to existing joints and fractures
$S_{min} = S_{max} = S_{ovb}$ = overburden rock stress for K = 1.0
$P_f = 0$ formation pore pressure

$B_p = 2S_{ovb} = 2(\gamma_r)(H_r)$

setting Bp = ρ maximum hydrostatic pressure and solving for H_r yields the following:

Minimum rock cover: $H_{r(min)} = \rho/2\gamma_r =$ 175.5 feet

Plain Concrete Bulkhead Design

Calculate minimum bulkhead length for unreinforced bulkhead to resist maximum bending moment due to the hydrostatic pressure. Treat bulkhead as simply supported beam.
Design in accordance with ACI 318-10 Chapter 22 Plain Structural Concrete.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
ϕ = 0.60 strength reduction factor for plain concrete (per ACI 318 9.3.5)

Maximum bulkhead forces:
Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8 =$ 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2 =$ 393,120 lbs/lf

Plain Concrete Bending Capacity per ACI 318 22.5.1

Mu ≤ øMn $øM_n = ø5(f'c)^{1/2}S$ for tension controlled sections
where S = section modulus of section per unit foot = (12 inches)$L^2/6$
where L = bulkhead length (in inches)
$øM_n = ø5(f'c)^{1/2}(12(L^2)/6)$

Setting ϕMn = Mu and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi 5(f'c)^{1/2}(12))]^{1/2} =$ 176.29199 inches = 14.69 feet

Mu ≤ øMn $øM_n = ø(0.85)(f'c)S$ for compression controlled sections
$øM_n = ø(0.85)(f'c)(12(L^2)/6)$
Setting ϕMn = Mu and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi(0.85)(f'c)(12))]^{1/2} =$ 53.76 inches = 4.48 feet

Therefore, bending tensile stress controls and min. plain concrete bulkhead length = 14.69 feet

Reinforced Concrete Bulkhead Design

Determine minimum steel area for bulkhead based on selected bulkhead length. Design in accordance with ACI 318-10 reinforced concrete design methodology. Analyze a one foot unit width (12") beam.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
ϕ_t = 0.90 tension controlled strength reduction factor (per ACI 318 9.3.2.1)
ϕ_c = 0.65 compression controlled strength reduction factor (per ACI 318 9.3.2.2)
ϕ_v = 0.75 shear strength reduction factor (per ACI 318 9.3.2.3)

Maximum bulkhead forces:
Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8$ = 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2$ = 393,120 lbs/lf

Compression Resultant Force:
C = 0.85(f'c)(12"/ft)a

Tension Resultant Force:
$T = AsF_y$
Set C=T and solve for a: a = AsFy/(0.85(f'c)12) = 1.4706 As

Nominal Moment Capacity: ϕMn
$\phi Mn = \phi_t AsFy(d-a/2)$ $d = L_1 - c_c$ = 116.5 inches

Set ϕMn = Mu, substitute a in terms of As, and solve for As; resulting quadratic equation:
39705.88 As^2 - 6291000 As + 11753894 = 0
As = 1.891 $in^{2/}$lf minimum steel area required

Shear Capacity:
Design as a deep flexural member utilizing simplified shear calculations presented in 1999 or earlier ACI 318 Section 11.8.7.

Shear Capacity Limit (per ACI 318 11.8.7):
$\phi Vc = \phi 6((f'c)^{0.5})(12''/ft)(d)$ = 397,878 lbs/lf

Reinforced Concrete Bulkhead Design (Continued)

Nominal Shear Capacity (per ACI 318 11.8.7):

$$\phi Vc = \phi(3.5\text{-}2.5Mu_c/(Vu_c(d)))(1.9(f'c)0.5 + 2500(As/((12'/ft)(d))(Vu_c d/Mu_c))(12''/ft)(d)$$

where: Vu_c= shear at critical section

Mu_c = moment at critical section

Critical section distance: $L_c = 0.15x$ = 1.5 feet

$Vu_c = (Vu(0.5x - L_c))/(0.5x)$ = 275,184 lbs/lf

$Mu_c = 1.4(\rho(L_c)/2)(x\text{-}L_c)$ = 501,228 lb-ft/lf = 6,014,736 lb-in/lf

$3.5\text{-}(2.5Mu_c/(Vu_c(d)))$ = 3.0309626 ≤ 2.5 max ; limit to 2.5

ϕVc = 404,751 lbs/lf ≤ 397,878 lbs/lf shear limit

ϕVc = 397,878 lbs/lf shear capacity limit controls

Since, $\phi Vc > Vuc$; shear capacity is adequate

Earthquake Resistant Design

Verify that the bulkhead capacity is adequate to resist the peak ground acceleration associated with the maximum credible seismic event. Total design load:

U_e = 1.2(dead load) + 1.0(earthquake load) per ACI 318 9.2.1.

Conservative estimate of earthquake load is assuming that the unobstructed water mass is fully accelerated by the seismic event.

Earthquake Load: $E = PGA(W_t + W_f)$ where:

Peak ground acceleration: PGA = 0.188 g

For selected bulkhead thickness: L_1 = 10 ft

Typical unit weight of concrete: γ_c = 150 pcf

Typical unit weight of water: γ_w = 62.4 pcf

Bulkhead total weight: $W_t = (b)(h)(L_1)(\gamma_c)$ = 150,000 lbs

Total weight of water: $W_f = (b)(h)(S_1)(\gamma_w)$ = 1,872,000 lbs

Earthquake Load: $E = PGA(W_t + W_f)$ = 380,136 lbs

Dead Load: $D = \rho(b)(h)$ = 5,616,000 lbs

Total Design Load: $Ue = 1.2D + 1.0E$ = 7,119,336 lbs

Prior static design was based on $U_s = 1.4D$ = 7,862,400 lbs

Since Us > Ue; static design controls and bulkhead design is adequate for earthquake

Design Summary

Minimum bulkhead length for ungrouted plain concrete bulkhead:	78.0	feet
Minimum bulkhead length for contact grouted plain concrete bulkhead:	14.7	feet
Selected bulkhead length for contact grouted reinforced bulkhead:	10	feet
Minimum area of steel for reinforced bulhead:	1.891	in^2/lf
Minimum required overburden cover above bulkhead:	175.5	feet

Preliminary
Design Report

For the

IDARADO MINE
2900 MILL LEVEL BULKHEAD

APPENDIX G: STRUCTURAL CALCULATIONS

Submitted to:

Newmont Mining Corporation

Design underground pressure bulkhead utilizing design methodology presented in J.F. Abel "*Bulkhead Design for Acid Mine Drainage*" (in Proceedings of Western United States Mining-Impacted Watersheds, Denver, CO (1998))

Input:
10 ft b = adit width
10 ft h = adit height
900 ft D = hydrostatic head acting on bulkhead (to adit invert)
4000 psi f'c = concrete compressive strength (28 day)
200 psi fr_s = minimum rock shear strength (intact rock)
160 pcf γ_r = unit weight of rock
10 ft L_1 = selected bulkhead length
3.5 in c_c = depth to reinforcment center from tensile face
60,000 psi Fy = yield strength of reinforcement
0.188 g PGA = peak ground acceleration due to maximum seismic event
300 ft S_1 = line-of-sight distance on pressure side of bulkhead

Hydraulic Pressure Gradient

Calculate minimum bulkhead length to satisfy allowable hydraulic pressure gradient:

Maximum hydrostatic pressure: $\rho = D(\gamma_w) =$ 56,160 psf = 390.0 psi

For an ungrouted pressure plug, allowable pressure gradient of 5 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{ungrouted} = \rho/(5 \text{ psi/lf}) =$ 78.0 lf

For a contact grouted pressure plug, allowable pressure gradient of 40 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{contact} = \rho/(40 \text{ psi/lf}) =$ 9.8 lf

Perimeter Shear Strength

Verify adequate perimeter shear strength:

Concrete ultimate shear strength (per ACI 318 11.3.1.1.)
$f'_s = 2(f'c)^{0.5} =$ 126 psi

Minimum rock shear strength: $fr_s =$ 200 psi

Since, the shear strength of the concrete is less than the rock shear strength, concrete shear controls.
Critical shear strength: $fs_{critical} =$ 126.5 psi

Minimum bulkhead length for perimeter shear: $L_{shear} = \rho(h)(b)/(2(h+b)fs_{critical}) =$ 7.7 feet

Minimum Bulkhead Depth

Calculate minimum rock cover to avoid rock hydrofracing due to hyrdrostatic pressure in the adit.

Breakdown pressure for hydrofracing: $B_p = T_s + 3S_{min} - S_{max} - P_f$

Assume: $T_s = 0$ tensile strength of rock due to existing joints and fractures
$S_{min} = S_{max} = S_{ovb}$ = overburden rock stress for K = 1.0
$P_f = 0$ formation pore pressure

$B_p = 2S_{ovb} = 2(\gamma_r)(H_r)$

setting Bp = ρ maximum hydrostatic pressure and solving for H_r yields the following:

Minimum rock cover: $H_{r(min)} = \rho/2\gamma_r =$ 175.5 feet

Plain Concrete Bulkhead Design

Calculate minimum bulkhead length for unreinforced bulkhead to resist maximum bending moment due to the hydrostatic pressure. Treat bulkhead as simply supported beam.
Design in accordance with ACI 318-10 Chapter 22 Plain Structural Concrete.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
$\phi = 0.60$ strength reduction factor for plain concrete (per ACI 318 9.3.5)

Maximum bulkhead forces:
Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8 =$ 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2 =$ 393,120 lbs/lf

Plain Concrete Bending Capacity per ACI 318 22.5.1

$Mu \leq \text{ø}Mn$ $\text{ø}M_n = \text{ø}5(f'c)^{1/2}S$ for tension controlled sections
where S = section modulus of section per unit foot = (12 inches)$L^2/6$
where L = bulkhead length (in inches)
$\text{ø}M_n = \text{ø}5(f'c)^{1/2}(12(L^2)/6)$

Setting $\phi Mn = Mu$ and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi 5(f'c)^{1/2}(12))]^{1/2} =$ 176.29199 inches = 14.69 feet

$Mu \leq \text{ø}Mn$ $\text{ø}M_n = \text{ø}(0.85)(f'c)S$ for compression controlled sections
$\text{ø}M_n = \text{ø}(0.85)(f'c)(12(L^2)/6)$
Setting $\phi Mn = Mu$ and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi(0.85)(f'c)(12))]^{1/2} =$ 53.76 inches = 4.48 feet

Therefore, bending tensile stress controls and min. plain concrete bulkhead length = 14.69 feet

Reinforced Concrete Bulkhead Design

Determine minimum steel area for bulkhead based on selected bulkhead length. Design in accordance with ACI 318-10 reinforced concrete design methodology. Analyze a one foot unit width (12") beam.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
ϕ_t = 0.90 tension controlled strength reduction factor (per ACI 318 9.3.2.1)
ϕ_c = 0.65 compression controlled strength reduction factor (per ACI 318 9.3.2.2)
ϕ_v = 0.75 shear strength reduction factor (per ACI 318 9.3.2.3)

Maximum bulkhead forces:
Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8$ = 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2$ = 393,120 lbs/lf

Compression Resultant Force:
C = 0.85(f'c)(12"/ft)a

Tension Resultant Force:
$T = AsF_y$
Set C=T and solve for a: a = AsFy/(0.85(f'c)12) = 1.4706 As

Nominal Moment Capacity: ϕMn
$\phi Mn = \phi_t AsFy(d-a/2)$ $d = L_1 - c_c$ = 116.5 inches

Set ϕMn = Mu, substitute a in terms of As, and solve for As; resulting quadratic equation:
$39705.88\ As^2 - 6291000\ As + 11753894 = 0$
As = 1.891 $in^{2/}lf$ minimum steel area required

Shear Capacity:
Design as a deep flexural member utilizing simplified shear calculations presented in 1999 or earlier ACI 318 Section 11.8.7.

Shear Capacity Limit (per ACI 318 11.8.7):
$\phi Vc = \phi 6((f'c)^{0.5})(12"/ft)(d)$ = 397,878 lbs/lf

Reinforced Concrete Bulkhead Design (Continued)

Nominal Shear Capacity (per ACI 318 11.8.7):

$$\phi Vc = \phi(3.5\text{-}2.5Mu_c/(Vu_c(d)))(1.9(f'c)0.5 + 2500(As/((12'/ft)(d))(Vu_c d/Mu_c))(12''/ft)(d)$$

where: Vu_c= shear at critical section

Mu_c = moment at critical section

Critical section distance: $L_c = 0.15x$ = 1.5 feet

$Vu_c = (Vu(0.5x - L_c))/(0.5x)$ = 275,184 lbs/lf

$Mu_c = 1.4(\rho(L_c)/2)(x\text{-}L_c)$ = 501,228 lb-ft/lf = 6,014,736 lb-in/lf

$3.5\text{-}(2.5Mu_c/(Vu_c(d)))$ = 3.0309626 ≤ 2.5 max ; limit to 2.5

ϕVc = 404,751 lbs/lf ≤ 397,878 lbs/lf shear limit

ϕVc = 397,878 lbs/lf shear capacity limit controls

Since, $\phi Vc > Vuc$; shear capacity is adequate

Earthquake Resistant Design

Verify that the bulkhead capacity is adequate to resist the peak ground acceleration associated with the maximum credible seismic event. Total design load:

U_e = 1.2(dead load) + 1.0(earthquake load) per ACI 318 9.2.1.

Conservative estimate of earthquake load is assuming that the unobstructed water mass is fully accelerated by the seismic event.

Earthquake Load: $E = PGA(W_t + W_f)$ where:

Peak ground acceleration: PGA = 0.188 g

For selected bulkhead thickness: L_1 = 10 ft

Typical unit weight of concrete: γ_c = 150 pcf

Typical unit weight of water: γ_w = 62.4 pcf

Bulkhead total weight: $W_t = (b)(h)(L_1)(\gamma_c)$ = 150,000 lbs

Total weight of water: $W_f = (b)(h)(S_1)(\gamma_w)$ = 1,872,000 lbs

Earthquake Load: $E = PGA(W_t + W_f)$ = 380,136 lbs

Dead Load: $D = \rho(b)(h)$ = 5,616,000 lbs

Total Design Load: $Ue = 1.2D + 1.0E$ = 7,119,336 lbs

Prior static design was based on $U_s = 1.4D$ = 7,862,400 lbs

Since Us > Ue; static design controls and bulkhead design is adequate for earthquake

Design Summary

Minimum bulkhead length for ungrouted plain concrete bulkhead:	78.0	feet
Minimum bulkhead length for contact grouted plain concrete bulkhead:	14.7	feet
Selected bulkhead length for contact grouted reinforced bulkhead:	10	feet
Minimum area of steel for reinforced bulhead:	1.891	in^2/lf
Minimum required overburden cover above bulkhead:	175.5	feet

Appendix H
Finite Element Analysis

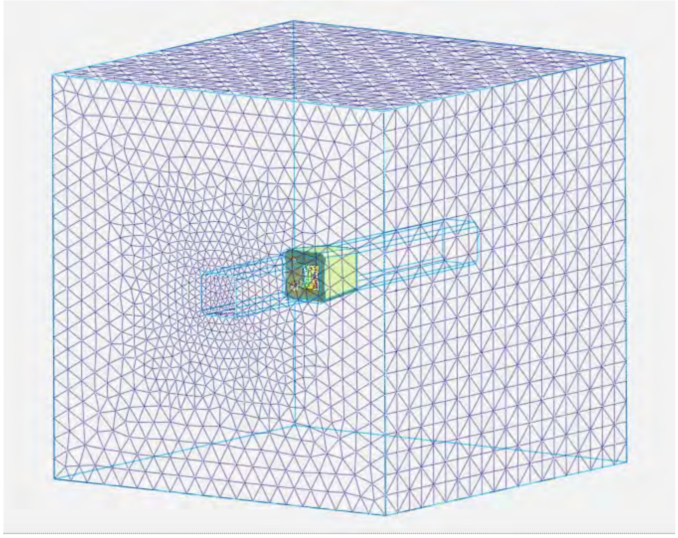
Overview:

In recognition that the proposed concrete bulkhead in the Idarado Mill Level adit will have a significant number of penetrations through the bulkhead, including a relatively large access way opening, a 3D finite element analysis (FEA) has been performed to quantify rock and concrete deformations, bulkhead stresses, and rock reactions. The initial sizing of the bulkhead has been performed following the structural methodology by Professor Abel, but the access way and two other pipes through the bulkhead will disrupt the one-way beam action that the Abel approach is based upon. However, many of the calculations remain applicable for the bulkhead, particularly the calculations for hydraulic gradient, perimeter shear, and seismic design. A copy of the initial sizing calculations following the Abel approach is attached. Key results include that the current bulkhead length of 15 feet exceeds the minimum required for an acceptable dissipation of water pressure (roughly 10 foot minimum length), perimeter shear (7.7 foot minimum length); reinforced concrete bulkhead length (10 feet); and plain concrete bulkhead length (14.7 feet). Note that the perimeter shear has been calculated based on the lower one-way beam shear (opposed to punching or direct shear) and as an independent verification, check the bulkhead for shear transfer on only 3 sides assuming that the back is blockier and less stiff due to gravity induced strata separation over time: L_{min} = 390psi(10.5')(10.5')/[(3 sides)(10.5')(126.5 psi)] = 10.8 feet. The 15 foot bulkhead length provides a safety factor of SF =15'/10.8' = 1.39 over one-way shear and even greater for two way shear.

To assess the actual load distribution within the bulkhead, a 3D FEA model has been developed and the maximum load case associated with the bulkhead restraining 900 vertical feet of water head has been simulated. The following sections document the initial simulation performed for the bulkhead; it is anticipated that the model will be further refined during final design.

Finite Element Model:

The numerical modeling has been performed utilizing Midas GTS, a specialized software intended for geotechnical simulation and utilizes the robust DIANA solver. The Idarado 3D FEA model consists of 100 foot rock cube with the 15 foot long tapered concrete bulkhead installed near the center. The overburden pressure has been applied as a uniform load directly on the upper surface of the cube to minimize solution times. The adit has been simulated as a square opening with chamfered corners 10.5 feet high by 10.5 wide to approximate the adit dimensions at the proposed bulkhead location at Sta. 10+30. The minimum taper of the plug of 1 feet in all directions has also been included.



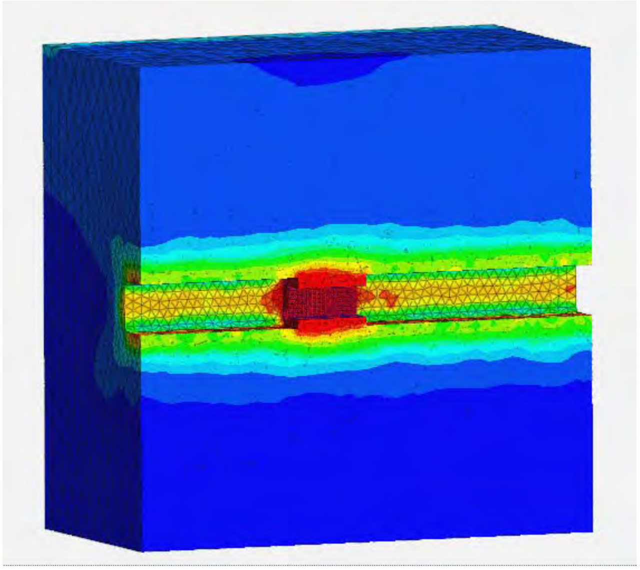


Figure 1: Overall Model View (showing rock mass, adit, and bulkhead) and Cut Model View (along adit showing bulkhead)

All three major penetrations have also been included with the following dimensions and initial steel lining thicknesses:

Access Way:	6.5 feet high by 5.75 feet wide lined with 1” thick steel plate
Conveyance Pipe:	30” diameter lined with 0.5” thick steel pipe
Overflow Pipe:	18” diameter lined with 0.375” thick steel pipe

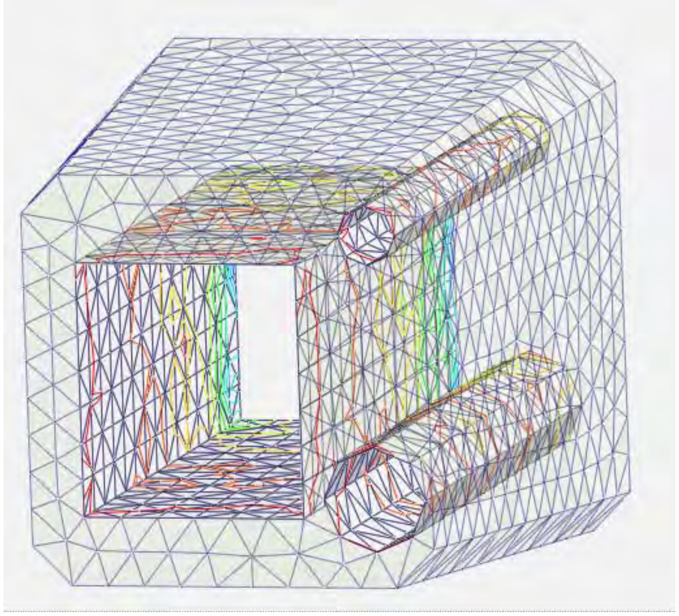


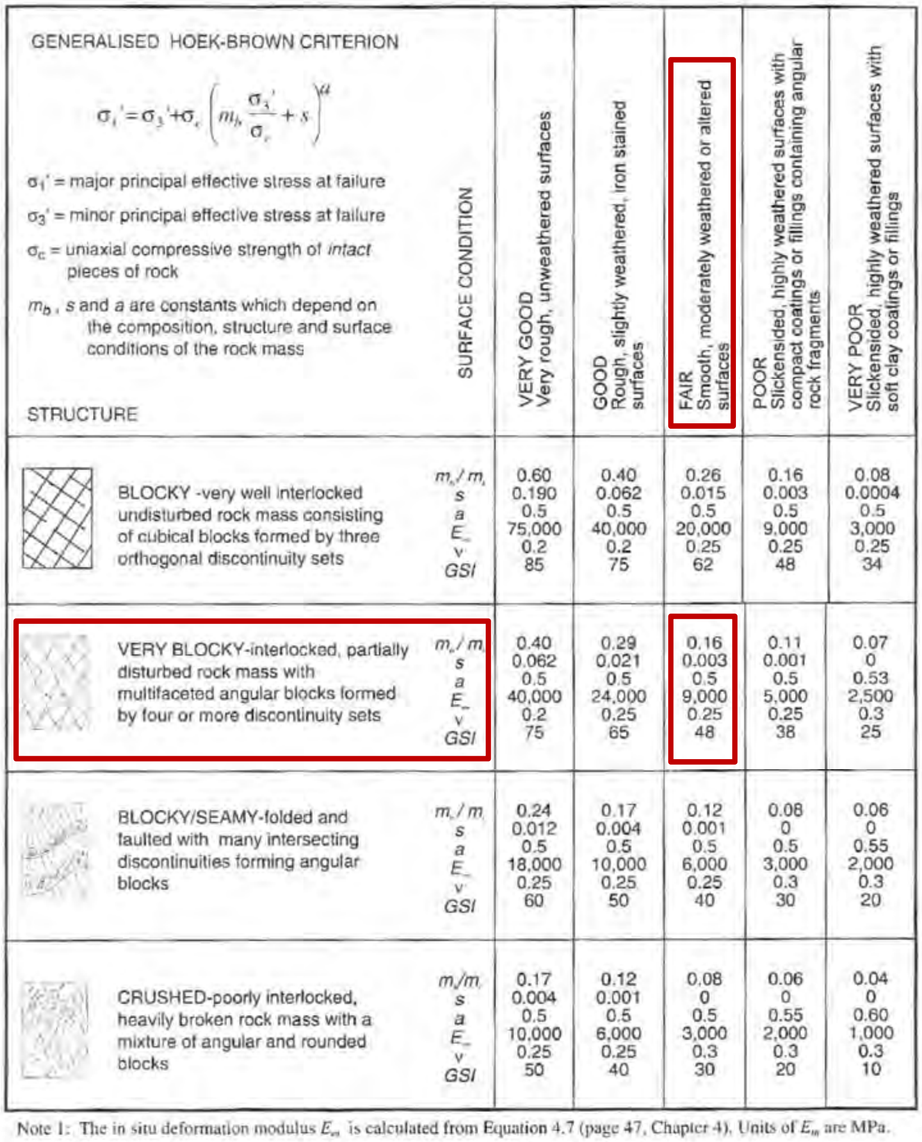
Figure 2: Tapered Bulkhead with Access Way and Piping

One subtle item to note is that the piping has been inadvertently located on the opposite side of adit than what is planned. This will not affect the results of the FEA, but maybe visually confusing in the graphic above (and subsequent graphics) and will be corrected during final design.

Material Parameters:

Initial subsurface stresses are based on the full unit weight of the rock and a lateral earth pressure coefficient (Ko) of 0.5 to reflect the proximity to the valley. For simplicity, no groundwater has been simulated for this initial model, but hydrostatic pressures have been applied directly to the bulkhead as either distributed area loads or nodal loads. For final design, the water pressure and groundwater regime will need to be simulated to apply external pressure to the bulkhead if the door is located on the inby face.

