TUNNEL CONDITION ASSESSMENT REPORT
Rev. 1

SENIOR CANYON TUNNEL
OJAI, CALIFORNIA

May 15, 2017

PREPARED FOR:

Senior Canyon Mutual Water Company
603 W. Ojai Ave
Ojai, CA 93023-3732

PREPARED BY:

JCK UNDERGROUND

61 S. Baldwin Ave #187
Sierra Madre, CA 91025

Distribution

Prepared By: Joel Kantola, P.E.

Phaidra Campbell, P.E.

Reviewed By: Jennifer Jordan, P.E.

Rafael Castro, P.E.

Thomas Hennings, P.E., P.Eng.

Joel Kantola, P.E.

Rafael Castro, P.E.

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1 INTRODUCTION

The Senior Canyon Mutual Water Company (SCMWC) constructed a water supply tunnel in 1929 from a work site located at the end of Ladera Road in Senior Canyon, north of the Ojai Valley in Ojai, California. Approximately 88 years later, this tunnel, hereinafter referred to as "the Senior Canyon Tunnel" or simply "the tunnel", is still owned and operated by SCMWC. Per the officials at the water company:

- The tunnel is believed to be between 3,000-feet to 3,400-feet in length.
- Sometime in the 1980's, soil-like material fell into the tunnel at 2,400 feet from the tunnel entrance (portal) and effectively sealed off the remaining length of the tunnel.
- The tunnel has produced water for 88 years.
- The historic minimum water discharging from the tunnel is 60 gallons per minute (gpm).
- During heavy rain storms the water discharge has peaked at 450 gpm.
- Other than maintenance, the tunnel has had little work performed on it since the original construction.

In 1994, Dr. Scott from Rolla, Missouri provided recommendations on how to improve the tunnel in order to ensure its reliable use as a water resource. Dr. Scott also provided recommendations on how to enhance the water discharge from the tunnel. These recommendations are summarized later in this report.

SCMWC hired JCK Underground to inspect the accessible 2,400 feet of tunnel and assess the effort required to implement Dr. Scott's recommendations, including:

- Gathering data on tunnel geometry, geology, rock mass properties, and groundwater inflow.
- Using the data to determine tunnel improvements needed to:
  - Create a safe environment to support work associated with enhancing water inflow.
  - Provide long-term ground support to ensure the tunnel's use as a water resource.
- Recommended means and methods for improving water discharge from the tunnel.
- Providing a cost estimate for tunnel improvements, enhancing inflows and improving discharge.
- Providing project work considerations.

This report summarizes the results of our inspection and provides recommendations and a cost estimate for the work required to implement the improvements and enhancements.

2 PROJECT BACKGROUND

The SCMWC is a non-profit company, located within the Casitas Municipal Water District (CMWD), which collects and treats water from three sources: two creek diversions, a connection to Casitas' treated surface water, and the Senior Canyon Tunnel. The company serves between 600 to 800 people with a mixture of residential and agricultural users within the upper Ojai Valley.

The Senior Canyon Tunnel is located to the north of the Ojai Valley at the end of Ladera Road. The tunnel's entrance (portal) location is shown in relation to the Ojai Valley. The tunnel was driven somewhere between 2,400-feet to 3,500-feet into the bedrock that forms the Santa Ynez Mountains, specifically Chief Peak. Based on the United States Geological Survey (USGS) Ojai Quadrangle and measurements taken within the tunnel, the first 1,588-feet of the tunnel alignment bears at N 55° E. Per the same USGS map, the tunnel floor (invert) at the portal is at elevation 2,430 feet. The plan view of the tunnel with topography is provided below. The tunnel was driven at a slight incline, but the actual rise in elevation over the length of the tunnel was not measured during this inspection.