Rock behavior has been simulated utilizing the Generalized Hoek Brown rock material model. The input parameters have been conservatively selected based on a rock structure corresponding to “Very Blocky” and joint surfaces corresponding to “Fair” per the chart below – the actual adit conditions visually appear to be better than these parameters.



GENERALISED HOEK-BROWN CRITERION

$$\sigma_1' = \sigma_3' + \sigma_c \left(m_b \frac{\sigma_3'}{\sigma_c} + s \right)^a$$

σ_1' = major principal effective stress at failure

σ_3' = minor principal effective stress at failure

σ_c = uniaxial compressive strength of *intact* pieces of rock

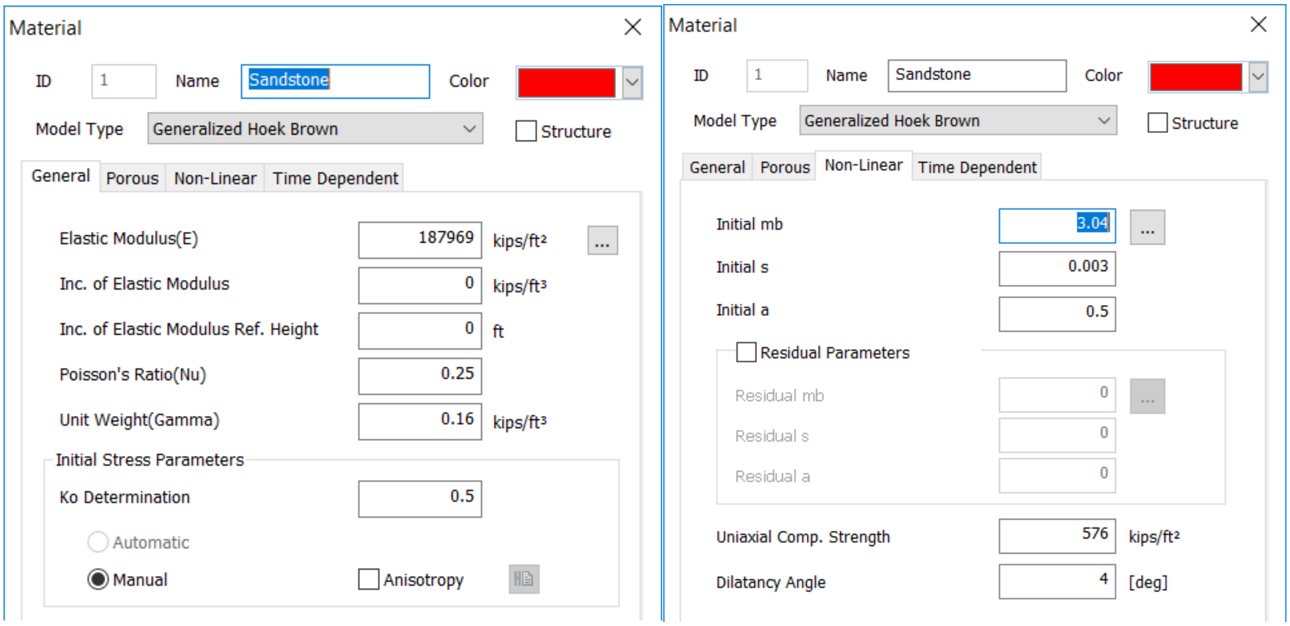
m_b, s and a are constants which depend on the composition, structure and surface conditions of the rock mass

STRUCTURE	SURFACE CONDITION	VERY GOOD Very rough, unweathered surfaces	GOOD Rough, slightly weathered, iron stained surfaces	FAIR Smooth, moderately weathered or altered surfaces	POOR Slickensided, highly weathered surfaces with compact coatings or fillings containing angular rock fragments	VERY POOR Slickensided, highly weathered surfaces with soft clay coatings or fillings
BLOCKY -very well interlocked undisturbed rock mass consisting of cubical blocks formed by three orthogonal discontinuity sets	m_b/m_i s a E_m ν GSI	0.60 0.190 0.5 75,000 0.2 85	0.40 0.062 0.5 40,000 0.2 75	0.26 0.015 0.5 20,000 0.25 62	0.16 0.003 0.5 9,000 0.25 48	0.08 0.0004 0.5 3,000 0.25 34
VERY BLOCKY-interlocked, partially disturbed rock mass with multifaceted angular blocks formed by four or more discontinuity sets	m_b/m_i s a E_m ν GSI	0.40 0.062 0.5 40,000 0.2 75	0.29 0.021 0.5 24,000 0.25 65	0.16 0.003 0.5 9,000 0.25 48	0.11 0.001 0.5 5,000 0.25 38	0.07 0 0.53 2,500 0.3 25
BLOCKY/SEAMY-folded and faulted with many intersecting discontinuities forming angular blocks	m_b/m_i s a E_m ν GSI	0.24 0.012 0.5 18,000 0.25 60	0.17 0.004 0.5 10,000 0.25 50	0.12 0.001 0.5 6,000 0.25 40	0.08 0 0.5 3,000 0.3 30	0.06 0 0.55 2,000 0.3 20
CRUSHED-poorly interlocked, heavily broken rock mass with a mixture of angular and rounded blocks	m_b/m_i s a E_m ν GSI	0.17 0.004 0.5 10,000 0.25 50	0.12 0.001 0.5 6,000 0.25 40	0.08 0 0.5 3,000 0.3 30	0.06 0 0.55 2,000 0.3 20	0.04 0 0.60 1,000 0.3 10

Note 1: The in situ deformation modulus E_m is calculated from Equation 4.7 (page 47, Chapter 4). Units of E_m are MPa.

Figure 3: Generalized Hoek-Brown Parameters for Rock Mass Surrounding Bulkhead (modified from Hoek, Kaiser, Brown *Support of Underground Excavation in Hard Rock* (2000))

Properties of the rock material are shown below based on m_i for sandstone of 19 (per Table 8.3 from Hoek, Kaiser, & Bawden 2000):



ID 1
Name Sandstone
Model Type Generalized Hoek Brown
☐ Structure

Elastic Modulus(E) 187969 kips/ft²
Inc. of Elastic Modulus 0 kips/ft³
Inc. of Elastic Modulus Ref. Height 0 ft
Poisson's Ratio(Nu) 0.25
Unit Weight(Gamma) 0.16 kips/ft³
Initial Stress Parameters
Ko Determination 0.5
○ Automatic
● Manual
☐ Anisotropy

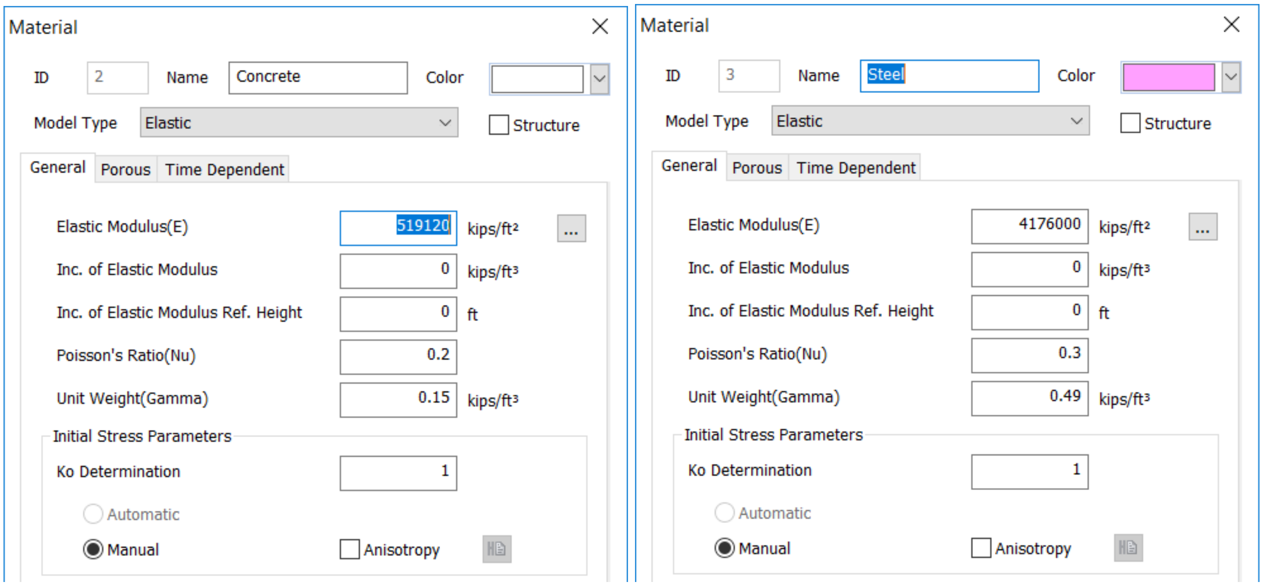
ID 1
Name Sandstone
Model Type Generalized Hoek Brown
☐ Structure

Initial mb 3.04
Initial s 0.003
Initial a 0.5
☐ Residual Parameters
Residual mb 0
Residual s 0
Residual a 0
Uniaxial Comp. Strength 576 kips/ft²
Dilatancy Angle 4 [deg]

Figure 4: Generalized Hoek-Brown Material Parameters utilized for Cutler Sandstone

Comparing the elastic modulus utilized (1305 ksi) with the elastic modulus results from the laboratory testing program (4410 ksi & 9190 ksi) indicates a conservative effective stiffness reduction of 1/3 to 1/8 the intact value. This will likely overestimate the lateral displacement of the bulkhead due to the water pressure. Similarly, the sandstone compressive strength has been set to 4 ksi to reflect the lower bound of the testing results and the dilatancy angle has been approximated based on 1/8(internal friction angle, ϕ).

Conventional elastic strength parameters have been utilized for the bulkhead concrete and the steel linings of the access way, conveyance pipe, and overflow pipe:



ID 2
Name Concrete
Model Type Elastic
☐ Structure

Elastic Modulus(E) 519120 kips/ft²
Inc. of Elastic Modulus 0 kips/ft³
Inc. of Elastic Modulus Ref. Height 0 ft
Poisson's Ratio(Nu) 0.2
Unit Weight(Gamma) 0.15 kips/ft³
Initial Stress Parameters
Ko Determination 1
○ Automatic
● Manual
☐ Anisotropy

ID 3
Name Steel
Model Type Elastic
☐ Structure

Elastic Modulus(E) 4176000 kips/ft²
Inc. of Elastic Modulus 0 kips/ft³
Inc. of Elastic Modulus Ref. Height 0 ft
Poisson's Ratio(Nu) 0.3
Unit Weight(Gamma) 0.49 kips/ft³
Initial Stress Parameters
Ko Determination 1
○ Automatic
● Manual
☐ Anisotropy

Figure 5: Elastic Material Parameters utilized for Concrete and Steel

Applied Loads

As alluded to above, there are two distinct sets of loads that have been utilized in the numerical model. The first is a vertical pressure corresponding to the overburden weight above the rock mass cube. Based on the ground surface elevation of El. 10,050 above the bulkhead location and the upper elevation of rock mass cube at El. 9222.25, a total vertical load of (927.75 vf)(160 pcf) = 148,400 psf = 148.4 ksf has been applied on upper surface of the rock cube.

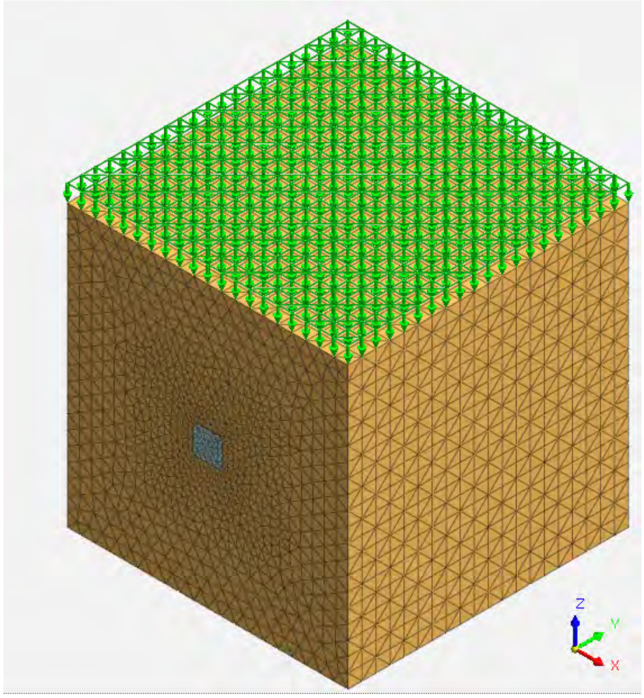


Figure 6: Vertical Overburden Pressure Applied to Upper Surface of Rock Mass Cube

The full 900 vertical feet of hydrostatic water head has been applied directly to the inby surface of the bulkhead as a uniform pressure load of (900 vf)(62.4 pcf) = 56,160 psf = 56.16 ksf. Due to the one foot lookout of the tapered bulkhead, it was assumed that the water pressure would act on the full inby concrete surface and according, this pressure has been applied over the full 12.5 feet x 12.5 feet concrete area. Note that no groundwater pressure has been applied to the invert, back, or rib surfaces of the concrete plug to maximize the reaction force imparted upon the rock. For final design, simulations will include the external pressure gradient to ensure adequate structural capacity of the access way and surrounding bulkhead concrete.

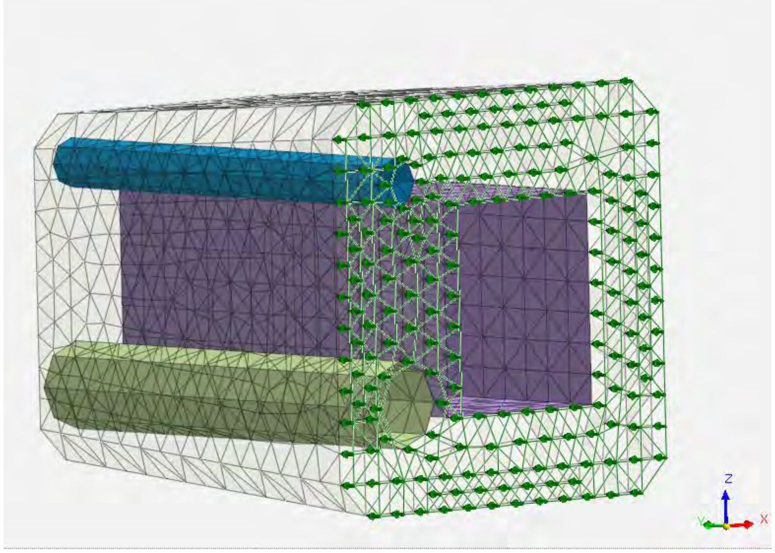


Figure 7: Maximum Hydrostatic Pressure applied to Inby Face of Bulkhead Concrete

For the access way opening, the exact door configuration has not been finalized and conservatively the door has been assumed to transfer the loads laterally on both sides of the door as a one-way slab. Based on clear door opening width of 5.75 feet and height of 6.5 vertical feet, a typical node load of (5.75'/2)(56.16 ksf)(6.5')/7 increments = 150 k/node. At the corners, the tributary height of the nodes will be half and the applied node load is 75 k/node. total load. For simplicity, theese loads have been applied to the nodes adjacent to the clear opening and in reality, the door loads will be uniformly distributed over a much larger area and further away from the clear opening. Similar to the door load, the forces associated with the conveyance and overflow pipes being full closed have been applied as node loads. Unlike the door loads bearing on the inby face, these loads are likely to be transferred via thrust plates welded to the pipes and have been simulated near the mid-length of the pipe (7 feet from the outby face of the bulkhead to correspond to existing mesh). For the 30" conveyance pipe, the force per node is approximately (56.16 ksf)(π(2.5')(2.5')/4) = 275.7 kips/8 nodes = 34.5 k/node. For the 18" overflow pipe, the force per node is approximately (56.16 ksf)(π(1.5')(1.5')/4) = 99.2 kips/8 nodes = 12.4 k/node. The door and pipe node loads are shown below:

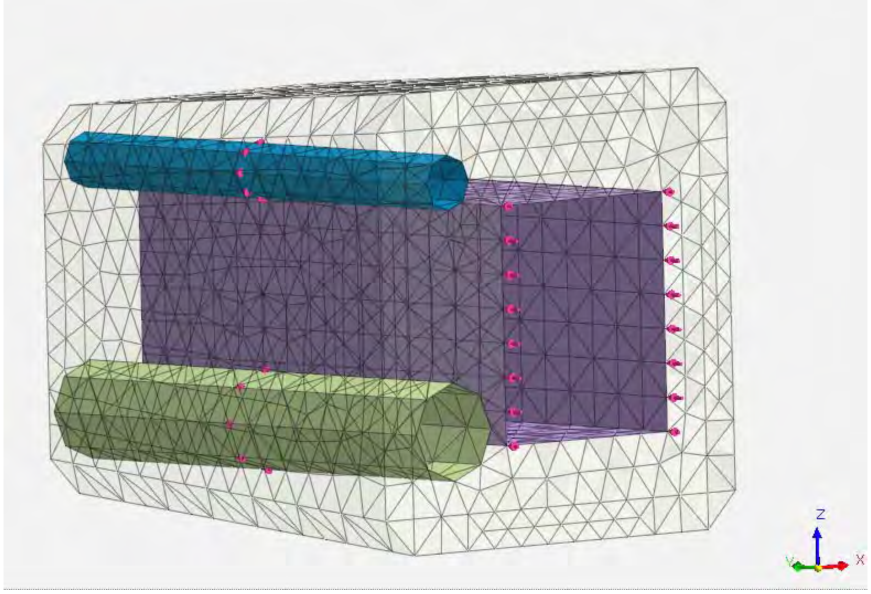


Figure 8: Maximum Hydrostatic Loads (pink node loads) Applied to Penetrations in Bulkhead

In addition to the applied loads, self-weight of the rock, concrete, and steel linings were also simulated in the negative Z-axis direction. Boundary restraints were applied to the sides and underside of the rock cube to provide the needed reactions.

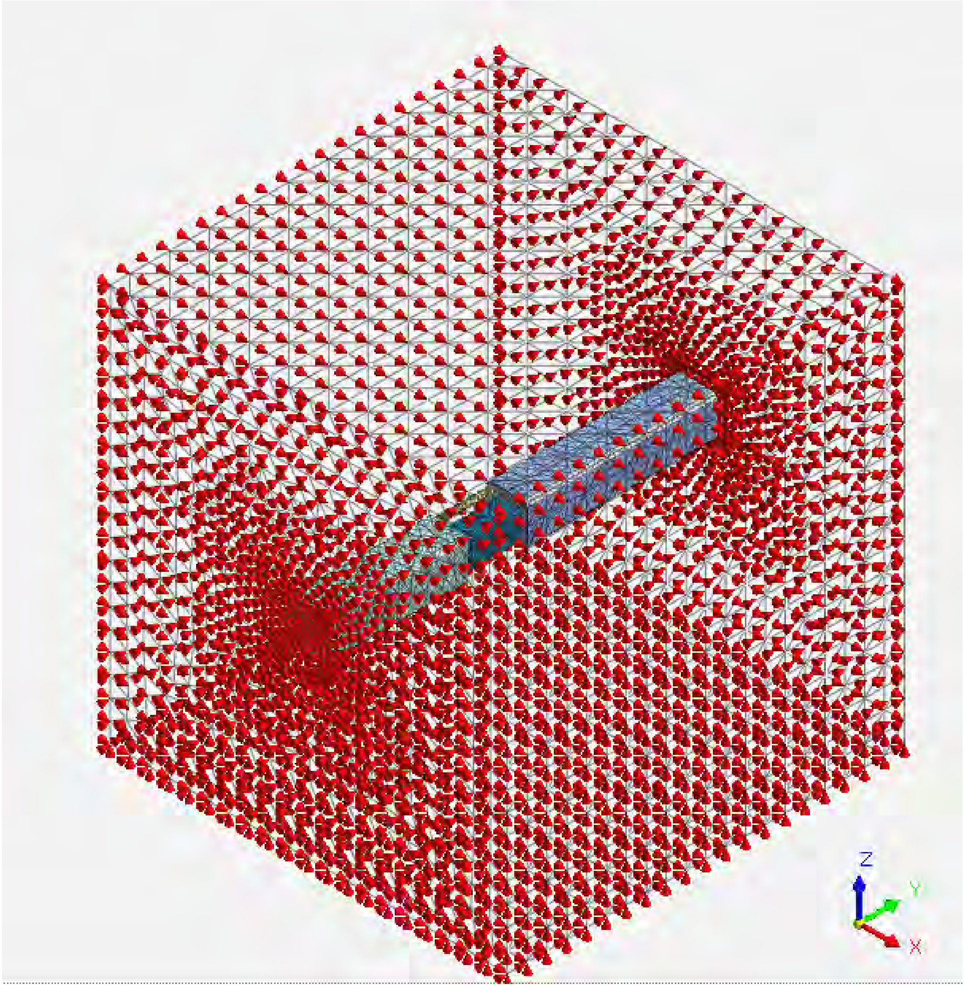
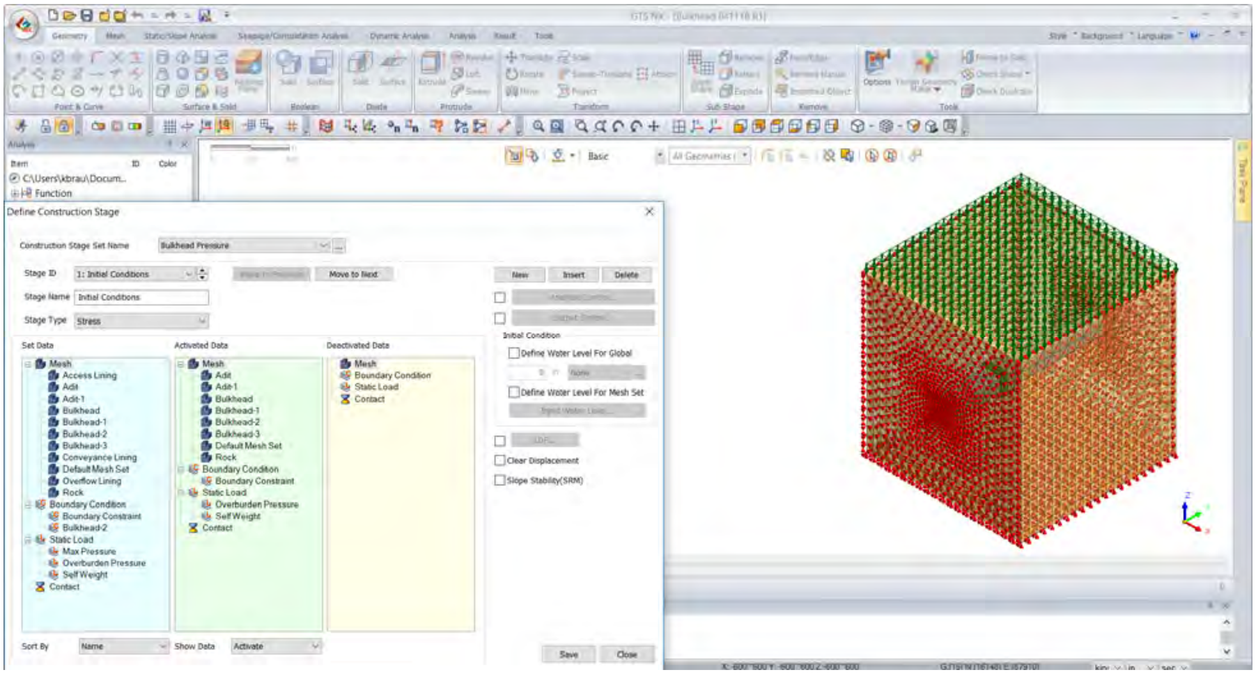


Figure 9: Boundary Conditions

Construction Simulation

A simple construction sequence has been simulated to reflect the concrete bulkhead placement in a stable rock adit and the subsequent inby pressurization corresponding the maximum potential hydrostatic head. The basic construction stages for the finite element model are as follows:

Step 1: Initial Ground Conditions: All volumes are activated as sandstone rock (including adit and bulkhead) and the initial stresses are obtained based on vertical self-weight, the applied vertical overburden pressure, and the at-rest lateral earth pressure coefficient (Ko = 0.5). The model boundary conditions and self-weight load conditions are activated.



Define Construction Stage

Construction Stage Set Name: Bulkhead Pressure
Stage ID: 1: Initial Conditions
Stage Name: Initial Conditions
Stage Type: Stress

Set Data
- Mesh
  - Access Lining
  - Adit
  - Adit-1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Conveyance Lining
  - Default Mesh Set
  - Overflow Lining
  - Rock
- Boundary Condition
  - Boundary Constraint
  - Bulkhead-2
- Static Load
  - Max Pressure
  - Overburden Pressure
  - Self Weight
- Contact

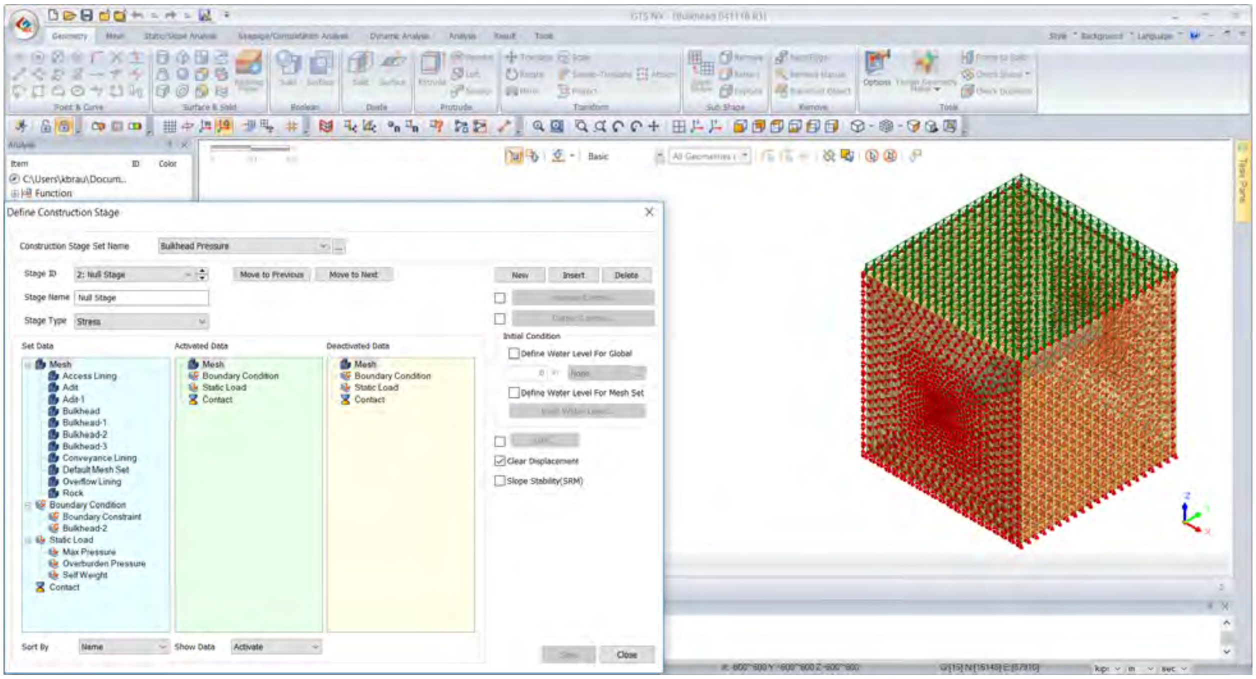
Activated Data
- Mesh
  - Adit
  - Adit-1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Default Mesh Set
  - Rock
- Boundary Condition
  - Boundary Constraint
- Static Load
  - Overburden Pressure
  - Self Weight
- Contact

Deactivated Data
- Mesh
- Boundary Condition
- Static Load
- Contact

Initial Condition
☐ Define Water Level For Global
☐ Define Water Level For Mesh Set
☐ Clear Displacement
☐ Slope Stability(SRM)

Sort By: Name
Show Data: Activate

Step 2: Null Stage and Groundwater: For the initial simulation, no groundwater has been included. No other major stresses are induced in this step to allow the model mesh to reach full equilibrium. Mesh displacements are reset to zero at the end of this step.



Define Construction Stage

Construction Stage Set Name: Bulkhead Pressure
Stage ID: 2: Null Stage
Stage Name: Null Stage
Stage Type: Stress

Set Data
- Mesh
  - Access Lining
  - Adit
  - Adit-1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Conveyance Lining
  - Default Mesh Set
  - Overflow Lining
  - Rock
- Boundary Condition
  - Boundary Constraint
  - Bulkhead-2
- Static Load
  - Max Pressure
  - Overburden Pressure
  - Self Weight
- Contact

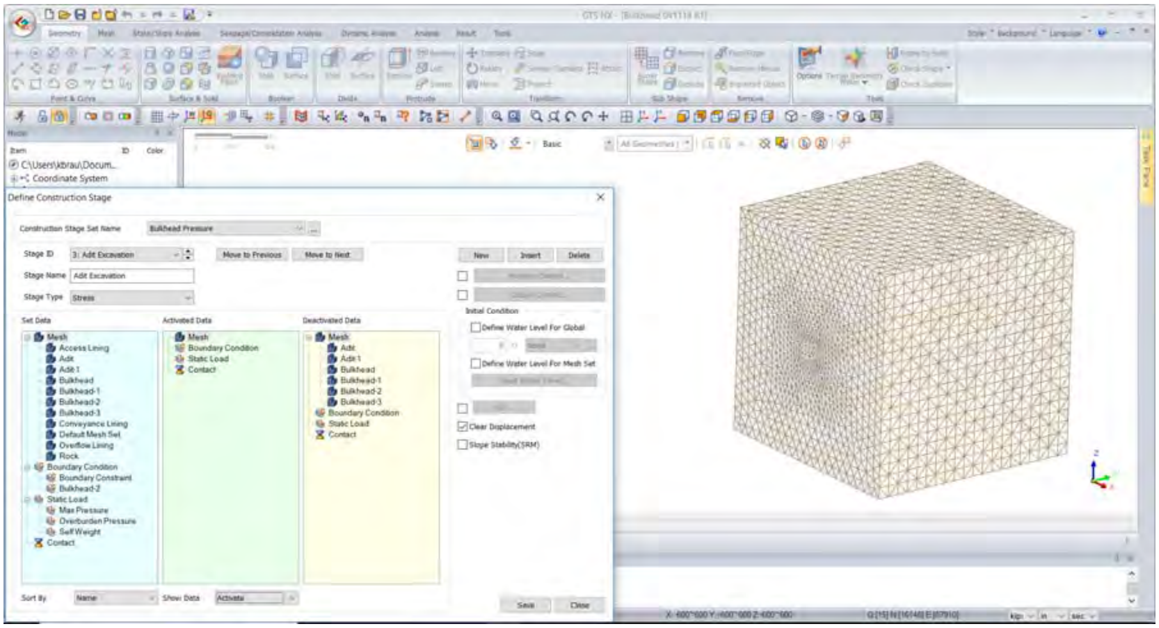
Activated Data
- Mesh
- Boundary Condition
- Static Load
- Contact

Deactivated Data
- Mesh
- Boundary Condition
- Static Load
- Contact

Initial Condition
☐ Define Water Level For Global
☐ Define Water Level For Mesh Set
☑ Clear Displacement
☐ Slope Stability(SRM)

Sort By: Name
Show Data: Activate

Step 3: Adit Excavation: The rock volumes for the inby adit, the bulkhead, and the outby adit are deactivated corresponding to adit excavation. No initial support has been included in the simulation for simplicity and since the initial support will not have a significant influence on the rock reaction to the large bulkhead loads and are not required for opening stability. The boundary conditions and vertical overburden loads remain remain active from the initial conditions stage but are not shown in subsequent images for visual clarity.



Define Construction Stage

Construction Stage Set Name: Bulkhead Pressure

Stage ID: 3: Adit Excavation

Stage Name: Adit Excavation

Stage Type: Stress

Set Data:
- Mesh
  - Access Lining
  - Adit
  - Adit 1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Conveyance Lining
  - Default Mesh Set
  - Overflow Lining
  - Rock
- Boundary Condition
  - Boundary Constraint
  - Bulkhead-2
- Static Load
  - Max Pressure
  - Overburden Pressure
  - Self Weight
- Contact

Activated Data:
- Mesh
- Boundary Condition
- Static Load
- Contact

Deactivated Data:
- Mesh
  - Adit
  - Adit 1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
- Boundary Condition
- Static Load
- Contact

Initial Condition

☐ Define Water Level For Global

☐ Define Water Level For Mesh Set

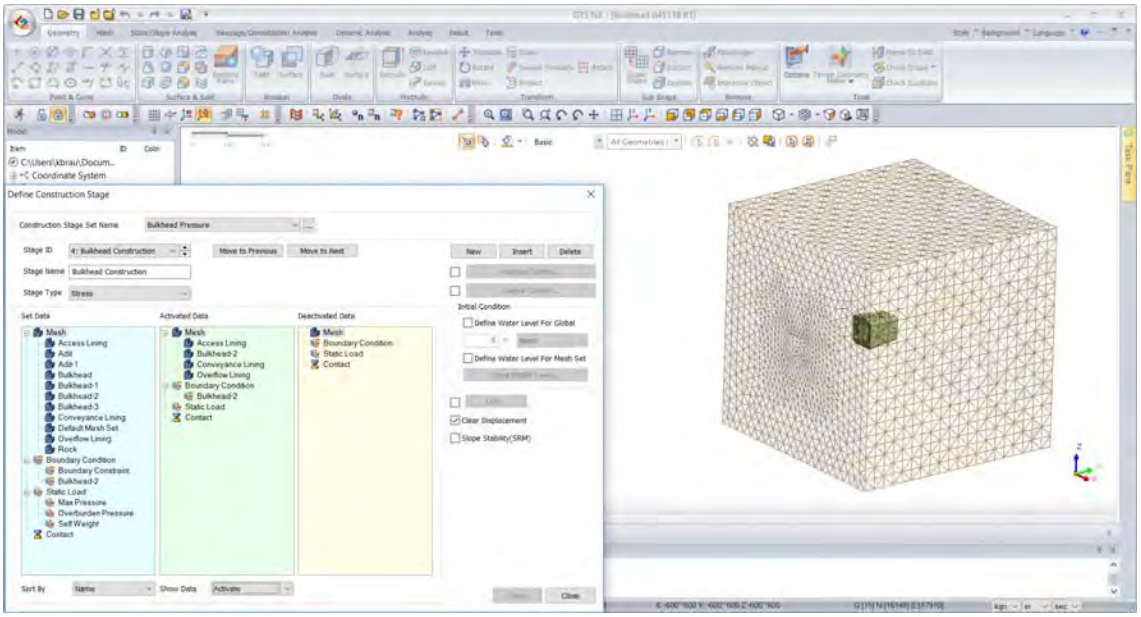
☑ Clear Displacement

☐ Slope Stability(SRM)

Sort By: Name

Show Data: Activate

Step 4: Adit Construction: The concrete bulkhead, steel access way lining, steel conveyance pipe, and steel overflow pipe are activated. The concrete bulkhead is a volume element with properties changed from rock to concrete (4 ksi) ("Bulkhead-2" boundary). The steel linings are represented as shell elements. The displacements in the model are reset at the end of this step to allow quantification of the movements associated with the large hydrostatic pressure in the following step.



Define Construction Stage

Construction Stage Set Name: Bulkhead Pressure

Stage ID: 4: Bulkhead Construction

Stage Name: Bulkhead Construction

Stage Type: Stress

Set Data:
- Mesh
  - Access Lining
  - Adit
  - Adit 1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Conveyance Lining
  - Default Mesh Set
  - Overflow Lining
  - Rock
- Boundary Condition
  - Boundary Constraint
  - Bulkhead-2
- Static Load
  - Max Pressure
  - Overburden Pressure
  - Self Weight
- Contact

Activated Data:
- Mesh
  - Access Lining
  - Bulkhead-2
  - Conveyance Lining
  - Overflow Lining
- Boundary Condition
  - Bulkhead-2
- Static Load
- Contact

Deactivated Data:
- Mesh
- Boundary Condition
- Static Load
- Contact

Initial Condition

☐ Define Water Level For Global

☐ Define Water Level For Mesh Set

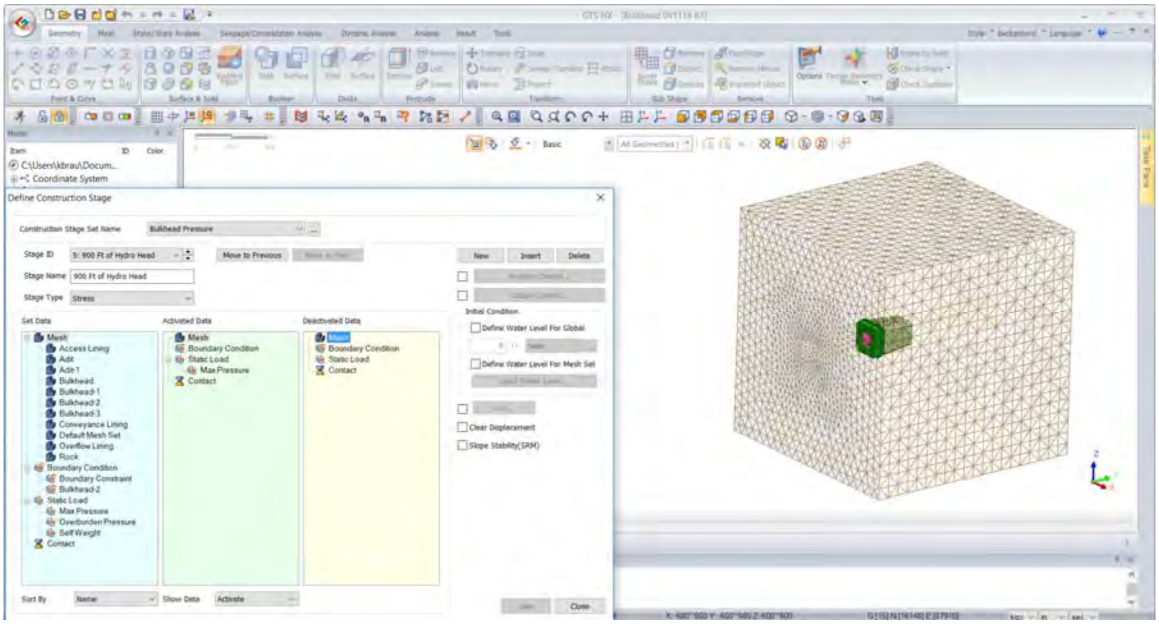
☑ Clear Displacement

☐ Slope Stability(SRM)

Sort By: Name

Show Data: Activate

Step 5: 900 Ft of Hydro Head: With the bulkhead in place, this construction step simulates the maximum water pressures as lateral loads acting on the inby face of the bulkhead and near mid-length for the two pipes. The maximum water pressure corresponds to a fully inundated mine complex to the Meldrum Level where any additional flow would discharge. Although the typical water pressures will be much lower, the maximum water pressure represents the critical load case for the bulkhead.



Define Construction Stage

Construction Stage Set Name: Bulkhead Pressure

Stage ID: 5: 900 Ft of Hydro Head

Stage Name: 900 Ft of Hydro Head

Stage Type: Stress

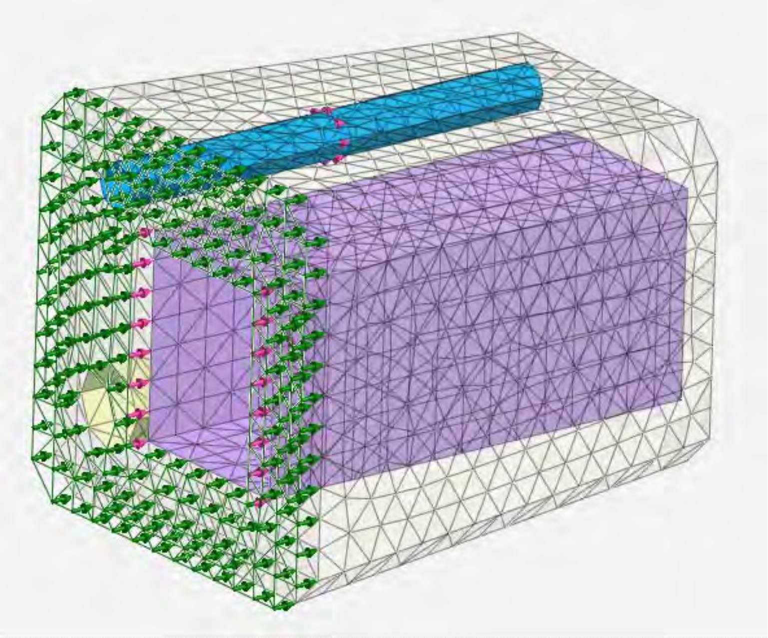
Set Data:
- Mesh
  - Access Lining
  - Adit
  - Adit 1
  - Bulkhead
  - Bulkhead-1
  - Bulkhead-2
  - Bulkhead-3
  - Conveyance Lining
  - Default Mesh Set
  - Overflow Lining
  - Rock
- Boundary Condition
  - Boundary Constraint
  - Bulkhead-2
- Static Load
  - Max Pressure
  - Overburden Pressure
  - Self Weight
- Contact

Activated Data:
- Mesh
- Boundary Condition
- Static Load
  - Max Pressure
- Contact

Deactivated Data:
- Mesh
- Boundary Condition
- Static Load
- Contact

Initial Condition
☐ Define Water Level For Global
☐ Define Water Level For Mesh Set
☐ Clear Displacement
☐ Slope Stability(SRM)

Sort By: Name
Show Data: Activate



Step 5: Maximum Hydrostatic Pressure Loads

Finite Element Analysis Results

As a check of the overall model both the vertical and lateral force summations were reviewed for accuracy. After the initial stage, the total vertical reaction (on the model lower boundary) is 1,644,000 kips which processing for the applied rock unit weight of 0.160 ksf and the 100 sf x 100 sf model footprint, corresponds to a rock height of 1027.5 vf. For the ground surface at El. 10,050, adit springline at El. 9072.25, and the lower model boundary at El. 9022.25 resulting in a total rock column height of 1027.75 ft. Thus the vertical loads appear reasonable. For the lateral water pressure on the bulkhead, the total horizontal reaction (in the Y-axis direction) is 8667.7 kips. The pressure load is applied over the full inby concrete surface ((12.5')(12.5') – 2 sf chamfer corners = 154.25 sf resulting in an effective applied pressure of 8667.7 kips/154.25 sf = 56.2 ksf; the hydrostatic pressure has been correctly applied.

Ground Displacements and Reactions:

The maximum water pressure results in minor displacement of the rock with a maximum total displacement of 0.0280" (shown below). This magnitude includes the major displacement parallel to the adit (0.019"; due to large pressure) but also a minor amount of displacement inwards. It is noted that a portion of the deformation occurs inby of the bulkhead and this is due to mesh connectivity essentially "pulling" the rock. For final design, an interface can be introduced to reduce this aberration. Regardless, the fully loaded bulkhead will not result in significant deformation of the surrounding rock mass.

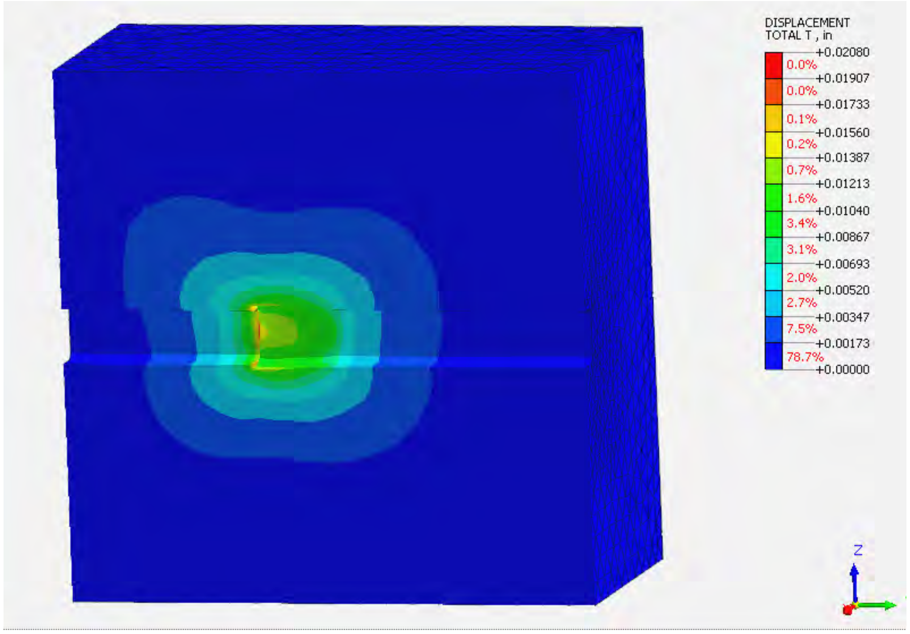


Figure 10: FEA Output for Total Displacements in Surrounding Rock Mass

With regards to the imposed rock stresses, the lateral stress in the direction of the pressure (Y-axis) has increased as shown below but does not represent a significant increase in the in situ rock stress. One item to note is that there is significant compressive rock stress in the vertical direction due to approximately 1000 feet of overlying rock and even with a lateral coefficient of Ko =0.5, there is a substantial existing horizontal in situ rock stress. While the water pressure is a significant pressure increase, the water pressure remains less than the original in-situ lateral pressure and in some sense, the bulkhead will be partially reloading the rock surfaces to pre-adit stress conditions. Observing the stress field outby of the bulkhead, consideration will be given to extending the model boundaries further in the outby direction to allow the stress concentrations to fully dissipate.

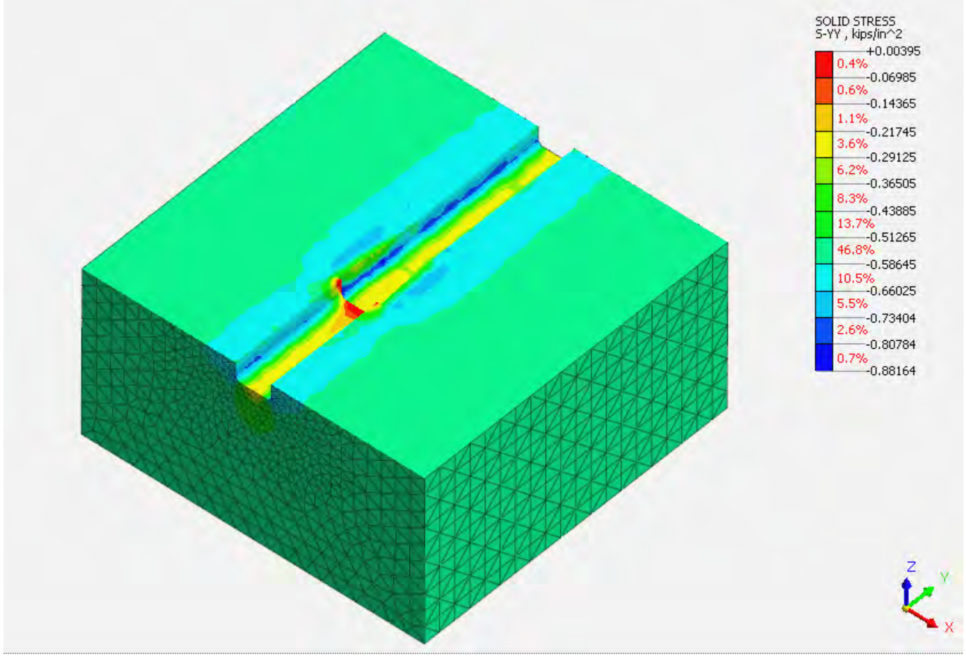


Figure 11: FEA Output for Lateral Stress In-Line with Adit in Surrounding Rock Mass

The principal stresses (shown below) indicate only a minor level of compressive rock stress around the bulkhead with the maximum stress of 2.2 ksi which is approximately half of the minimum intact rock strength. Interestingly, the induced bulkhead stresses are not large enough to overcome the vertical in situ stress concentrations at the corners of the adit and the largest principal stress remains unchanged from the construction stage of the bulkhead. The benefit of the tapered plug configuration is that it spreads out the rock reaction over the entire length of the bulkhead and avoids stress concentrations. Again, for final design, consideration will be given to simulating a steady-state groundwater table corresponding to the maximum head and reflecting the pressure decrease along the bulkhead. Also for reference, the magnitude of the induced tension in the rock is relatively minor (4 psi) and will be refined during final design.

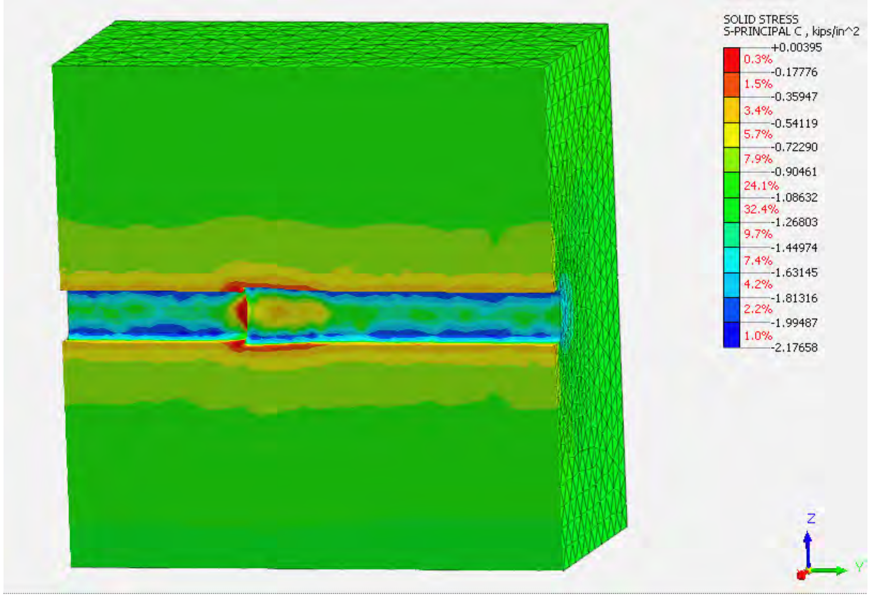


Figure 12: FEA Output for Principal Compressive Stresses in Surrounding Rock Mass

Concrete Bulkhead Displacements and Stresses:

One of the key items of interest for the FEA is the stresses and displacements of the concrete in response to the maximum hydrostatic pressure. As shown below, the maximum total displacement of the bulkhead concrete is minor (0.037 inches) indicating that deflection cracking will not be a concern. The maximum deflection is concentrated along the two vertical corners of the access opening where the door loads bear directly on the concrete. The node loads along with the one-way structural assumption for the door result in a significant loading at the exact corner. In reality, this load will be distributed over a larger area and will require embedded structural members to transfer the load to the concrete; essentially these concentrated deflections will be eliminated with a proper door and access way design. The other item to note is that the deflections of the concrete for the area near the inby face are into the access way, indicating that the 1" steel plate lining is not sufficiently stiff by itself. Additional FEA simulations will be conducted during final design to determine if increasing the access way stiffness will decrease the concrete distortions and accompanying other stresses. Also note that the images below amplify the deflections considerably to provide a indication of distortions; the actual distortions are not readily discernable.

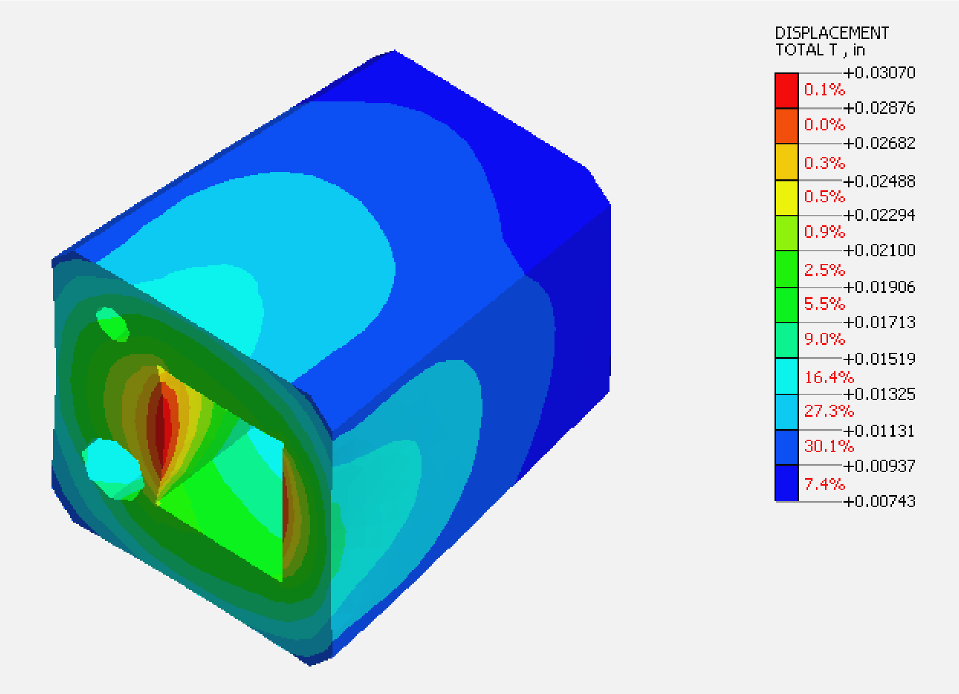


Figure 13: FEA Output for Total Displacements in Concrete Bulkhead

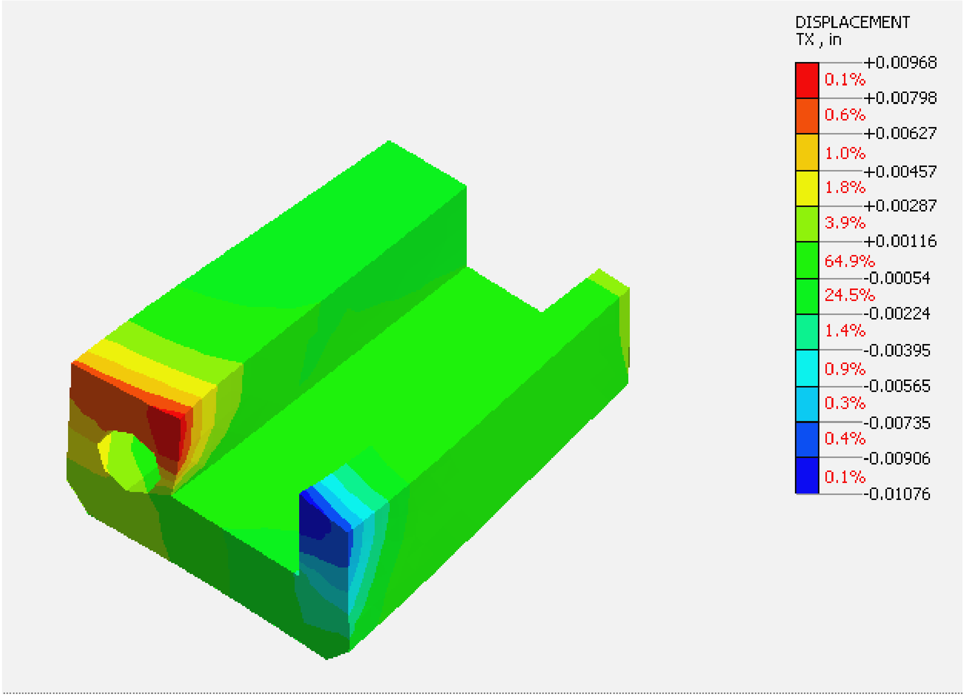


Figure 14: FEA Output for Transverse Displacements in Concrete Bulkhead

With regards to stresses, the principal stresses in the concrete bulkhead remain within the limits of the 4000 psi concrete. Per ACI 318 22.5.2, the maximum compressive stress for compression controlled sections is limited to:

$\phi Pn = 0.60\phi(f'c)$ where: ϕ = strength reduction factor = 0.60 for plain concrete
f'c = 28 day concrete compressive strength = 4000 psi

Since the FEA loads are unfactored, the design limit will need to be further reduced by the 1.4 static load factor:
Design limit = $\phi Pn/LF = 0.60\phi(f'c)/(LF) = 0.60(0.6)(4000\ psi)/1.4 = 1029\ psi$

This limit is conservatively based upon plain concrete recognizing that the steel reinforcement will be only located near the inby and outby concrete faces. For these areas, the design limit (per ACI 318 10.3.6.2) increases to 0.80(0.85)(0.65)(4000 psi)/1.4 = 1263 psi. Per the FEA output below, the maximum principal stress is 1.14 ksi occurring at the vertical corners of the access opening on the pressure side of the bulkhead. As noted previously, this stress concentration is associated with the load transfer of the door and is a bearing load situation which has an increased design limit. Also note that these design limits incorporate the prescribed ACI safety factors via load factors and strength reduction factors.

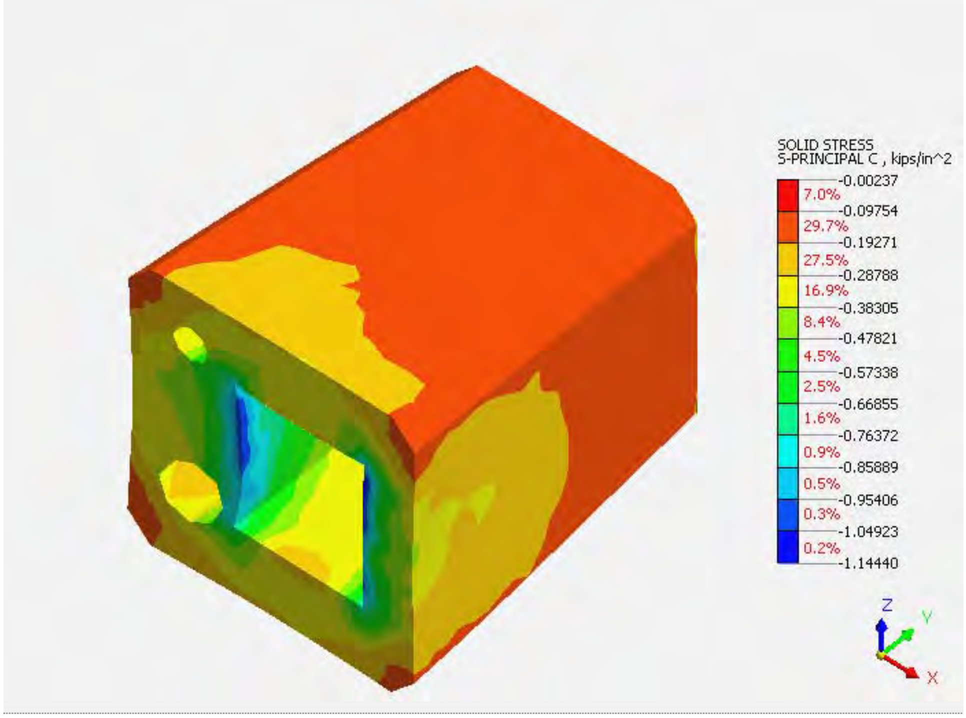


Figure 15: FEA Output for Principal Compressive Stresses in Concrete Bulkhead

In addition to direct compression, the concrete bulkhead will need to have adequate shear capacity to transfer the loads to the rock perimeter. One benefit of the access way is that it does transfer loads closer to the perimeter of the bulkhead and conventional shear mechanisms, such as beam shear and punching shear, do not have a free face for failure. This will require that the linings for all of the penetrations have adequate capacity to resist both the external water pressure directly and resulting load distributions within the concrete. The FEA quantifies the pure shear distribution in the concrete (shown below). For pure or direct concrete shear, the design limit is indicated in ACI 318 11.6.3 Commentary for shear friction without any reinforcement and is 400 psi for normal concrete. Reducing this ultimate limit for the load factor (1.4) and strength reduction factor results in a direct shear design factor of $\phi V_c/LF = 0.60(400 \text{ psi})/1.4 = 171$ psi for plain concrete and $(0.75/0.60)(171 \text{ psi}) = 214$ psi for reinforced concrete. These limits are based on unconfined concrete and imposed confining pressures will increase the failure limits significantly. Per the FEA output (below), the maximum shear stress for the majority of the bulkhead remain within these design limits indicating structural adequacy. Also, the lower bound of the rock strength is on the order of the concrete strength, the shear capacity of the rock will be similar or greater than the concrete and again there is not a clear failure path within the rock.

Near the inby surface, there are some localized concentrations of shear that exceed the design limits that will need to be resolved during final design. It is anticipated that refining the FEA model to more realistically simulate the load transfer from the door will reduce the shear values significantly. Stiffening of the access way near the inby face will also reduce inward displacement and accompanying shear; note that the shear distribution shown is towards the access way rather than into the rock. Consideration will be given during final design to simulating the concrete as a Mohr-Coulomb material to take into the account the increased shear capacity due to confining pressures.

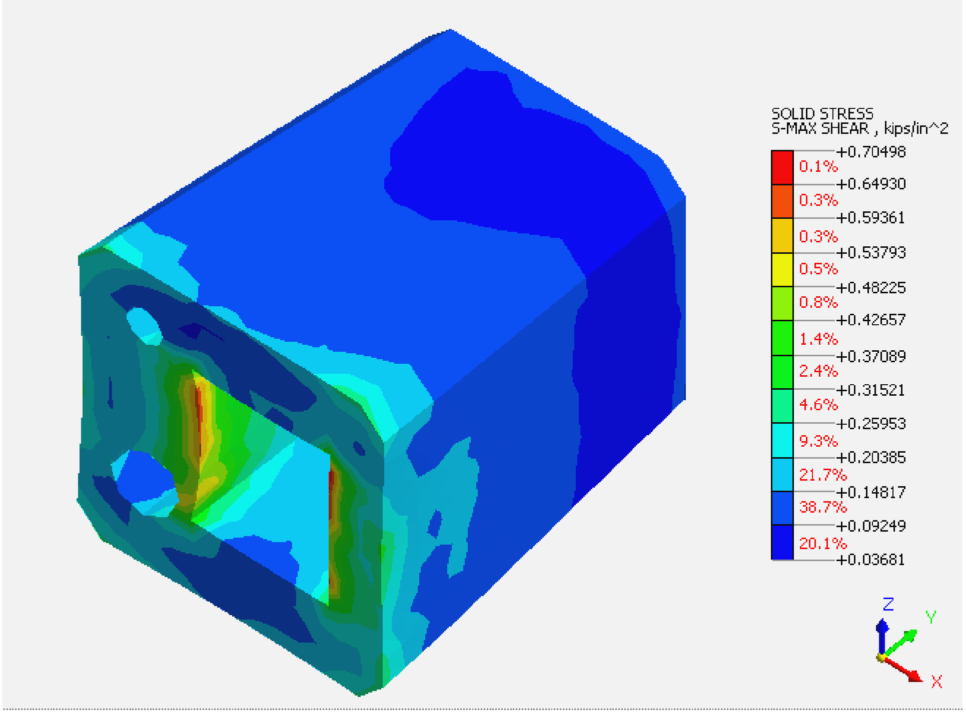


Figure 16: FEA Output for Shear Stresses in Concrete Bulkhead

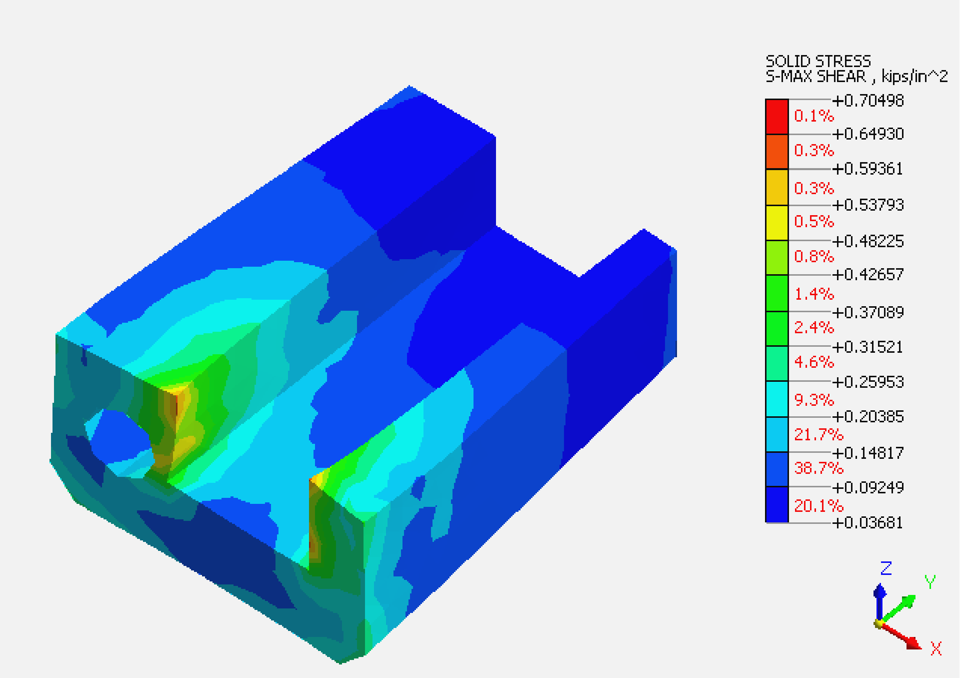


Figure 17: FEA Output for Shear Stresses in Concrete Bulkhead (cut view for clarity)

Steel Lining Displacements and Stresses:

For the access way, the lower conveyance pipe, and the upper overflow/vent pipe, the corresponding steel linings have been included in the initial FEA simulation. One of the primary purposes was to identify any significant issues with having the multiple penetrations in close proximity to one another in the concrete bulkhead. The other benefit is that it does allow for direct quantification of the lining deformations and stresses, although the direct application of the water pressure as load does limit the usefulness of the output. Additional design evaluation will be required for the steel linings.

The maximum displacements are shown below and match the distortions of the surrounding concrete.

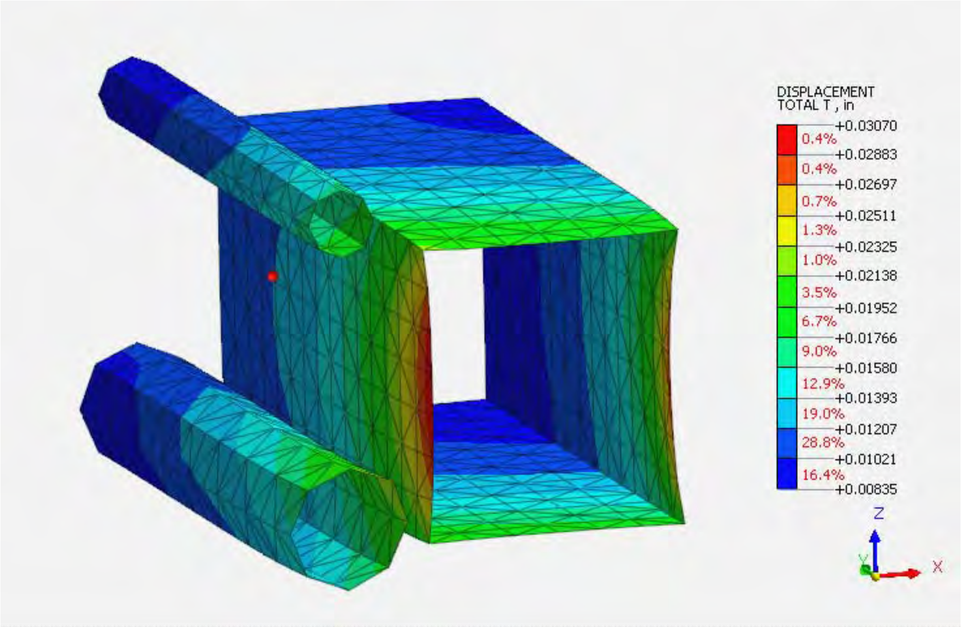


Figure 18: FEA Output for Total Displacements in Steel Linings

Based on the stresses (Von Mises) obtained from the FEA output, the steel lining thicknesses appear adequate for even relatively low yield associated with stainless steel grades (Fy = 30 ksi; allowable steel stress = 0.6Fy = 18.0 ksi). The maximum combined stress of 8.2 ksi is well within the allowable design range for stainless steel (including stainless Type 304). Again, the pipe and access way do not have any external pressures applied only axial forces associated with the pressure resistance of the openings themselves.

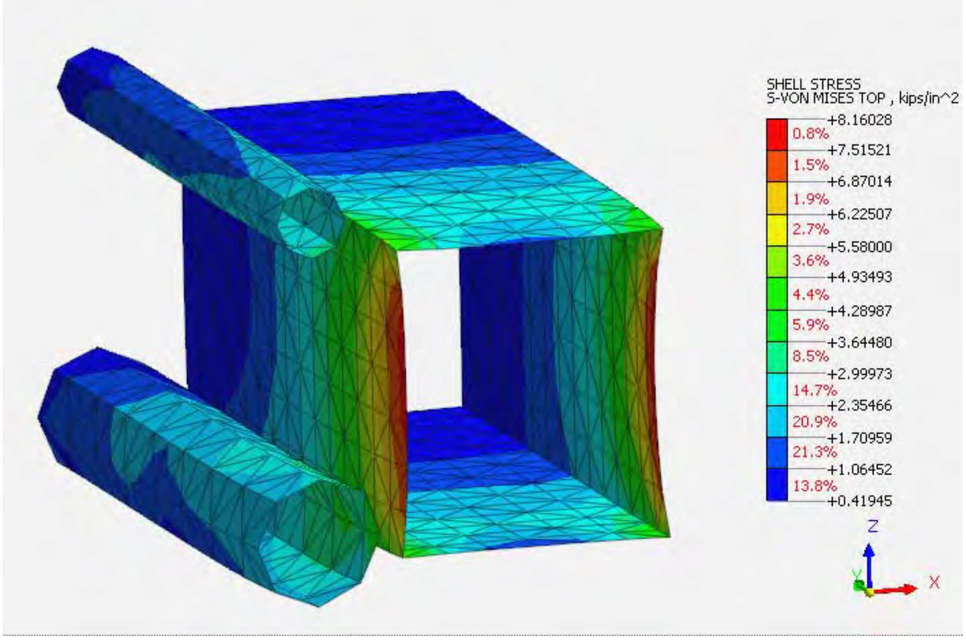


Figure 19: FEA Output for Combined Stresses in Steel Linings

Conclusions:

The initial 3D FEA evaluation has simulated the response of the concrete bulkhead to the maximum anticipated hydrostatic pressure and confirmed that the current 15 foot bulkhead length is acceptable. One key item to note is that the rock deformations and stresses remain low (even with conservative assumptions on rock mass parameters), indicating adequate transfer of load into the rock mass. Similarly, the concrete bulkhead deformations and stresses appear to be within the capacity of the concrete for the bulkhead areas away from the door loads. Additional refinements in the model will be performed during final design to assess the interaction with the selected pressure door, door frame, and stiffened access way.

Attachments:

Preliminary Bulkhead Design Calculations (per Prof. Abel design methodology; 5 pages)

Design underground pressure bulkhead utilizing design methodology presented in J.F. Abel "*Bulkhead Design for Acid Mine Drainage*" (in Proceedings of Western United States Mining-Impacted Watersheds, Denver, CO (1998))

Input:
10 ft b = adit width
10 ft h = adit height
900 ft D = hydrostatic head acting on bulkhead (to adit invert)
4000 psi f'c = concrete compressive strength (28 day)
200 psi fr_s = minimum rock shear strength (intact rock)
160 pcf γ_r = unit weight of rock
10 ft L_1 = selected bulkhead length
3.5 in c_c = depth to reinforcment center from tensile face
60,000 psi Fy = yield strength of reinforcement
0.188 g PGA = peak ground acceleration due to maximum seismic event
300 ft S_1 = line-of-sight distance on pressure side of bulkhead

Hydraulic Pressure Gradient

Calculate minimum bulkhead length to satisfy allowable hydraulic pressure gradient:

Maximum hydrostatic pressure: $\rho = D(\gamma_w) =$ 56,160 psf = 390.0 psi

For an ungrouted pressure plug, allowable pressure gradient of 5 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{ungrouted} = \rho/(5\ psi/lf) =$ 78.0 lf

For a contact grouted pressure plug, allowable pressure gradient of 40 psi/lf (includes SF of 4.0):
Minimum bulkhead length: $L_{contact} = \rho/(40\ psi/lf) =$ 9.8 lf

Perimeter Shear Strength

Verify adequate perimeter shear strength:

Concrete ultimate shear strength (per ACI 318 11.3.1.1.)
$f'_s = 2(f'c)^{0.5} =$ 126 psi

Minimum rock shear strength: $fr_s =$ 200 psi

Since, the shear strength of the concrete is less than the rock shear strength, concrete shear controls.
Critical shear strength: $fs_{critical} =$ 126.5 psi

Minimum bulkhead length for perimeter shear: $L_{shear} = \rho(h)(b)/(2(h+b)fs_{critical}) =$ 7.7 feet

Minimum Bulkhead Depth

Calculate minimum rock cover to avoid rock hydrofracing due to hyrdrostatic pressure in the adit.

Breakdown pressure for hydrofracing: $B_p = T_s + 3S_{min} - S_{max} - P_f$

Assume: $T_s = 0$ tensile strength of rock due to existing joints and fractures
$S_{min} = S_{max} = S_{ovb}$ = overburden rock stress for K = 1.0
$P_f = 0$ formation pore pressure

$B_p = 2S_{ovb} = 2(\gamma_r)(H_r)$
setting Bp = ρ maximum hydrostatic pressure and solving for H_r yields the following:

Minimum rock cover: $H_{r(min)} = \rho/2\gamma_r =$ 175.5 feet

Plain Concrete Bulkhead Design

Calculate minimum bulkhead length for unreinforced bulkhead to resist maximum bending moment due to the hydrostatic pressure. Treat bulkhead as simply supported beam.
Design in accordance with ACI 318-10 Chapter 22 Plain Structural Concrete.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
$\phi = 0.60$ strength reduction factor for plain concrete (per ACI 318 9.3.5)

Maximum bulkhead forces:
Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8 =$ 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2 =$ 393,120 lbs/lf

Plain Concrete Bending Capacity per ACI 318 22.5.1
Mu ≤ øMn $\quad øM_n = ø5(f'c)^{1/2}S$ for tension controlled sections
where S = section modulus of section per unit foot = (12 inches)$L^2/6$
where L = bulkhead length (in inches)
$øM_n = ø5(f'c)^{1/2}(12(L^2)/6)$

Setting ϕMn = Mu and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi 5(f'c)^{1/2}(12))]^{1/2} =$ 176.29199 inches = 14.69 feet

Mu ≤ øMn $\quad øM_n = ø(0.85)(f'c)S$ for compression controlled sections
$øM_n = ø(0.85)(f'c)(12(L^2)/6)$
Setting ϕMn = Mu and solving for the minimum bulkhead L_{min}:
$Lmin = [(6Mu/(\phi(0.85)(f'c)(12))]^{1/2} =$ 53.76 inches = 4.48 feet

Therefore, bending tensile stress controls and min. plain concrete bulkhead length = 14.69 feet

Reinforced Concrete Bulkhead Design

Determine minimum steel area for bulkhead based on selected bulkhead length. Design in accordance with ACI 318-10 reinforced concrete design methodology. Analyze a one foot unit width (12") beam.

Utilize 1.4 dead load factor for fluid (per ACI 318 9.2.4)
ϕ_t = 0.90 tension controlled strength reduction factor (per ACI 318 9.3.2.1)
ϕ_c = 0.65 compression controlled strength reduction factor (per ACI 318 9.3.2.2)
ϕ_v = 0.75 shear strength reduction factor (per ACI 318 9.3.2.3)

Maximum bulkhead forces:

Design as a one-way slab for smaller adit dimension: x = 10 feet

Moment: $Mu = 1.4(\rho)x^2/8 =$ 982,800 lb-ft/lf = 11,793,600 lb-in/ft
Shear: $Vu = 1.4(\rho)x/2 =$ 393,120 lbs/lf

Compression Resultant Force:

C = 0.85(f'c)(12"/ft)a

Tension Resultant Force:

$T = AsF_y$

Set C=T and solve for a: a = AsFy/(0.85(f'c)12) = 1.4706 As

Nominal Moment Capacity: ϕMn

$\phi Mn = \phi_t AsFy(d-a/2)$ $d = L_1 - c_c =$ 116.5 inches

Set ϕMn = Mu, substitute a in terms of As, and solve for As; resulting quadratic equation:

$39705.88\ As^2 - 6291000\ As + 11753894 = 0$

As = 1.891 $in^{2/}lf$ minimum steel area required

Shear Capacity:

Design as a deep flexural member utilizing simplified shear calculations presented in 1999 or earlier ACI 318 Section 11.8.7.

Shear Capacity Limit (per ACI 318 11.8.7):

$\phi Vc = \phi 6((f'c)^{0.5})(12"/ft)(d) =$ 397,878 lbs/lf

Reinforced Concrete Bulkhead Design (Continued)

Nominal Shear Capacity (per ACI 318 11.8.7):

$\phi Vc = \phi(3.5\text{-}2.5Mu_c/(Vu_c(d)))(1.9(f'c)0.5 + 2500(As/((12'/ft)(d))(Vu_c d/Mu_c))(12''/ft)(d)$

where: Vu_c= shear at critical section

Mu_c = moment at critical section

Critical section distance: $L_c = 0.15x$ = 1.5 feet

$Vu_c = (Vu(0.5x - L_c))/(0.5x)$ = 275,184 lbs/lf

$Mu_c = 1.4(\rho(L_c)/2)(x\text{-}L_c)$ = 501,228 lb-ft/lf = 6,014,736 lb-in/lf

$3.5\text{-}(2.5Mu_c/(Vu_c(d)))$ = 3.0309626 ≤ 2.5 max ; limit to 2.5

ϕVc = 404,751 lbs/lf ≤ 397,878 lbs/lf shear limit

ϕVc = 397,878 lbs/lf shear capacity limit controls

Since, $\phi Vc > Vuc$; shear capacity is adequate

Earthquake Resistant Design

Verify that the bulkhead capacity is adequate to resist the peak ground acceleration associated with the maximum credible seismic event. Total design load:

U_e = 1.2(dead load) + 1.0(earthquake load) per ACI 318 9.2.1.

Conservative estimate of earthquake load is assuming that the unobstructed water mass is fully accelerated by the seismic event.

Earthquake Load: $E = PGA(W_t + W_f)$ where:

Peak ground acceleration: PGA = 0.188 g

For selected bulkhead thickness: L_1 = 10 ft

Typical unit weight of concrete: γ_c = 150 pcf

Typical unit weight of water: γ_w = 62.4 pcf

Bulkhead total weight: $W_t = (b)(h)(L_1)(\gamma_c)$ = 150,000 lbs

Total weight of water: $W_f = (b)(h)(S_1)(\gamma_w)$ = 1,872,000 lbs

Earthquake Load: $E = PGA(W_t + W_f)$ = 380,136 lbs

Dead Load: $D = \rho(b)(h)$ = 5,616,000 lbs

Total Design Load: Ue = 1.2D + 1.0E = 7,119,336 lbs

Prior static design was based on U_s = 1.4D = 7,862,400 lbs

Since Us > Ue; static design controls and bulkhead design is adequate for earthquake

Design Summary

Minimum bulkhead length for ungrouted plain concrete bulkhead:	78.0	feet
Minimum bulkhead length for contact grouted plain concrete bulkhead:	14.7	feet
Selected bulkhead length for contact grouted reinforced bulkhead:	10	feet
Minimum area of steel for reinforced bulhead:	1.891	in^2/lf
Minimum required overburden cover above bulkhead:	175.5	feet

Appendix I
Seismic Evaluation

Summary:

The primary structural calculations for the bulkhead are based on the maximum static forces with a conventional dead load factor of 1.4, which is assumed to control the design. Verify that the factored seismic forces remain lower than the factored static forces.

The peak ground acceleration for the Idarado Mine Site is 0.179g for the maximum seismic event (per USGS online seismic hazard tool). Due to the linear nature of the Mill Level adit, the Abel seismic approach of assuming that the entire inby mass of water within line of sight is instantly accelerated by the maximum seismic event results in extremely large seismic surge forces. A more refined seismic approach is presented in Sawyer “A Method for Calculating Hydrodynamic Loads on Underground Bulkheads” in the *Proceedings of the 2007 SME Annual Meeting* adapting hydrodynamic loads for dams to the underground bulkhead situation. Per Sawyer for hydrostatic heads greater than the bulkhead height, the total hydrodynamic force is:

$$F_t = 0.354(PGA)\gamma_w b[H(h^2-H^2)^{1/2} + h^2 \text{asin}(H/h)]$$

where: Ft = total hydrodynamic force acting on bulkhead in pounds
PGA = peak horizontal ground acceleration as a fraction of gravity = 0.179
γ_w = unit weight of water = 62.4 pcf
b = bulkhead width = 10 feet
H = bulkhead height = 10 feet
h = maximum fluid height = 900 feet
asin(H/h) is converted to radians

$$F_t = 0.354(0.179)(62.4\text{pcf})(10')[(10')((900')^2-(10')^2)^{1/2} + (900')^2\text{asin}(10'/900')]$$
$$F_t = 711{,}349 \text{ lbs} = 711.3 \text{ kips}$$

Per ACI 318 9.2.1., the total design load for seismic load is:

U_e = 1.2(dead load) + 1.0(earthquake load)
This results in the following total lateral design pressure on the bulkhead:
$U_e = (1.2)(56.2 \text{ ksf})(10')(10') + 1.0(711.3 \text{ kips}) = 7450.5 \text{ kips}$

The prior static design was based on $U_s = 1.4D = 1.4(56.2\text{ksf})(10')(10') = 7862.4$ kips.

Therefore, static design will be the controlling design case ($U_s > U_e$) and no design modifications are needed for the seismic event.

Refer to attached USGS output for documentation of the peak ground acceleration (PGA) at the site.

USGS Design Maps Detailed Report

2009 NEHRP Recommended Seismic Provisions (37.93821°N, 107.81117°W)

Site Class B – "Rock", Risk Category IV (e.g. essential facilities)

Section 11.4.1 — Mapped Acceleration Parameters and Risk Coefficients

Note: Ground motion values contoured on Figures 22-1, 2, 5, & 6 below are for the direction of maximum horizontal spectral response acceleration. They have been converted from corresponding geometric mean ground motions computed by the USGS by applying factors of 1.1 (to obtain S_{SUH} and S_{SD}) and 1.3 (to obtain S_{1UH} and S_{1D}). Maps in the Proposed 2015 NEHRP Provisions are provided for Site Class B. Adjustments for other Site Classes are made, as needed, in Section 11.4.3.

Figure 22–1: Uniform–Hazard (2% in 50–Year) Ground Motions of 0.2-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B

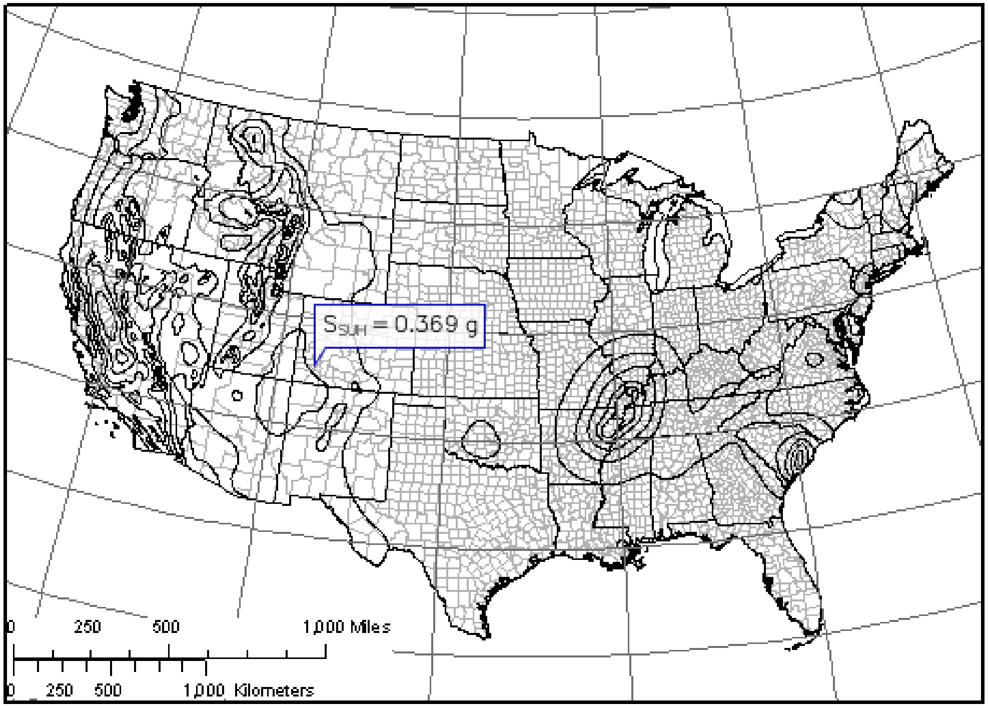
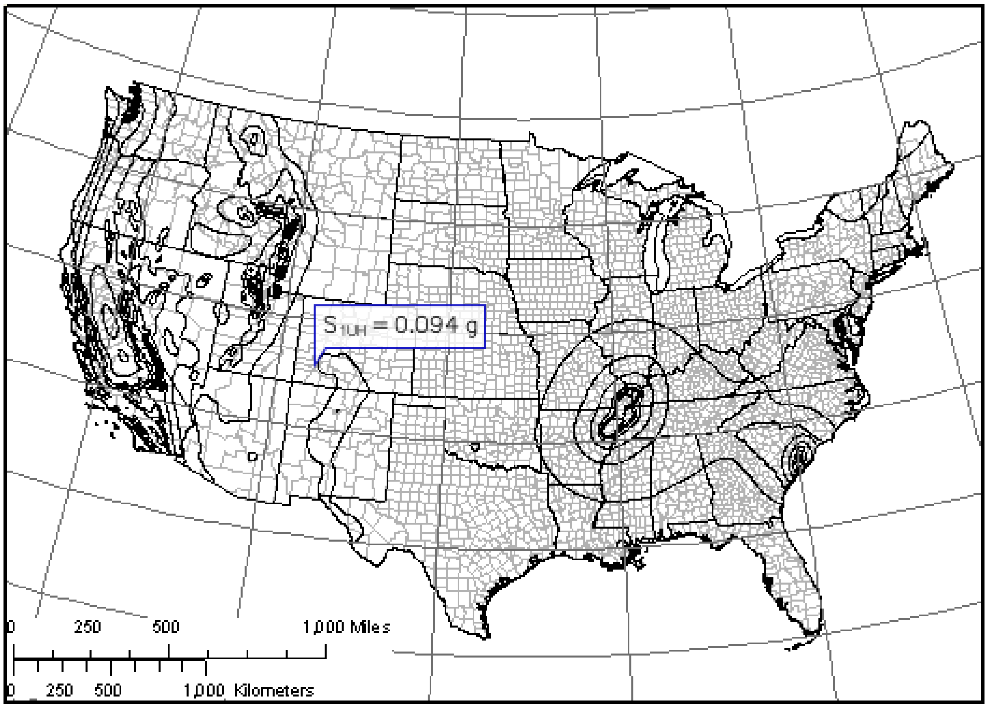


Figure 22–2: Uniform–Hazard (2% in 50–Year) Ground Motions of 1.0-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B


S_{1UH} = 0.094 g
0
250
500
1,000 Miles
0
250
500
1,000 Kilometers

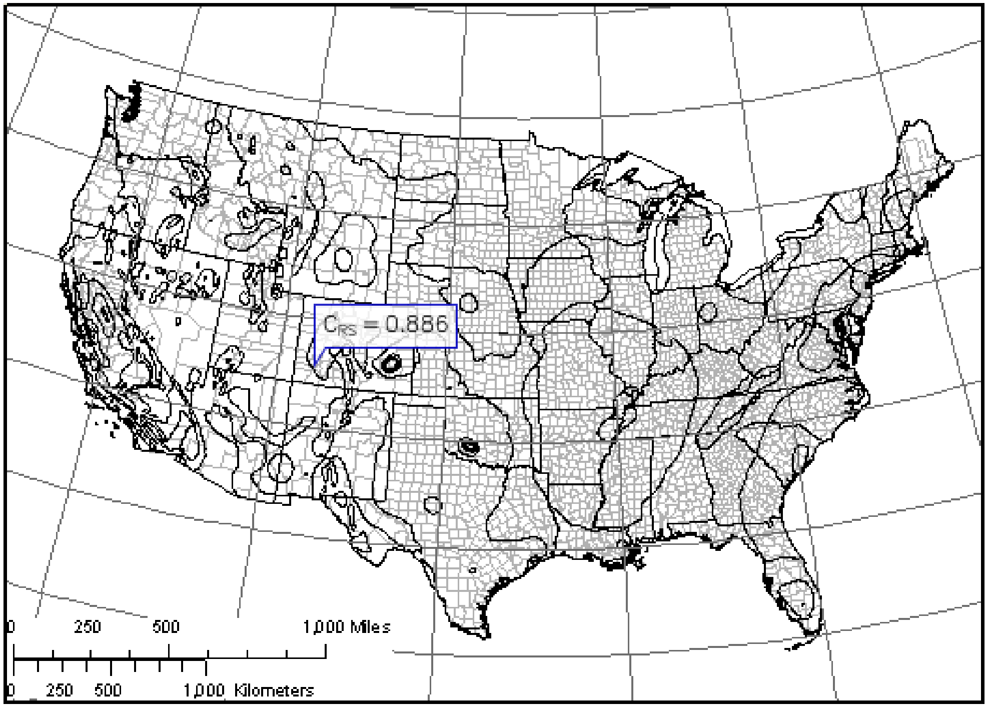


Figure 22–3: Risk Coefficient at 0.2-Second Spectral Response Period

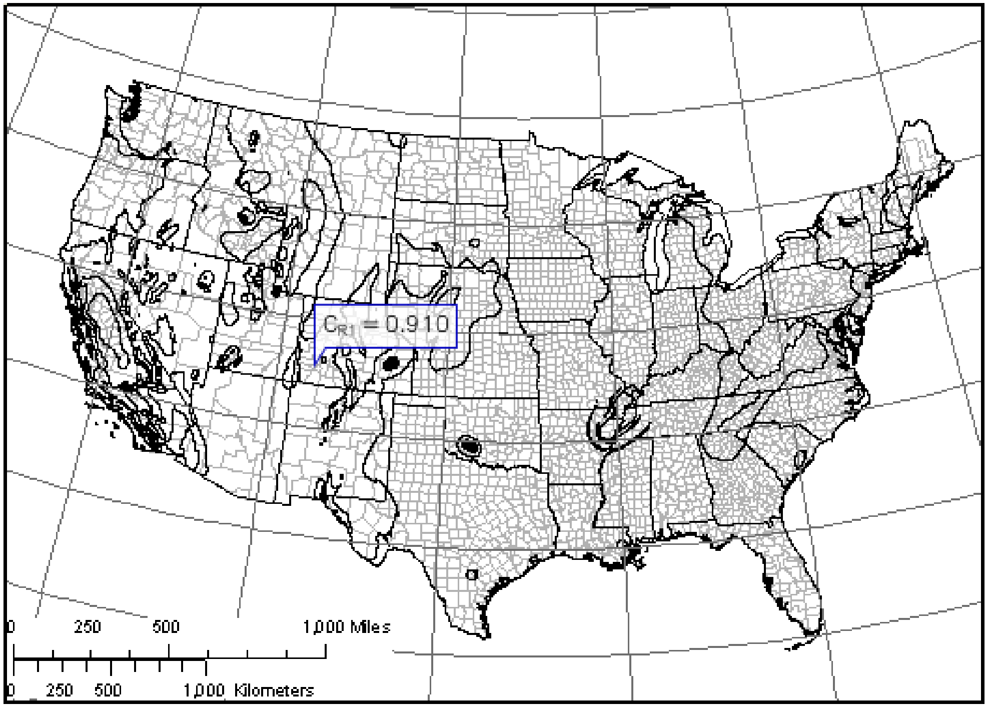


Figure 22–4: Risk Coefficient at 1.0-Second Spectral Response Period

Figure 22–5: Deterministic Ground Motions of 0.2-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B

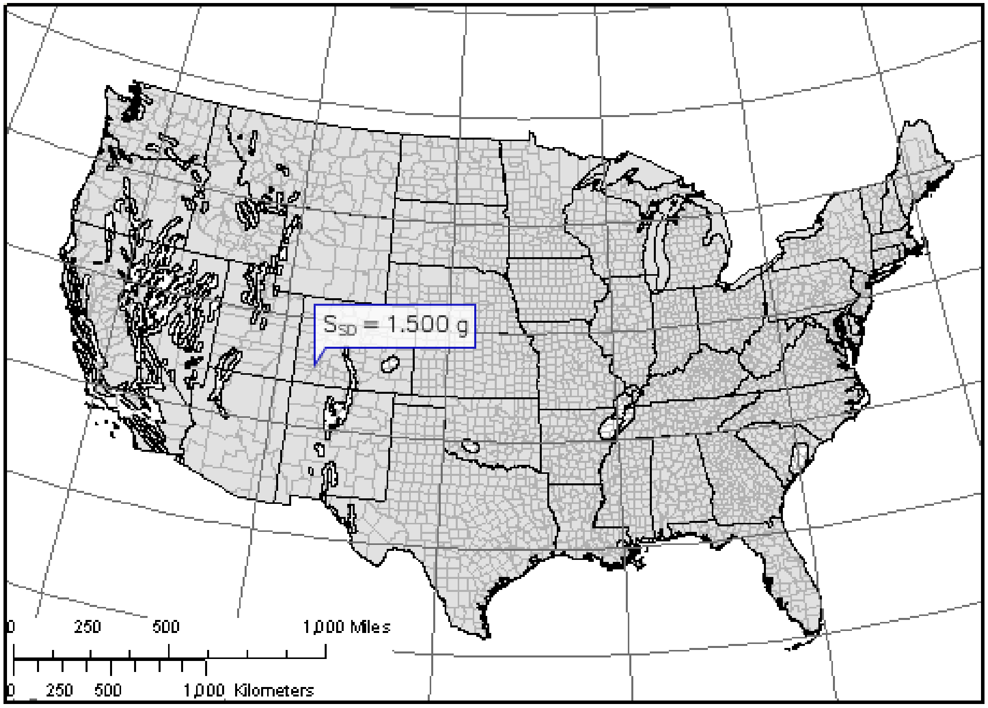
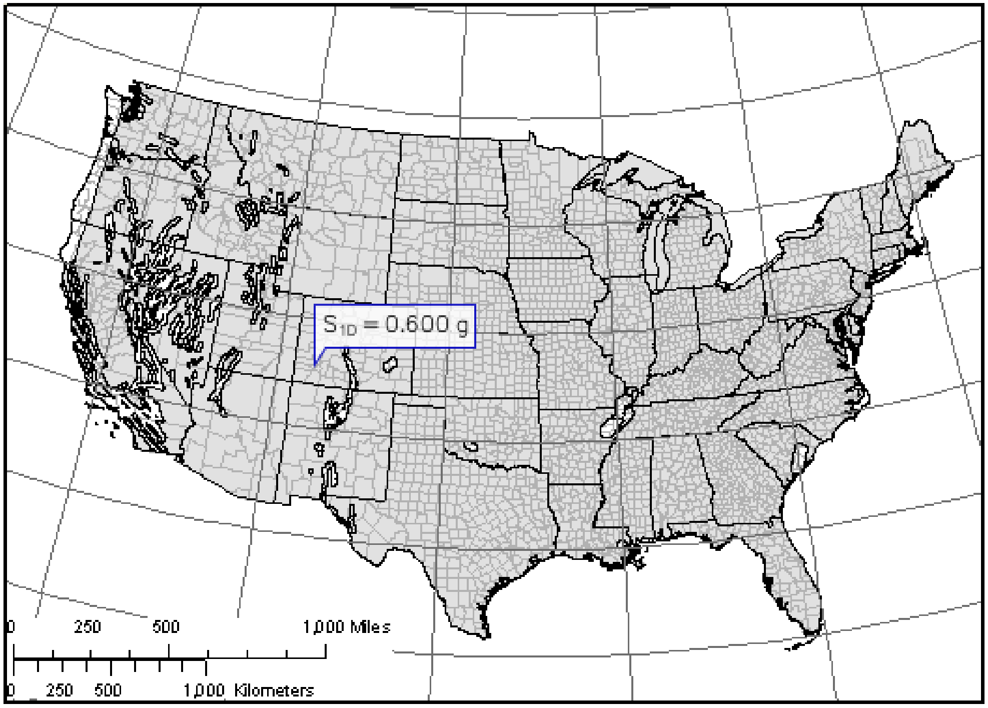


Figure 22–6: Deterministic Ground Motions of 1.0-Second Spectral Response Acceleration (5% of Critical Damping), Site Class B



Section 11.4.2 — Site Class

The authority having jurisdiction (not the USGS), site-specific geotechnical data, and/or the default has classified the site as Site Class B, based on the site soil properties in accordance with Chapter 20.

Table 20.3–1 Site Classification

Site Class	$\bar{v}_S$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard Rock	>5,000 ft/s	N/A	N/A
B. Rock	2,500 to 5,000 ft/s	N/A	N/A
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff Soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the characteristics: • Plasticity index PI > 20, • Moisture content w ≥ 40%, and • Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1ft/s = 0.3048 m/s 1lb/ft² = 0.0479 kN/m²

Section 11.4.3 — Site Coefficients, Risk Coefficients, and Risk–Targeted Maximum Considered Earthquake (MCE_R) Spectral Response Acceleration Parameters

Equation (11.4–1): $C_{RS}S_{SUH}$ = 0.886 x 0.369 = 0.327 g

Equation (11.4–2): S_{SD} = 1.500 g

S_S ≡ “Lesser of values from Equations (11.4–1) and (11.4–2)” = 0.327 g

Equation (11.4–3): $C_{R1}S_{1UH}$ = 0.910 x 0.094 = 0.085 g

Equation (11.4–4): S_{1D} = 0.600 g

S_1 ≡ “Lesser of values from Equations (11.4–3) and (11.4–4)” = 0.085 g

Table 11.4–1: Site Coefficient F_a

Site Class	Spectral Response Acceleration Parameter at Short Period				
	$S_S \le 0.25$	$S_S = 0.50$	$S_S = 0.75$	$S_S = 1.00$	$S_S \ge 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_S

For Site Class = B and S_S = 0.327 g, F_a = 1.000

Table 11.4–2: Site Coefficient F_v

Site Class	Spectral Response Acceleration Parameter at 1–Second Period				
	$S_1 \le 0.10$	$S_1 = 0.20$	$S_1 = 0.30$	$S_1 = 0.40$	$S_1 \ge 0.50$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of S_1

For Site Class = B and S_1 = 0.085 g, F_v = 1.000

Equation (11.4–5): $S_{MS} = F_aS_S = 1.000 \times 0.327 = 0.327$ g

Equation (11.4–6): $S_{M1} = F_vS_1 = 1.000 \times 0.085 = 0.085$ g

Section 11.4.4 — Design Spectral Acceleration Parameters

Equation (11.4–7): $S_{DS} = ⅔ S_{MS} = ⅔ \times 0.327 = 0.218$ g

Equation (11.4–8): $S_{D1} = ⅔ S_{M1} = ⅔ \times 0.085 = 0.057$ g

Section 11.4.5 — Design Response Spectrum

Figure 22–7: Long–period Transition Period, T_L (s)

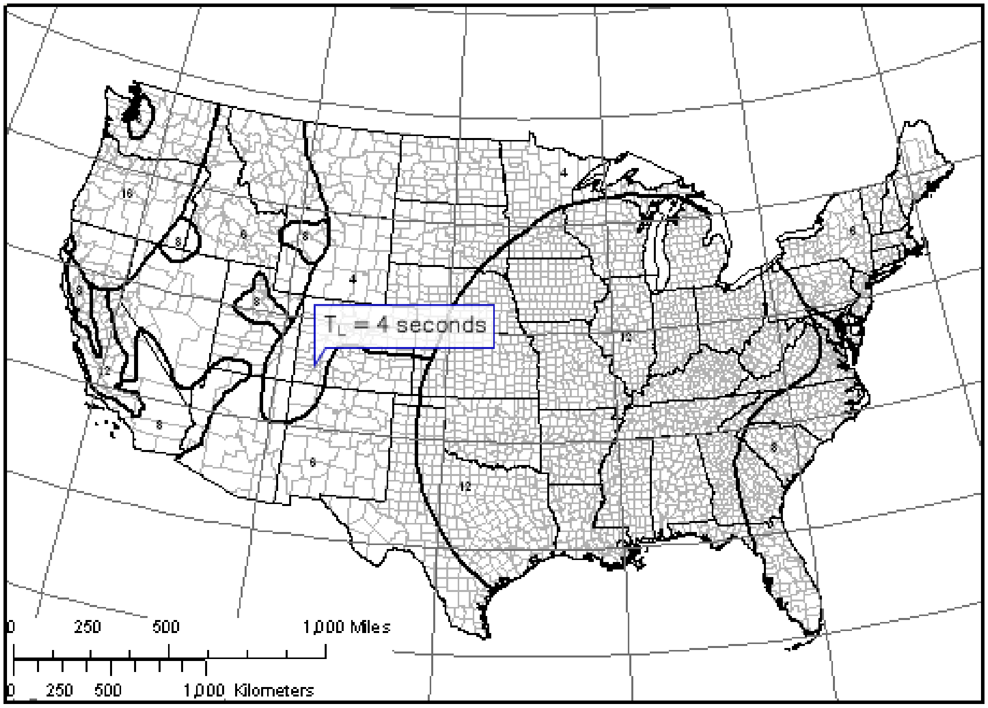
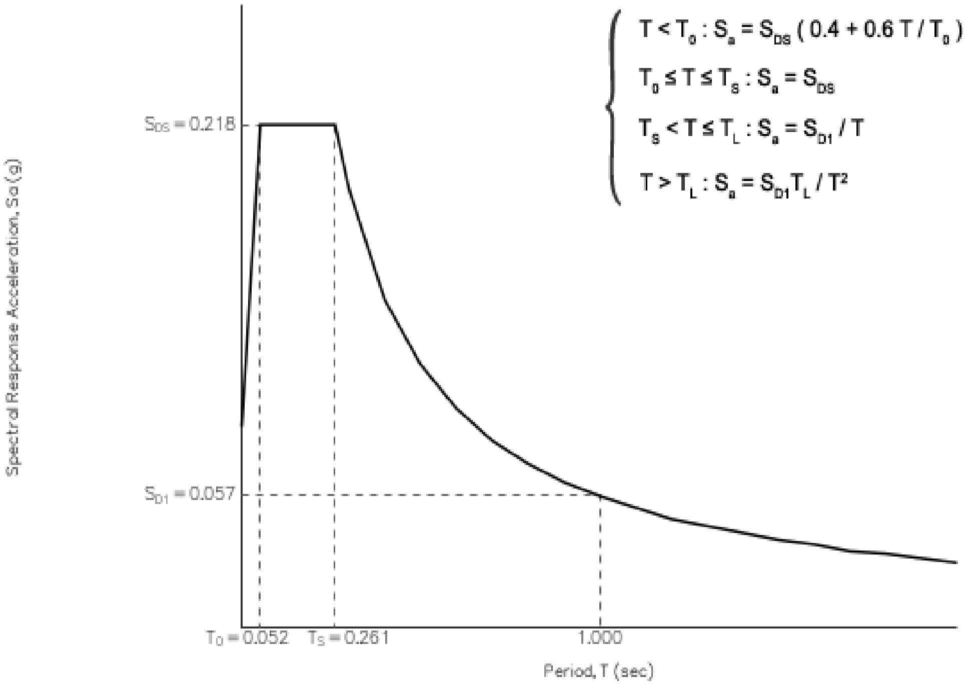
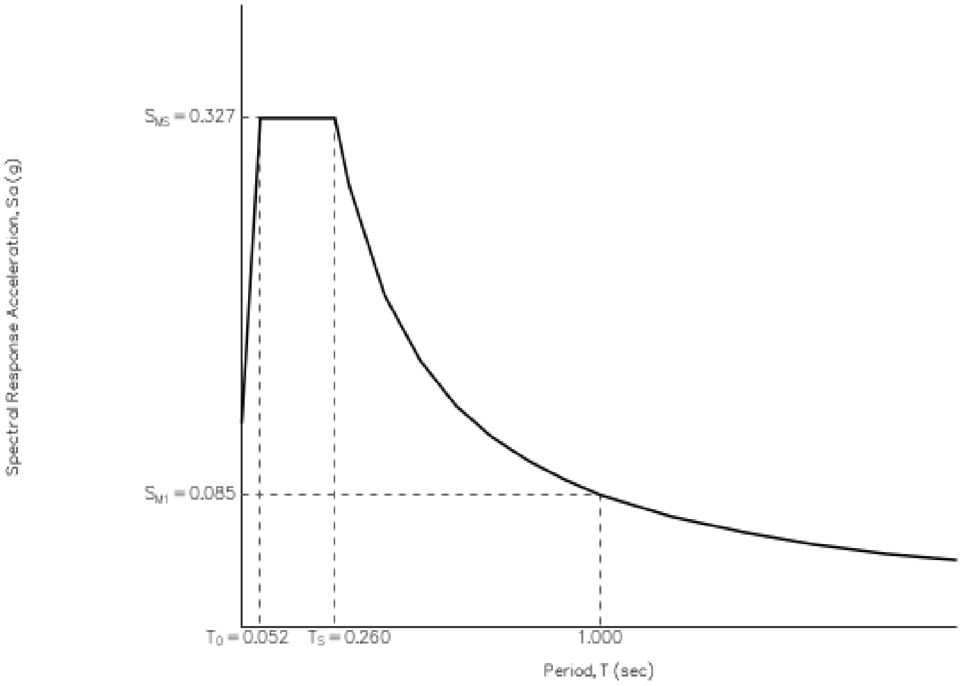


Figure 11.4–1: Design Response Spectrum



Section 11.4.6 — MCE_R Response Spectrum

The MCE_R response spectrum is determined by multiplying the design response spectrum above by 1.5.



Section 11.8.3 — Additional Geotechnical Investigation Report Requirements for Seismic Design Categories D through F

Table 11.8–1: Site Coefficient F_{PGA}

Site Class	Mapped MCE Geometric Mean Peak Ground Acceleration, PGA				
	PGA ≤ 0.10	PGA = 0.20	PGA = 0.30	PGA = 0.40	PGA ≥ 0.50
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	See Section 11.4.7 of ASCE 7				

Note: Use straight–line interpolation for intermediate values of PGA

For Site Class = B and PGA = 0.179 g, F_{PGA} = 1.000

Mapped PGA	PGA = 0.179 g
Equation (11.8–1):	$PGA_M = F_{PGA}PGA = 1.000 \times 0.179 = 0.179$ g

Appendix J

Routine Monitoring Plan

Routine Monitoring Plan

Mill Level Tunnel Bulkhead

Idarado Mining Company
Telluride, Colorado
March 12, 2018

Prepared For:
Idarado Mining Company
Telluride, Colorado

Prepared By:
Worthington Miller Environmental, LLC
1027 W. Horsetooth Rd., Suite 200
Fort Collins, Colorado 80526

TABLE OF CONTENTS

1.0 Introduction.......... 1

1.1 Summary of Current Conditions and Existing Monitoring System.......... 1

1.2 Objectives.......... 2

1.3 Routine Monitoring Plan Organization.......... 2

2.0 Rountine Monitoring Requirements.......... 4

2.1 Monitoring Locations.......... 4

2.2 Parameters.......... 4

2.3 Details of Routine Monitoring Program at the Various Locations.......... 5

2.3.1 Mill Level Tunnel Bulkhead Water Level, Flow Rates and Field Parameters.......... 5

2.3.2 Meldrum Tunnel Flow Rates and Field Parameters.......... 6

2.3.3 Springs/Seeps Survey.......... 6

3.0 Monitoring Procedures and Methods.......... 7

3.1 Monitoring Methods.......... 7

3.1.1 Equipment Calibration and Operation.......... 7

3.1.2 Water Level Measurement.......... 7

3.1.3 Water Flow Measurements.......... 7

3.1.4 Field Parameter Measurements.......... 7

3.2 Data Quality Assurance/Quality Control (QA/QC) Review.......... 8

3.2.1 Data Quality Assessment and Validation.......... 8

3.2.2 Data Management.......... 8

4.0 Data Evaluation.......... 9

4.1 Mill Level Tunnel.......... 9

4.2 Meldrum Tunnel.......... 9

4.3 Springs/Seeps.......... 10

5.0 Systematic Review and Revision of Monitoring Plan.......... 11

5.1 Need For Periodic Review And Revision of Monitoring Plan.......... 11

5.2 Procedure for Modification of Plan.......... 11

6.0 Reporting.......... 13

7.0 References.......... 14

LIST OF TABLES

Table 1. Monitoring Locations, Parameters and Frequencies

1.0 Introduction

This Routine Monitoring Plan (RMP) and the Contingency Plan (CP) (EA, 2018) govern the long-term implementation of the Mill Level Tunnel bulkhead at the Idarado Mine Site, located near Telluride, Colorado. The purpose of this RMP is to collect the appropriate type, amount, and quality of data needed to support the decision-making process described in the CP.

The Mill Level Tunnel flow-control bulkhead will serve to regulate the water flowrate delivered to the infiltration lagoons and infiltration ditch during peak flows by temporarily impounding water within the tunnel behind the bulkhead. The impounded water will be released under controlled flowrate conditions. This RMP describes the objectives of the monitoring program, monitoring points and parameters, monitoring procedures and methods, quality assurance procedures, data evaluation methods, and reporting requirements to be implemented during the routine monitoring mode of operation of the CP.

1.1 Summary of Current Conditions and Existing Monitoring System

Water drains from the Idarado underground mine through the Mill Level Tunnel and Meldrum Tunnel located in the upper San Miguel River watershed. This RMP addresses only the underground mine Hydrologic System associated with the Mill Level Tunnel and Meldrum Tunnel.

Water from the Meldrum Tunnel flows to a weepline and infiltration area. During the fourth quarter of 2017, instrumentation was installed at the Meldrum Tunnel portal to monitor water flow from the Meldrum Tunnel. Water from the Mill Level Tunnel is piped from the portal to a series of infiltration lagoons and/or an infiltration ditch. A headgate at the Mill Level portal allows water to be diverted into two separate pipelines that convey water to the infiltration lagoons or the infiltration ditch. A third pipeline connected to the infiltration lagoons pipeline can also be used to divert water to the infiltration ditch. As such, two pipe outlets exist at the infiltration ditch. During the second quarter of 2017, flumes and instrumentation were installed at each of the two pipe outlets to monitor flow to the infiltration ditch. Instrumentation was also installed at the existing flume at the outlet of the infiltration lagoons pipeline to monitor flow to the infiltration lagoons. The sum of the flows recorded at the three flumes represents the total flow from the Mill Level Tunnel.

As a contingency measure, a pipeline was installed from the Mill Level portal to the Meldrum infiltration area in the second quarter of 2017. Water can be pumped from the Mill Level portal to the Meldrum infiltration area using a portable pump. The pumping rate is recorded when operated.

Flow rates vary from both tunnels in response to climatic conditions. Peak flows generally occur in mid-June to early July due to increased recharge into the underground mine workings caused by snowmelt and precipitation in the upper basins of the San Miguel River watershed. Historically, flow data was collected from the Mill Level Tunnel and over the last few years observations and estimation of flows has been performed for both tunnels. This RMP provides for monitoring flows from the tunnels on a more consistent and current basis, to improve the understanding of baseline conditions. Due to the year-to-year and seasonal variability in snowpack, snowmelt, precipitation and flows from the Mill Level Tunnel and Meldrum Tunnel, several years of data collection will be required to fully characterize the range in tunnel flows before most of the decision making processes described in the CP can be implemented.

Weather stations were installed in Marshall Basin and at the Idarado Red Mountain yard in the third quarter of 2017 to record climatic data to allow assessment of the variability in flows from the Mill Level Tunnel and Meldrum Tunnel.

1.2 Objectives

The general objectives of the RMP are to:

- Provide information to further develop baseline hydrologic conditions for comparison to future conditions.
- Monitor conditions resulting from installation of a bulkhead in the Mill Level Tunnel.
- Provide information on hydrologic changes that may occur.
- Provide information to support decisions regarding the need for enhanced monitoring activities, additional investigations and the need for response actions, as described in the CP.
- Document the effectiveness of response actions that have been implemented, if necessary, to address adverse water conditions.

These objectives assure that the decision-making steps described in the CP can be made effectively and defensibly. In particular, routine monitoring consists of recording hydrologic data to further develop current baseline conditions and over time to allow assessment of any significant future changes in conditions. As described in detail in the CP, the major decisions related to data evaluation are whether adverse water conditions exist due to 1) a sudden, significant and unanticipated increase in the water level at the bulkhead unrelated to normal operations, 2) a significant and unanticipated change in flow or pH, specific conductance, and temperature (field parameters) from the Mill Level Tunnel or Meldrum Tunnel, 3) the emergence of a new seep/spring or a new discharge from a mine opeining that results from a significant increase in the water level at the bulkhead, 4) catastrophic plugging of the bulkhead piping, or 5) unauthorized direct discharge of Mill Level Tunnel or Meldrum Tunnel water to a stream or surface water.

1.3 Routine Monitoring Plan Organization

Section 1 presents the overall purpose and objectives of the RMP. Section 2 presents monitoring and evaluation requirements to ensure that the relevant hydrologic conditions are adequately documented and the information necessary for the CP decision-making processes is generated. Section 3 provides the methods which will be employed during monitoring activities. The data quality review, data evaluation, and data management procedures are discussed in Section 4. Procedures for systematically reviewing additional data and revising the monitoring plan are discussed in Section 5. Section 6 discusses the reporting requirements for the routine monitoring program. References are presented in Section 7. The terms used in this RMP shall have the same definition as that provided in the CP.

2.0 Rountine Monitoring Requirements

The routine monitoring program is designed to collect adequate data regarding the current and future conditions of the Hydrologic System and support decision-making in the CP. Data collected during routine monitoring will be evaluated to determine the current state of the Hydrologic System and what, if any, changes to the Hydrologic System have occurred. Following is a discussion of the monitoring locations, parameters, and frequencies which are contained in the routine monitoring program. The monitoring requirements discussed in this section are summarized in Table 1.

2.1 Monitoring Locations

This RMP provides for continuing monitoring of flowrates from the tunnels to establish current conditions. The existing monitoring locations for the routine monitoring program include:

- Mill Level flume at infiltration lagoons (flow);
- Mill Level flumes at infiltration ditch (flow);
- Meldrum Tunnel portal (flow); and,
- Weather stations in Marshall Basin and at the Idarado Red Mountain yard.

The following additional monitoring locations will be implemented as part of the routine monitoring program:

- Mill Level Tunnel bulkhead pressure transducer (water levels);
- Mill Level Tunnel bulkhead pipeline flow meter (flow);
- Mill Level Tunnel portal instrumentation (field parameters);
- Meldrum Tunnel portal instrumentation (field parameters); and,
- Any identified existing seeps and springs in Marshall Creek and other areas in the vicinity of the Mill Level Tunnel and Meldrum Tunnel.

Locations and monitoring activities to evaluate the Hydrologic System are discussed below and are summarized in Table 1.

2.2 Parameters

Parameters that will be monitored under the routine monitoring program are listed on Table 1. These parameters will be used for: (1) ongoing characterization of short- and long-term natural variability for defining baseline conditions; and (2) interpretation of significant departures from baseline conditions, should they occur. Data collected pursuant to the RMP will allow for ongoing evaluation during the Routine Monitoring Mode of Operation (RMM) to assess whether an adverse water condition results from changes within the Hydrologic System, as defined in the CP. To provide that information, the parameters routinely monitored include:

- Water level elevation behind the Mill Level Tunnel bulkhead;

- Mill Level Tunnel flowrates and field parameters;
- Meldrum Tunnel flowrates and field parameters;
- Climatic data from the weather stations; and
- The occurrence, location, flow rate, and field parameters of any existing seeps and springs in Marshall Creek and other areas in the vicinity of the Mill Level Tunnel and Meldrum Tunnel.

2.3 Details of Routine Monitoring Program at the Various Locations

This section describes the rational for the monitoring locations and parameters. A summary of the routine monitoring program, including monitoring locations, parameters, and frequency, is provided in Table 1.

2.3.1 *Mill Level Tunnel Bulkhead Water Level, Flow Rates and Field Parameters*

Mill Level Tunnel water data that will be monitored include the bulkhead water levels, flowrate of the bulkhead conveyance pipeline, flowrates at the existing infiltration lagoon and ditch flumes, and field parameters at the Mill Level Tunnel portal. The water level behind the bulkhead will be monitored with a pressure transducer to record the daily depth of water impounded in the tunnel and evaluated for changes that are unrelated to bulkhead operation or seasonal or daily fluctuations. The Mill Level Tunnel flowrate is measured with pressure transducers at the existing flumes located at the infiltration lagoons and infiltration ditch. The flowrate at the flumes will be reported daily. The flowrate of the bulkhead conveyance pipeline will be measured daily with a totalizing flow meter.

During most of the year, the Mill Level Tunnel flowrate at the bulkhead will represent nearly free-flowing conditions since water will not be impounded behind the bulkhead. During periods of peak flow, water may be impounded for periods of time to regulate flow to the infiltration lagoons and/or infiltration ditch. When water is impounded behind the bulkhead, the flowrates recorded at the flumes will not represent free-flowing conditions. The flowrate will be recorded at the conveyance pipeline totalizing flow meter and verified by flowrates measured at the flumes.

Field parameters provide an indication of the seasonal variability in water quality and evaluating whether changes have occurred due to impounding water behind the bulkhead. Field water quality parameters will be monitored daily at the portal to characterize baseline conditions and to provide data for evaluating changes in the parameters.

A substantial, unanticipated rise in the water level at the bulkhead (unrelated to normal bulkhead operation), a sudden, unanticipated change in the Mill Level Tunnel flowrate, and/or a significant, unanticipated change in the field parameters, could lead to changes in the frequency of monitoring water levels and flowrates at the bulkhead, changes in the frequency of monitoring water flows from the Meldrum Tunnel, and/or performing an inspection to identify any newly-observed seeps or springs. The data will be evaluated in the decision-making process described in the CP to determine whether enhanced monitoring or additional investigations are required, whether an adverse water condition exists, and whether a response action is necessary.

2.3.2 *Meldrum Tunnel Flow Rates and Field Parameters*

Meldrum Tunnel water data that will be monitored include flowrates and field parameters at the portal. The flow and field parameter data will be recorded daily and used to further develop baseline conditions for comparing to future data to assess whether changes have occurred. A sudden, unanticipated and significant increase or decrease in the Meldrum Tunnel flowrate could lead to changes in the frequency of monitoring flows from the tunnel. The data will be evaluated in the decision-making process described in the CP to determine whether enhanced monitoring or additional investigations are required, an adverse water condition exists, and if a response action is necessary.

2.3.3 *Springs/Seeps Survey*

The emergence of new springs or seeps may indicate that the Mill Level Tunnel water level has risen to an elevation leading to surface discharge along faults or fractures, or from a mine opening. Initial spring/seep baseline surveys will be conducted prior to bulkhead installation during high flow (e.g., early July) and low flow (e.g., September) to identify any existing springs or seeps. Reconnaissance baseline surveys of seeps and springs will focus in Marshall Creek and in other areas surrounding the Mill Level and Meldrum tunnels where surface discharge would most likely occur. Winter access to Marshall Creek and other areas is not possible due to unsafe conditions posed by snowpack and potential avalanche hazards. The locations, elevations, field parameter measurements, and flowrate of any existing springs or seeps will be recorded for evaluating possible future changes or the occurrence of new springs/seeps that may result if a substantial rise in water levels was to occur at the bulkhead.

The need to conduct systematic reconnaissance surveys of springs and seeps following bulkhead installation will be evaluated if a substantial and prolonged water level rise occurs at the bulkhead (unrelated to normal bulkhead operation) and/or a sudden, unanticipated change occurs in the Mill Level Tunnel flowrate. If spring/seep surveys are determined to be necessary following bulkhead installation, the surveys will be conducted during the same time periods as the baseline survey to measure field parameters at the existing springs/seeps and to identify the emergence of any new springs/seeps or a new discharge from a mine opening that may be related to a substantial water level rise at the bulkhead. The locations, elevations, field parameter measurements, and flowrate of the existing and any newly observed springs/seeps would be recorded.

The occurrence of new springs/seeps or new discharge from a mine opening will be evaluated in the decision-making process described in the CP to determine whether enhanced monitoring or additional investigations are required, whether an adverse water condition exists, and whether a response action is necessary. The data collected from the new springs/seeps would be used to assess the source of the new springs/seeps and possible hydrologic relationship to the Mill Level Tunnel. If the evaluation determines that an adverse water condition exists, further investigations, as described in the CP, would be performed to determine the appropriate response action.

3.0 Monitoring Procedures And Methods

This section addresses requirements for monitoring, quality assurance, data validation, and recordkeeping. Data will be collected in accordance with the following procedures to ensure the information needed to support the CP decision process is obtained. Standard Operating Procedures (SOPs) required for the RMP include:

SOP Number	**Title**
1	Water Level Measurement Using Pressure Transducers
2	Water Flow Measurement
3	Field Instrument Calibration and Operation

Specific procedures to perform routine monitoring are provided below.

3.1 Monitoring Methods

3.1.1 *Equipment Calibration and Operation*

Equipment and instrumentation used for measurement of water levels, flowrates, and field parameters will be calibrated, maintained and operated properly to ensure that representative measurements are obtained.

3.1.2 *Water Level Measurement*

A pressure transducer will be used to measure the water pressure behind the Mill Level Tunnel bulkhead. This pressure will then converted to water levels and elevations. The measurements will be taken and data collected according to the methods described in SOP No. 1 – Water Level Measurement Using Pressure Transducers.

3.1.3 *Water Flow Measurements*

Flow measurements will typically be made using the installed flow meters or flumes with pressure transducers. However, in some cases other methods such as volumetric measurements, weirs, or velocity-area measurements may be used. Flow measurements will be performed in accordance with the methods described in SOP No. 2 – Water Flow Measurements. If SOP No. 2 does not contain the method to be used, then the manufacturer's instructions will be followed for flow measurements.

3.1.4 *Field Parameter Measurements*

Instruments for field parameter measurements will be calibrated and operated according to the methods described in SOP No. 3 – Field Instrument Calibration and Operation.

3.2 Data Quality Assurance/Quality Control (QA/QC) Review

QA/QC protocols serve to assure that the data collected pursuant to this plan meet specified standards of precision, accuracy, representativeness, comparability, and completeness.

3.2.1 *Data Quality Assessment and Validation*

The quality of data obtained for RMP purposes will initially be assessed by comparing the data against historic data and looking for significant deviations. The data will be reviewed to verify their usability and to identify any transcriptional or computational errors. The presence of anomalous data will initiate a review of monitoring methods and data management procedures, and in the event that data of questionable quality are identified, water levels, flow rates, and/or field parameters may be re-measured. Data errors, corrections, or deletions will be discussed in the Annual Remedial Action Plan (RAP) Report submitted pursuant to the Consent Decree.

3.2.2 *Data Management*

Data collected under the routine monitoring program will be maintained in a database.

4.0 Data Evaluation

During routine monitoring, data will be obtained as described in Section 2. Following the data quality review (Section 3), the monitored data will be evaluated as soon as practicable to provide the information necessary to support CP decision-making. The parameters listed on Table 1 were selected to support the decision-making process described in the CP. Data and information collected under this RMP will be evaluated using standard data reduction and analysis methods.

4.1 Mill Level Tunnel

Monitoring data that will be collected relative to the Mill Level Tunnel include: bulkhead water levels, flowrates at the bulkhead conveyance pipeline flow meter and at the existing flumes to the infiltration lagoons and ditch, and field parameters. If water from the Mill Level Tunnel portal is pumped to the Meldrum infiltration area, the pumping rate will be recorded on a daily basis. In addition, visual inspections of the water management system will be performed as part of operations and maintenance. Monitoring data will be evaluated as follows:

- Daily water levels measured behind the bulkhead will be graphed versus time.
- Total daily flow of the bulkhead conveyance pipeline and flumes will be graphed versus time. Climatic data (precipitation, snow water equivalent, and snowmelt) available from the Marshall Basin and Red Mountain weather stations will also be included on the graphs to aid in the interpretation of flowrates.
- Daily field parameters will be graphed versus time and compared to water levels measured behind the bulkhead.

Correlations with previous seasonal or annual trends in water levels, flowrates, and field parameters will be evaluated.

4.2 Meldrum Tunnel

Monitoring data that will be collected relative to the Meldrum Tunnel include: flowrates and field parameters at the portal. In addition, visual inspections of the water management system will be performed, when access allows, as part of operations and maintenance. Monitoring data will be evaluated as follows:

- Total daily flow will be graphed versus time. Climatic data (precipitation, snow water equivalent, and snowmelt) available from the Marshall Basin and Red Mountain weather stations will also be included on the graphs to aid in the interpretation of flowrates.
- Daily field parameters will be graphed versus time.

Correlations with previous seasonal or annual trends in flowrates and field parameters will be evaluated.

4.3 Springs/Seeps

Information collected during the baseline spring/seep reconnaissance surveys will include visual observations of the spring/seep occurrence, elevation, flowrate, and field parameters. This information will be documented by photographs, field notes, GPS or using other reliable methods. In the event that a new spring/seep or new discharge from a mine opening is identified, it will be evaluated according to the CP and determined if enchanced monitoring is required (Decision 1 of the CP), additional investigations are required (Decision 2 of the CP) or it consistitues an adverse water condition (Decision 3 of the CP).

5.0 Systematic Review And Revision Of Monitoring Plan

5.1 Need For Periodic Review And Revision of Monitoring Plan

Systematic review and revision of the RMP will take place under Decision 6 and Task F of the CP. As the routine monitoring program progresses, modification of the RMP may be necessary. In general, routine monitoring requirements will be modified whenever a better understanding of the Hydrologic System suggests that monitoring elements should be updated, or when the specific objectives of the monitoring program change. These objectives may change if, as a result of Decisions 1 and 2 in the CP, the decision is made that enhanced monitoring or additional investigations are needed, respectively. In such a case, the objectives and requirements of the additional investigations or enhanced monitoring may be incorporated into the RMP after consultation with the State. Additional monitoring or data analysis may also be required to provide sufficient evidence to support a “Yes” or “No” response to Decisions 3, 4A and 4B of the CP; that is, to determine whether an adverse water conditions exists and whether a response action is required. Finally, additional monitoring requirements may be added to the RMP as a component of one or more response actions selected under Task E of the CP.

The types of changes that may be made to the RMP as a result of systematic review and revision of the monitoring program may include:

- Addition or deletion of monitoring points;
- Change in the frequency or location(s) of monitoring;
- Addition or deletion of flow monitoring or field water quality parameters;
- Modification of the methods used to perform field measurements; and,
- Changes in the methods of analysis applied during data evaluation.

5.2 Procedure for Modification of Plan

The basic procedure for modification of the RMP consists of the periodic review of the contents of the RMP, confirmation of conformance with the objectives of the program and the effectiveness of the program in supporting decision-making pursuant to the CP. If it is determined that the RMP is not meeting these objectives, recommended improvements will be presented to the State for approval. The review will include all aspects of routine monitoring as well as specific evaluations and analyses. At a minimum, the RMP will be reviewed annually at the time the Annual Remedial Action Plan (RAP) Report is being prepared.

As more information is gained about the Hydrologic System, and as data collection procedures, monitoring methods, methods used for data evaluation and technology changes, and as the usefulness of the collected data is reevaluated, modifications may be appropriate to improve the efficiency and/or cost-effectiveness of routine monitoring. In such events, this RMP may likewise be modified with the approval of the State.

Decision 6 of the CP considers whether or not the RMP requires revision. At the conclusion of the RMP review under Decision 6 of the CP, recommendations may be made for modification of the RMP. These recommendations will be presented and justified in the Annual RAP Report. The revised RMP will be implemented immediately after receipt of State approval of the revised document. If the revision requires a phased implementation of the recommended changes, the schedule for implementation will be provided in the revised RMP.

6.0 Reporting

Information developed from the routine monitoring program will be presented in the Annual Remedial Action Plan (RAP) Report and submitted as required by the Consent Decree. The Annual RAP Report constitutes the reporting component of Task A of the CP, and will summarize the results of the routine monitoring program, investigations, enhanced monitoring, and evaluations made during consideration of Decisions 1, 2, 3 and 6 of the CP. The data evaluation summary will contain the results of data evaluation procedures such as statistical analyses; interpretations of data correlations; and evaluations of data completeness, representativeness, comparability, precision, and accuracy. A current description of hydrologic conditions will be provided, and any unusual events observed throughout the year will be noted.

The report will include the following information:

- Summary and evaluation of Mill Level Tunnel bulkhead data including water levels, flows, and field parameter data;
- Summary and evaluation of Meldrum Tunnel data including flows and field parameter data;
- Summary of any enhanced monitoring activities;
- Summary of additional investigations; and,
- Conclusions and recommendations.

Finally, the Annual RAP Report will review the current status of the RMP, summarize revisions that have been considered or adopted during the year, and if necessary, recommend changes or improvements to routine monitoring that might be justified for the upcoming year. Topics that will be discussed in this part of the report include existing or proposed modifications to the monitoring program, if any, and objectives and results of any enhanced monitoring or additional investigations that were undertaken during the previous year.

7.0 References

Engineering Analytics, Inc., 2018. Contingency Plan Mill Level Tunnel Bulkhead. Prepared for Idarado Mining Company. March.

TABLES

Table 1. Monitoring Locations, Parameters and Frequencies

Location	Parameter	Method	Data Collection Frequency
Mill Level Tunnel Bulkhead	Water Level	Transducer	Daily
	Flow Rate (Conveyance Pipeline)	Flow Meter	Daily
Mill Level Tunnel	Flow Rate (Infiltration Lagoon Flume)	Flume/ Transducer	Daily
	Flow Rate (Infiltration Ditch Flume #1)	Flume/ Transducer	Daily
	Flow Rate (Infiltration Ditch Flume #2)	Flume/ Transducer	Daily
	Pumping Rate (to Meldrum Infiltration Area)	Pump Capacity	Daily when operated
	Field Water Quality Parameters$^{(1)}$	Probes	Daily
Meldrum Tunnel	Flow Rate (Portal)	Transducer	Daily
	Field Water Quality Parameters$^{(1)}$	Probes	Daily
Springs/Seeps	Occurrence/Elevation	Observation / GPS	Baseline (See Section 2)
	Flow	Flume	Baseline (See Section 2)
	Field Water Quality Parameters$^{(1)}$	Field Meter	Baseline (See Section 2)

Notes: (1) Field parameters consist of pH, specific conductance and temperature.

Appendix K
Contingency Plan

NEWMONT.

Contingency Plan

Mill Level Tunnel Bulkhead

Idarado Mining Company
Telluride, Colorado
March 12, 2018

Prepared For:
Idarado Mining Company
Telluride, Colorado

Prepared By:
Engineering Analytics, Inc.
1600 Specht Point Road, Suite 209
Fort Collins, Colorado 80525

TABLE OF CONTENTS

1.0 INTRODUCTION 1

1.1 Summary of Current Conditions 1

1.2 Contingency Plan Objectives 2

1.3 Contingency Plan Overview 2

2.0 ROUTINE MONITORING MODE OF OPERATION 4

2.1 Task A: Routine Monitoring Plan, Data Evaluation, and Reporting 4

2.1.1 Objectives of the Routine Monitoring Plan 4

2.1.2 Monitoring Elements 4

2.1.3 Methods of Data Evaluation During Routine Monitoring 5

2.2 Decision-Making Process in RMM 5

2.2.1 Decision 1: Is Enhanced Monitoring Required? 5

2.2.2 Task B: Develop, Select, Implement, Evaluate and Report on Enhanced Monitoring 6

2.2.3 Decision 2: Are Additional Investigations Required? 6

2.2.4 Task C: Develop, Select, Implement, Evaluate, and Report on Additional Investigations 7

2.2.5 Decision 3: Does an Adverse Water Condition Exist in the Hydrologic System 7

2.2.6 Decision 4A: Is Immediate Response Action Required? 8

2.2.7 Decision 4B: Is Non-Immediate Response Action Required? 8

2.2.8 Decision 6: Does Routine Monitoring Plan Require Revision? 9

2.2.9 Task F: Systematic Revision of Routine Monitoring Plan 9

3.0 RESPONSE ACTION MODE OF OPERATION 10

3.1 Task D: Implement, Evaluate, and Report on Immediate Response Actions 10

3.1.1 Conditions That Warrant Immediate Response Action 10

3.2 Task E: Develop, Select, Implement, Evaluate, and Report on Non-Immediate Response Actions 14

3.2.1 Development of Response Actions for Non-Immediate Situations 14

3.2.2 Discussion of Potential Long-Term Response Actions 15

3.3 Decision 5: Is Additional Response Required? 16

3.4 Reporting Requirements 16

4.0 REFERENCES 17

LIST OF TABLES

Table 1 Conditions That Constitute Adverse Water Conditions for the Idarado Underground Workings Hydrologic System 19

LIST OF FIGURES

Figure 1 Contingency Plan Flow Chart

LIST OF APPENDICES

Appendix A Glossary

1.0 Introduction

This Contingency Plan (CP) describes the decision-making process for identifying adverse water conditions related to the Idarado Mining Company (Idarado) underground mine Hydrologic System (Hydrologic System), and for designing and implementing appropriate actions to respond to such conditions. Conditions constituting adverse water conditions are presented in Table 1.

The Routine Monitoring Plan (RMP) describes the objectives, monitoring points and parameters, data criteria for implementation of the CP decision-making process, quality assurance procedures, data evaluation methods, and reporting requirements that will be implemented during the routine monitoring mode of operation of the CP.

The CP is organized around the decisions and tasks that form the basic elements of the two modes of operation, the Routine Monitoring Mode of Operation (RMM) and the Response Action Mode of Operation (RAM). Section 1.0 describes the overall objectives, presents an overview of the CP decision-making process, and describes the organization of the CP. The decisions and tasks associated with the RMM are described in Section 2.0. The RAM is discussed in Section 3.0. References are presented in Section 4.0. Finally, a glossary of technical terms is provided in Appendix A.

1.1 Summary of Current Conditions

This CP reflects current conditions within the Hydrologic System. Should changing conditions warrant, additional response actions may be required pursuant to this CP. Currently water from within the Hydrologic System drains to either the Meldrum Tunnel or the Mill Level Tunnel located in the upper San Miguel River watershed. This CP addresses only the underground mine Hydrologic System associated with the Mill Level Tunnel and Meldrum Tunnel.

Water from the Meldrum Tunnel flows to a weepline and infiltration area. Water from the Mill Level Tunnel is piped from the portal to a series of infiltration lagoons and/or an infiltration ditch. A headgate at the Mill Level portal allows water to be diverted into two separate pipelines that convey water to the infiltration lagoons or the infiltration ditch. A third pipeline connected to the infiltration lagoons pipeline can also be used to divert water to the infiltration ditch. As a contingency measure, a pipeline is installed from the Mill Level portal to the Meldrum infiltration area and water can be pumped from the Mill Level portal to the Meldrum infiltration area using a portable pump.

Historically, flow data was collected from the Mill Level Tunnel and over the last few years observations and estimation of flows has been performed for both tunnels. The RMP provides for monitoring flows from the tunnels on a more consistent and current basis, to improve the understanding of baseline conditions. There are limited historic pH, specific conductance and temperature data (field parameters) from the tunnels. Due to the year-to-year and seasonal variability in snowpack, snowmelt, precipitation and flows from the Mill Level Tunnel and Meldrum Tunnel, several years of data collection will be required to fully characterize the range in tunnel flows before most of the decision making processes described in the CP can be implemented.

1.2 Contingency Plan Objectives

The development of a contingency plan that addresses any potential adverse hydrologic change occurring in the Hydrologic System is one of the elements required for installation of a bulkhead in the Mill Level Tunnel. This CP was prepared to satisfy that requirement and to meet the following objectives:

- Define the decision-making process by which the status of bulkhead operation and the Hydrologic System will be evaluated to determine if an adverse water condition exists and whether that condition warrants a response action.
- Present the basis for the CP decision-making process, including the information needed to make each decision, the protocol that will be followed while each decision is being made, and the person(s) or decision-making body designated to make each decision.
- Describe the actions that will be taken to develop, select, implement, evaluate, and report on the outcome of the CP decisions and associated activities.
- Define the reporting, notification, and review requirements associated with the decisions and tasks identified in the CP.
- Define the degree of involvement and interactions among the parties charged with the implementation and operation of the CP.

In addition to the general objectives listed above, quality assurance and quality control (QA/QC) protocols serve to assure that the data collected as a part of the RMP meet specified standards of precision, accuracy, representativeness, comparability, and completeness. QA/QC protocols are presented in the RMP.

1.3 Contingency Plan Overview

The decision-making process that will be followed during evaluation of monitoring data and implementation of contingency measures, as necessary, is described below and shown in Figure 1. The CP decision-making process illustrates the relationship between the routine monitoring and response action components of the CP. Rectangular elements shown in the CP Flow Chart (Figure 1) represent contingency planning or activity tasks and diamond-shaped elements represent contingency planning decisions. The normal mode of operation of the CP, called the RMM, consists of all routine monitoring, data evaluation, and reporting activities associated with the execution of Tasks A, B, C and F and the evaluation of Decisions 1, 2, 3, 4A, 4B, and 6 of the CP. These activities are summarized in Section 2 of this document, and a detailed description of the associated monitoring activities is provided in the RMP. Activities associated with implementation of Tasks D and E and Decision 5 constitute the Response Action Mode of Operation (RAM) of the CP. The RAM is initiated when adverse hydrologic conditions have been demonstrated, and the need for response action is warranted.

Implementation of the routine monitoring program for the Hydrologic System occurs in Task A. Routine monitoring of various parameters provides information to understand the range of fluctuations within the hydrologic system, allowing for the evaluation of existing conditions and the overall system and to determine whether a significant change, as compared to previously recorded data, has occurred. A summary of the monitoring and data evaluation requirements for Task A is presented in Section 2.1.

During the RMM, modifications to the monitoring program may be implemented during execution of Task F, in consultation with the State. As part of this task, the monitoring program will be reevaluated on a routine basis and revised if necessary. The types of revisions that may be made to the RMP may include initiation or curtailment of enhanced monitoring or implementation of additional investigations. Once approved, the revised RMP will remain in effect until additional modifications become necessary.

The major decision that affects routine monitoring is Decision 3. Consideration of Decision 3 involves a determination of whether an adverse water condition is observed in the Hydrologic System. The term "adverse water condition" is defined in Table 1. If there is an adverse water condition (Answer to Decision 3 is YES), then Decision 4A will determine whether or not an immediate response action is required. If an immediate response action is found to be necessary (Answer to Decision 4A is YES), then the CP will enter the RAM. In this mode of operation, alternatives will be implemented, and evaluated during Task D. If consideration of Decision 4A results in a negative response (Answer to Decision 4A is NO), then Decision 4B will determine whether or not a non-immediate response action is required. If a non-immediate response action is found to be necessary (Answer to Decision 4B is YES), then the CP will enter the RAM. In this mode of operation, alternatives will be developed, selected, implemented, and evaluated during Task E. If consideration of either Decision 3 or Decision 4B results in a negative response (Answer to Decision 3 or 4B is NO), the process will continue with reevaluation of the RMP and revision of the RMP, if necessary, and a return to routine monitoring.

After a given response action has been implemented, either immediate or non-immediate, the need for additional response will be evaluated in Decision 5. If further response is required, additional alternatives will be developed, selected, implemented, and evaluated in Task E. If no additional action is required (Answer to Decision 5 is NO), the results of the response action will be reported to the State, and the RMP will be reevaluated and revised as necessary in Decision 6 and Task F. Routine monitoring will then continue.

2.0 Routine Monitoring Mode of Operation

2.1 Task A: Routine Monitoring Plan, Data Evaluation, and Reporting

2.1.1 *Objectives of the Routine Monitoring Plan*

The overall goal of the routine monitoring program is to obtain information about the Hydrologic System to support decision-making processes in the CP. This goal is part of the general objectives of the RMP, which are to:

- Provide information on current conditions of the Hydrologic System, and compare current conditions to previously recorded conditions.
- Monitor conditions resulting from installation of the bulkhead in the Mill Level Tunnel.
- Provide information on changes that may occur in the Hydrologic System.
- Provide information to support decisions regarding the need for enhanced monitoring activities, additional investigations, and the need for response actions.
- Document the effectiveness of response actions that have been implemented.

2.1.2 *Monitoring Elements*

A detailed discussion of the elements that comprise the routine monitoring program is provided in the RMP. Section 2 of the RMP identifies monitoring parameters that are useful for ongoing characterization of changes or fluctuations in the Hydrologic System, and evaluation of conditions to identify potential undesirable changes within the Hydrologic System. Section 3 of the RMP describes the monitoring methods and procedures and the procedures for qualitatively and quantitatively evaluating data. Section 4 of the RMP presents the data evaluations that will be performed. Data collected under Section 3 and evaluated under Section 4 of the RMP will provide the information necessary to support the CP decision-making process

Data collected during routine monitoring will be evaluated with previously collected data to determine what, if any, changes have occurred. Routine collection and evaluation of these data will provide an increased understanding of the Hydrologic System, and allow the recognition of significant changed conditions, should they occur. The parameters and conditions which will be routinely monitored and evaluated include:

- Mill Level Tunnel bulkhead water level elevation.
- Mill Level Tunnel bulkhead flow rates and field parameters.
- Mill Level Tunnel flow rates to the infiltration lagoons and ditch.
- Meldrum Tunnel flow rates and field parameters.
- The initial identification, surface elevation, flow rate, and field parameters of existing seeps and springs.

The monitoring parameters and locations are provided in Section 2 and Table 1 of the RMP.

2.1.3 *Methods of Data Evaluation During Routine Monitoring*

Data and information collected during routine monitoring will be evaluated using standard data reduction, graphical, and statistical analysis methods. These methods are described in Sections 3 and 4 of the RMP. As with the rest of the RMP, methods used for data evaluation will be reviewed periodically and updated, deleted, or replaced as appropriate during the course of the monitoring program.

2.2 Decision-Making Process in RMM

2.2.1 *Decision 1: Is Enhanced Monitoring Required?*

As indicated in Figure 1, Decision 1 evaluates whether an enhanced monitoring effort is needed to confirm existing monitoring data or to provide supplemental information for the routine monitoring program. Enhanced monitoring could include increased frequency of monitoring or additional monitoring of parameters at existing monitoring locations and monitoring points to provide specific information to address a suspected hydrologic condition. Enhanced monitoring could also include monitoring other locations and monitoring points which are not part of the RMP. Possible elements of enhanced monitoring activities are developed in Task B, as described in Section 2.2.2.

In Decision 1, the need for enhanced monitoring is evaluated. If needed (Answer to Decision 1 is YES), the enhancements to the monitoring program will be developed, selected, implemented, evaluated, and reported under Task B. If unnecessary (Answer to Decision 1 is NO), then Decision 2 will be considered. If there is insufficient information available to determine if an enhanced monitoring effort is needed, then a NO response will normally be made to Decision 1.

Although it is difficult to foresee all possible conditions where enhanced monitoring could be considered and selected, the following situations provide potential possibilities:

- A sudden and prolonged increase in head behind the Mill Level Tunnel bulkhead could lead to an additional spring and seep survey in the vicinity of the mine, or other additional monitoring activities.
- A sudden, unanticipated reduction in the Mill Level Tunnel flow rate or increase in head behind the bulkhead could lead to changes in the frequency of monitoring water levels behind the bulkhead, flows from the bulkhead, and/or flows from the Meldrum Tunnel. This situation could also initiate additional seep/spring surveys or the performance of bulkhead operation and maintenance (O&M) activities.
- A sudden, unanticipated reduction or increase in the Meldrum Tunnel flow rate could lead to changes in the frequency of monitoring flows from the tunnel, and/or flows from the Mill Level Tunnel. This situation could also initiate additional seep/spring surveys.
- A sudden, unexplained change in field parameters from the Mill Level or Meldrum tunnels could warrant increased frequency of field parameter collection.

Decision 1 will be made each time the routine monitoring results are evaluated. If the outcome of this decision suggests that enhanced monitoring is needed, this conclusion will be communicated in writing to the State within 10 working days after the decision has been made.

2.2.2 *Task B: Develop, Select, Implement, Evaluate and Report on Enhanced Monitoring*

If consideration of Decision 1 indicates that enhanced monitoring is necessary, an enhanced monitoring program will be developed under Task B of the contingency planning process and provided to the State. The program will be designed to meet the specific needs of the situation depending on the type of conditions encountered. The enhancements will be implemented as soon as practicable after the State has approved the proposed enhanced monitoring program. Enhanced monitoring results will be evaluated and reported in accordance with the requirements established and set forth in the enhanced program. Each enhanced monitoring program will contain the following elements:

- Summary of the conditions that led to enhanced monitoring.
- The objectives of the enhanced monitoring program.
- A description of the enhancements that will be made to monitoring.
- The analysis and evaluation procedures that are anticipated to be performed on the resulting data.
- The duration of the program.
- Reporting requirements.

When enhanced monitoring activities have been completed, the monitoring program will return to routine monitoring. If continuation of enhanced monitoring is determined necessary, the changes will be incorporated into the routine monitoring program under Task F of the CP, as described in Section 5 of the RMP.

2.2.3 *Decision 2: Are Additional Investigations Required?*

Decision 2 evaluates the need to carry out additional investigations that may be needed to clarify or supplement data obtained from routine or enhanced monitoring. If the answer to Decision 2 is YES, an additional investigation will be developed, selected, implemented, and evaluated under Task C. If a NO decision is reached, Decision 3 will be considered. If there is insufficient information available to determine if an additional investigation is needed, then a NO response will normally be made to Decision 2.

Additional investigations may become necessary whenever information is needed to clarify Decisions 3, 4A, 4B, and 5, and such information cannot be obtained from the routine monitoring program network, enhanced monitoring, or from other existing monitoring locations. In general, the objectives of an additional investigation will be more specific than those of an enhanced monitoring program. Circumstances that might lead to the initiation of an additional investigation include the following:

- The occurrence of a persistent, unexplained rise in water elevations within the Hydrologic System.
- The emergence of a new seep/spring that is discharging to a stream or a new discharge from a mine opening to a stream, that is related to a rise in water elevations within the Hydrologic System, and has water quality that exceeds the standard for the stream.

- The need to collect information to support the design or evaluation of a response action considered or selected in Tasks D or E.

Decision 2 will be made each time routine monitoring results are evaluated. The decision to conduct an additional investigation will depend on the specific conditions that exist at the time the decision is considered. If the decision is made to conduct an additional investigation, the State will be notified of the decision in writing and further planning/scoping of the investigation will begin.

2.2.4 *Task C: Develop, Select, Implement, Evaluate, and Report on Additional Investigations*

If the result of Decision 2 is to conduct an additional investigation, a Draft Additional Investigation Work Plan will be developed to respond to the specific conditions and questions that led to the decision. The Draft Additional Investigation Work Plan will contain the following elements:

- A summary of the conditions that led to the investigation.
- The specific objectives of the investigation.
- Details of the work to be conducted including a description of the location of any new monitoring points, monitoring activities that will be performed, and other data collection activities.
- Methods anticipated for data collection and evaluation.
- A summary of applicable water management, health and safety, and quality assurance/quality control (QA/QC) procedures that will be followed.
- An estimated schedule for completion of the investigation.
- Reporting requirements.
- Any permits or regulatory requirements necessary for completion of fieldwork.

The Draft Work Plan will be provided to the State for approval. The additional investigation will be initiated and implemented in conjunction with the routine monitoring or enhanced monitoring activities. If, as a result of the investigation, modifications to the routine monitoring program are made under Decision 6 of the CP, those modifications will be incorporated into the routine monitoring program as discussed in Section 5 of the RMP.

2.2.5 *Decision 3: Does an Adverse Water Condition Exist in the Hydrologic System*

Decision 3 evaluates whether an adverse water condition exists, and whether the adverse condition is caused by conditions within the Hydrologic System, or is caused by unrelated natural conditions (e.g., unusually high or low seasonal or annual precipitation). The term adverse water condition means those hydrologic, flow and water quality conditions associated with the Hydrologic System identified in Table 1. The presence of one or more of these Table 1 conditions indicates that the response to Decision 3 is YES and the need for response action should be considered in Decisions 4A or 4B. If none of the conditions listed in Table 1 exist, the program returns to routine monitoring and Decisions 1, 2, and 6 are considered.

Decision 3 will be made in conjunction with the State after sufficient information has been collected to perform an analysis of site conditions for adequate evaluation of the decision. If the operator determines that the answer to Decision 3 is YES, the State will be notified of the decision in writing. If there is insufficient information available to determine if an adverse water condition has occurred, then a NO response will normally be made to Decision 3.

2.2.6 *Decision 4A: Is Immediate Response Action Required?*

Decision 4A evaluates whether an immediate response action is required to address an adverse water condition, due to Conditions 3, 5, 6 as identified in Table 1. These conditions represent a potential adverse impact that would require immediate response action. Immediate response actions could result in either short-term or long-term response measures.

The following conditions or combinations of conditions represent circumstances that would require immediate response action. Immediate response actions are discussed further in Section 3.

Conditions Requiring Immediate Response Action

- Condition 3: Indicates possible discharge of Mill Level Tunnel water through a new seep or spring or mine feature that discharges into a stream.
- Condition 5: Indicates that bulkhead intakes are buried or flow-through pipes in the bulkhead are plugged and normal O&M clearing procedures have not been effective.
- Condition 6: Indicates that water from the Mill Level or Meldrum tunnels are discharging to a stream without a permit or authorization by the State.

Decision 4A will be made in conjunction with the State based on all information available at that time. A YES response to Decision 4A initiates Task D activities, during which an appropriate response action is implemented.

2.2.7 *Decision 4B: Is Non-Immediate Response Action Required?*

Decision 4B evaluates whether a non-immediate response action is required to address an adverse water condition, as identified in Table 1. Non-immediate response actions could result in either short-term or long-term response measures.

The following conditions or combinations of conditions represent circumstances that would require non-immediate response action. Non-immediate response actions are discussed further in Section 3.

Conditions Requiring Non-Immediate Response Action

- Condition 1: Indicates an unexpected and prolonged buildup of water within the Hydrologic System.
- Condition 2: Indicates an unexpected change in flow from the Mill Level or Meldrum tunnel that deviates from the range of historic flow unrelated to bulkhead operation.

- Condition 4: Indicates a significant change in field parameters of the Mill Level Tunnel water not caused by bulkhead operation, natural conditions, or other events.

Decision 4B will be made in conjunction with the State based on all information available at that time. A YES response to Decision 4B initiates Task E activities during which an appropriate response action is developed and implemented. If there is insufficient information available to determine if adverse water conditions require a response action, then a NO response will normally be made to Decision 4B. Routine monitoring will continue and the data will be evaluated to determine if enhanced monitoring, additional investigations, or revision of the routine monitoring plan is required.

2.2.8 *Decision 6: Does Routine Monitoring Plan Require Revision?*

Decision 6 considers whether or not the RMP requires revision. As knowledge of the Hydrologic System improves during the course of routine monitoring, elements of the RMP may need to be modified or updated. Modifications to the RMP may include changes in the locations being monitored, the field parameters being collected, the frequency or location of monitoring, or the methods of analysis applied during data evaluation.

If a decision is made to modify the RMP (Answer to Decision 6 is YES), then appropriate revisions and modifications will be made under Task F. These revisions will be submitted to the State for approval prior to being implemented. If no revisions of the RMP are required (Answer to Decision 6 is NO), then routine monitoring will continue with Task A.

2.2.9 *Task F: Systematic Revision of Routine Monitoring Plan*

In order to ensure that routine monitoring activities or response actions are consistent with the objectives of the CP, a mechanism for systematic revision of the monitoring program has been incorporated into Section 5 of the RMP. Revisions will be implemented in response to the routine evaluation of monitoring data or as a result of the implementation of enhanced monitoring, additional investigations, or response actions, where appropriate. Revisions to the RMP will be made with the approval of the State, and approved modifications will be documented in the Annual Monitoring Report, as provided by Section 6.0 of the RMP, or other documents, as appropriate. Modifications to the RMP may include:

- Incorporation of enhanced monitoring elements (e.g., increased monitoring frequency).
- Incorporation of additional investigations (e.g., additional monitoring locations).
- Reduction of monitoring frequency (e.g., less frequent collection of monitoring data).
- Elimination of ineffective monitoring points.

3.0 Response Action Mode of Operation

The elements of the RAM are discussed in the following subsections and include Task D, Task E and Decision 5, and potential response action alternatives.

3.1 Task D: Implement, Evaluate, and Report on Immediate Response Actions

The work performed under Task D consists of two types of activities: (1) implementation and evaluation of response actions applicable in situations where an immediate response action is needed; and (2) evaluation and reporting of the outcome of response actions that have been completed.

3.1.1 *Conditions That Warrant Immediate Response Action*

The following three conditions warrant immediate response action:

- Condition 3 - Occurrence of a new seep or spring discharging to a stream or a new discharge from a mine opening to a stream resulting from a change in the Hydrologic System, is hydrogeologically connected to the Hydrologic System, and has water quality that exceeds the standard for the stream.
- Condition 5 - Catastrophic plugging of one or more of the bulkhead intakes or pipes in which repeated O&M clearing procedures fail to restore flow.
- Condition 6 – Discharge of Mill Level or Meldrum tunnel water to a stream except when the discharge is authorized by the State.

The immediate response actions that may be required in each of these situations are described below. These actions will only be undertaken if the response to Decision 4A as discussed in Section 2.2.6 is a YES.

3.1.1.1 Response Action for Occurrence of Condition 3

The immediate response action to Condition 3 will be to contain and prevent the discharge of water from a new seep, spring, or mine opening to a stream. The factors that will be taken into account for designing the components of this response action are seep/spring location, mine opening location, flow rate, and the time of year that response is required. If the new seep, spring, or mine opening occurs in a remote location during the summer, it may be readily accessible for implementation of water containment and collection measures even if a new roadway is needed to provide access to that location. In addition, construction of water containment or collection structures could proceed relatively quickly during warm weather.

Logistical difficulties associated with the cold weather might make it impossible to implement response measures at the seep/spring location or mine opening until the spring melt occurs. In the event that immediate response action is necessary despite adverse winter weather conditions, containment of the seep/spring or water from the mine opening may have to be restricted to the point of discharge in an adjacent stream that is accessible. The containment would then be moved to the source of the seep, spring, or mine opening when weather conditions permit.

When Condition 3 is encountered the following actions will occur:

- The State will be notified, both verbally and in writing, of a YES response to Decision 4A based on the occurrence of Condition 3, and that a response action is being undertaken. Resources necessary to carry out response actions will be mobilized.
- After notification and approval of the State, immediate response actions will be implemented to contain and prevent the discharge of water from a seep/spring or mine opening to a stream. The response action would be dependent on site-specific conditions (location, flow rate, time of year, etc.). Examples of immediate response actions could include the following types of activities:
- Construction of an earthen containment berm.
- Placement of storage tank, construction of holding pond, or enlargement of a bermed area to increase capacity.
- Routing the water discharge from the mine opening back into the underground mine.
- Use of tanker truck or pipeline, to transfer or convey discharge water from storage devices to the infiltration areas.
- Preparation of a Draft Additional Investigation Work Plan under Task C of the CP. The purpose of the additional investigation will be to determine the cause of the water discharge from the seep/spring or mine opening, whether it is permanent or ephemeral, and to evaluate whether long-term actions are necessary and should be taken to eliminate the occurrence of water from a seep/spring or mine opening or to design a permanent control system for its discharge.
- The State will review and comment on the Draft Additional Investigation Work Plan.
- Preparation of a Final Additional Investigation Work Plan incorporating the State’s comments and submittal to the State for approval.
- Upon approval of the Final Additional Investigation Work Plan, the additional investigation will proceed according to the schedule presented in the Final Additional Investigation Work Plan.
- Evaluation of the likely causes for the occurrence of the seep/spring or new discharge from a mine opening and develop recommendations for additional action, if necessary, upon completion of the Final Additional Investigation Work Plan.
- The State will evaluate these recommendations and decide on the appropriate action in conjunction with Idarado. If additional action is required, a Response Action Plan (RAP) (see Section 3.2.1) describing the action to be taken and defining the schedule for its implementation will be prepared.
- When the State has determined that the response action for the seep/spring or mine opening has been completed, appropriate changes will be made to the RMP to incorporate additional monitoring or O&M specifications required by the action.

- Upon State approval of these revisions, the revised RMP will be implemented and the current response action will be closed out and routine monitoring will resume.

3.1.1.2 Response Action for Occurrence of Condition 5

Condition 5 occurs when normal operation of the Mill Level Tunnel bulkhead is prevented due to catastrophic blockage of the pipelines thorough the bulkhead or pipeline intakes immediately behind the bulkhead and application of normal O&M clearing methods fail to remove the blockage. The primary causes for this condition are likely to be: (1) burial of the bulkhead intakes by rubble transported during a sudden water surge; or (2) plugging of the bulkhead pipelines by timbers or other materials during the normal course of operations. In this case, the Decision 4A result will be a YES. Prior to the initiation of response action, it is assumed that O&M procedures appropriate for clearance of the bulkhead intakes and/or pipelines have been carried out with no success, indicating that other measures are required to restore flow through the bulkhead. If this is the case, access to the upstream side of the bulkhead via the access opening is likely to be restricted, and efforts to reestablish flow may need to be made either from the downstream face or the ground surface.

When Condition 5 is encountered, the following actions will occur:

- The State will be notified in writing that Condition 5 exists, appropriate O&M measures have been unsuccessful in reestablishing flow through the bulkhead, that Decision 4A results in a YES decision, and that a response action is being undertaken. Resources necessary to carry out response actions will be mobilized.
- After notification and approval by the State, response actions will occur to relieve the buildup of water behind the bulkhead and to clear the blockage on the upstream side of the bulkhead. The response action would be based on site-specific conditions. Examples of these response actions could include the following types of activities:
- Blow out debris with air or water through pipes.
- Drill through existing pipes and inlet pipes to open intake pathway.
- Install a well at a suitable location and pump Mill Level Tunnel water to relieve pressure and prevent backup behind the bulkhead.
- Construct a horizontal drain at a suitable location to allow gravity drainage of Mill Level Tunnel water from behind the bulkhead.
- When the bulkhead has been restored to normal operations, as determined by the State or changes caused by the response action, appropriate changes will be made to the RMP to incorporate additional O&M specifications required by the action.
- Upon State approval of the revisions, the revised RMP will be implemented and the response action will be closed out.

3.1.1.3 Response Action for Occurrence of Condition 6

When Condition 6 occurs, there is reason to suspect that Mill Level or Meldrum tunnel water may threaten the environment. The response action presented below is only appropriate if: (1) a

YES decision has been reached for Decision 4A; (2) it has been demonstrated that degradation of surface water quality is due to mine drainage from the Mill Level or Meldrum tunnels; and (3) the observed water quality presents an immediate threat to the environment.

The factors that will be taken into account for designing the components of this response action are discharge location, flow rate, and the time of year that response is required. If the new discharge occurs in a remote location during the summer, it may be readily accessible for implementation of water containment and collection measures even if a new roadway is needed to provide access to that location. In addition, construction of water containment or collection structures could proceed relatively quickly during warm weather.

Logistical difficulties associated with the cold weather might make it impossible to implement response measures at the discharge location until the spring melt occurs. In the event that immediate response action is necessary despite adverse winter weather conditions, containment of discharge water may have to be restricted to an area downgradient that is accessible. The containment would then be moved to the source of the discharge when weather conditions permit.

When Condition 6 is encountered the following actions will occur:

- The State will be notified, both verbally and in writing, of a YES response to Decision 4A based on the occurrence of Condition 6, and that response action is being undertaken. Resources necessary to carry out response actions will be mobilized.
- After notification and approval by the State, immediate response actions will be implemented to contain and prevent the discharge of Mill Level Tunnel or Meldrum Tunnel water to Marshall Creek, Ingram Creek, or the San Miguel River. The response action would be dependent on site-specific conditions (location, flow rate, time of year, etc.). Examples of immediate response actions could include the following types of activities:
- Construction of an earthen containment berm.
- Placement of storage tank, construction of holding pond, or enlargement of capacity of a bermed area.
- Use of tanker truck or pipeline, to transfer or convey discharge water from storage devices to the infiltration areas.
- Preparation of a Draft Additional Investigation Work Plan under Task C of this CP. The purpose of the additional investigation will be to determine the cause of the discharge, whether it is permanent or ephemeral, and to evaluate whether long-term actions are necessary and should be taken to eliminate the occurrence of the discharge or to design a permanent control/treatment system for its discharge.
- The State will review and comment on the Draft Additional Investigation Work Plan.
- Preparation of a Final Additional Investigation Work Plan incorporating the State's comments and submittal to the State for approval.

- Upon approval of the Final Additional Investigation Work Plan, the additional investigation will proceed according to the schedule presented in the Final Additional Investigation Work Plan.
- Evaluation of the likely causes for the occurrence of the discharge and develop recommendations for additional action, if necessary, upon completion of the Final Additional Investigation Work Plan.
- The State will evaluate these recommendations and in conjunction with Idarado decide on the appropriate action. If additional action is required, a RAP (see Section 3.2.1) describing the action to be taken and defining the schedule for its implementation will be prepared.
- When the State has determined that the response action for the discharge has been completed, appropriate changes will be made to the RMP to incorporate additional monitoring or O&M specifications required by the action.
- Upon State approval of these revisions, the revised RMP will be implemented and the current response action will be closed out and routine monitoring will resume.

3.2 Task E: Develop, Select, Implement, Evaluate, and Report on Non-Immediate Response Actions

In Task E of the CP, response action alternatives will be developed, selected, or modified to mitigate specific conditions that may be the cause of adverse water conditions resulting from a change in the Hydrologic System, as presented in Table 1. In order to select the most appropriate response action, it may be necessary to evaluate all changes that have affected the Hydrologic System since the adverse impacts were noticed.

The work performed under Task E consists of two activities: (1) development or modification of response actions to address conditions that do not require an immediate response action; and (2) evaluation and reporting of the outcome of response actions that have been completed.

3.2.1 *Development of Response Actions for Non-Immediate Situations*

In Section 2.2.7 of this document, circumstances that may require some form of non-immediate response action were presented with reference to the conditions listed in Table 1. When conditions that do not require immediate action are encountered, or when immediate situations have been mitigated, additional investigations may be needed to clarify or supplement existing monitoring data. After these have been conducted and the results from the investigations confirm that response is required, a RAP will be prepared to develop, select, and implement the appropriate response action.

Development of an Additional Investigation Work Plan

In general, an Additional Investigation Work Plan will be prepared under Task C of the contingency planning process if: (1) additional monitoring data are required to better understand the behavior of the Hydrologic System; (2) more information is needed to better define or identify the cause of one of the Table 1 conditions; or (3) additional engineering data are needed to support the development and design of a response action. The additional investigation will be developed, selected, implemented, evaluated and reported through Task C of the CP (Section 2.2.4). The work plan for each additional investigation will be developed to meet the specific objectives of that particular investigation.

Development of a Response Action Plan

Once the nature of the situation to be corrected is understood, a RAP will be developed to select, design and implement a suitable remedy. The RAP will present all pertinent information necessary for development and implementation of the selected remedy. Supporting documents such as the RMP may have to be modified or amended to ensure that the RAP can be successfully implemented.

The RAP will contain a concise summary of the relevant background data; the nature of the problem to be resolved; a summary of risk considerations or results from a risk assessment (if one has been performed); a discussion of alternative approaches that can be applied; selection and justification of the selected response action; design and cost of the selected remedy; and a schedule for implementation of the response action. The RAP will also define the criteria that will be used to determine whether the response action is successful. In more complex cases, a separate set of design plans may be required to describe the components of the selected remedy.

The Draft RAP will be prepared and submitted to the State for review and comment in compliance with the schedule proposed in the RAP. The State will review and comment, and a Final RAP that incorporates State comments on the Draft RAP will be prepared for the State's approval.

Implementation and Schedule of Response Action

The Final RAP will be implemented as soon as State approval has been obtained. Work will proceed according to the approved schedule and progress reports will be prepared as specified in the RAP.

After the remedy has been completed, its effectiveness and performance will be evaluated according to testing measures and criteria specified in the RAP. The results of this evaluation will serve as the primary basis for the determination of whether or not additional response is required in Decision 5 (Section 3.3).

3.2.2 *Discussion of Potential Long-Term Response Actions*

As described in Section 1.1, drainage of water to the Meldrum and Mill Level tunnels maintains water levels within the Hydrologic System. In the event a future condition precludes the ability to freely drain water through the Mill Level Tunnel bulkhead and Meldrum Tunnel Portal and maintain desired water levels, evaluation and implementation of future response actions may be required. The response action would be dependent on site-specific conditions or the specific circumstance. Examples of response actions that could be evaluated include:

- Pumping of water from an accessible shaft or borehole and conveying the pumped water to the infiltration systems.

- Installation of well(s) into areas of the mine workings and pumping of water from the wells to the infiltration systems.
- Construction of a horizontal drain at a suitable location to allow gravity drainage of water from the mine workings to the infiltration systems.
- Installation of a plug(s) or an additional bulkhead.

3.3 Decision 5: Is Additional Response Required?

Decision 5 evaluates whether a response action selected under either Task E or D is effective and whether additional response is required. If it is found that no additional response is needed based on the desired outcome established for the action in either Task E or D (Answer to Decision 5 is NO), then the contingency planning process will return to the RMM. If the response action is ineffective and additional response is required (Answer to Decision 5 is YES), the response will be reviewed and additional response actions will be developed, selected, and implemented as necessary. This process will continue until the results are satisfactory. Routine monitoring of unaffected portions of the Hydrologic System will continue while response actions are being implemented. Decision 5 is considered to be an iterative step that recycles through Task E until a given set of undesirable conditions is remediated. The contingency planning program returns to routine monitoring at Decision 6 following satisfactory completion of one or more response actions.

3.4 Reporting Requirements

Reports will be submitted to the State, as described above and prescribed in Section 6.0 of the RMP. Section 6.0 of the RMP outlines the information from the routine monitoring program that will be submitted to the State in the Annual Remedial Action Plan Report. The Annual Remedial Action Plan Report will also summarize any enhanced monitoring activities and any additional investigations that have been performed.

The results of all decisions made during the contingency planning process will be reported to the State in writing. If the response to these decisions is NO, this fact will be reported to the State in the Annual Remedial Action Plan Report. If the response to Decisions 1, 2 or 3 is YES, the State will be notified in writing within 10 working days after the decision is made. The evaluation of Decision 4A & B, 5, and 6 will be done in cooperation with the State. The results of Decisions 4A & B, 5, and 6 will be recorded in correspondence between Idarado and the State.

4.0 References

Worthington Miller Environmental, LLC, 2018. Routine Monitoring Plan, Mill Level Bulkhead. Prepared for Idarado Mining Company. March.

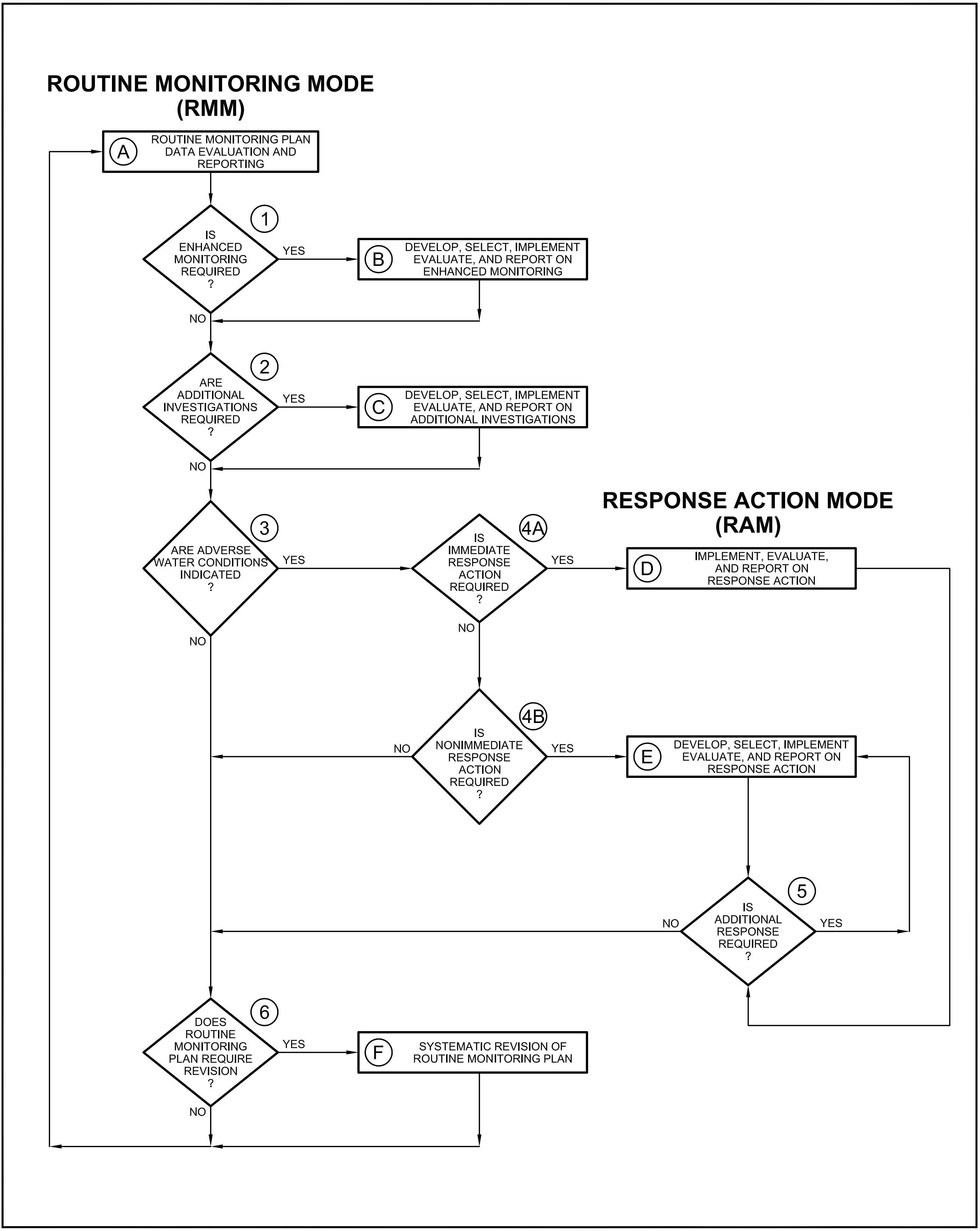
TABLES

Table 1 Conditions That Constitute Adverse Water Conditions for the Idarado Underground Workings Hydrologic System

Adverse Water Conditions	
1.	**Sudden and prolonged change in head behind the Mill Level Tunnel Bulkhead, where such conditions are unrelated to the operation of the bulkhead.**
2.*	**Sudden change in flow from the Mill Level or Meldrum tunnels that significantly deviates from historic flows, where the change in flow is unrelated to the operation of the bulkhead.**
3.**	**Discharge from a new seep/spring to a stream or a new discharge from a mine opening to a stream caused by a significant increase in water level behind the bulkhead, is hydrogeologically connected to the Hydrologic System, and the water quality exceeds the standard for the stream.**
4.*	**A significant change in pH or specific conductance at the Mill Level Tunnel where such change is not known to be caused by natural conditions, seasonal variations, bulkhead operation, or other events.**
5.**	**Catastrophic plugging of one or more of the bulkhead intakes or pipes in which repeated O&M clearing procedures fail to restore flow.**
6.**	**Direct discharge of Mill Level or Meldrum tunnel water to Marshall Creek, the San Miguel River, or Ingram Creek, except where discharge is authorized by the State.**

*May take several years of data collection to understand seasonal baseline conditions.
**The occurrence of Condition 3, Condition 5, or Condition 6 will result in an immediate response action.

FIGURES



T:\210118 Idarado\17b Flow chart\Flow Chart.dwg SAVED:11/15/17 PRINTED:11/15/17

Project No. 210118:17b

November 2017

Engineering Analytics, Inc.

FIGURE 1
CONTINGENCY PLAN FLOW CHART
IDARADO

APPENDIX A
GLOSSARY

Glossary

Unless otherwise defined below, terms used in this Contingency Plan shall have the meaning assigned to them in the Work Plan.

ADVERSE WATER CONDITIONS. Conditions described in Table 1 of the CP.

CONTINGENCY PLAN. The plan that describes options or contingencies that will be undertaken in the event that a predetermined set of undesirable hydrologic conditions occurs. The Contingency Plan for the Idarado Underground Workings Hydrologic System describes the undesirable conditions that will be monitored, the type of monitoring program that is required to detect their occurrence, and the actions that will be taken to control or mitigate these conditions.

PARAMETER. A monitored attribute of the Idarado Underground Workings Hydrologic System.

MONITORING POINT. The location at which an indicator or parameter is monitored, such as the location of a given discharge point or seep.

RESPONSE ACTION. An action that can be taken to mitigate or control an undesirable hydrologic condition such as the discharge from a new seep or spring that adversely affects the water quality of a stream. Response actions will be selected from a range of potentially applicable actions and will be developed or modified to meet site-specific conditions and response goals. The effectiveness of a given response action will be evaluated using criteria developed specifically for each action.

ROUTINE MONITORING. The Routine Monitoring Mode of Operation of the Contingency Plan during which the Routine Monitoring Plan is implemented.

ROUTINE MONITORING PLAN. The plan that describes the objectives, monitoring points, indicators, indicator thresholds, sampling and laboratory methods, quality assurance procedures, data evaluation methods, and reporting requirements that will be implemented during the baseline and routine monitoring programs.

IDARADO UNDERGROUND WORKINGS HYDROLOGIC SYSTEM. The subsurface flow system that consists of the groundwater which flows to or from the Mill Level and Meldrum tunnels.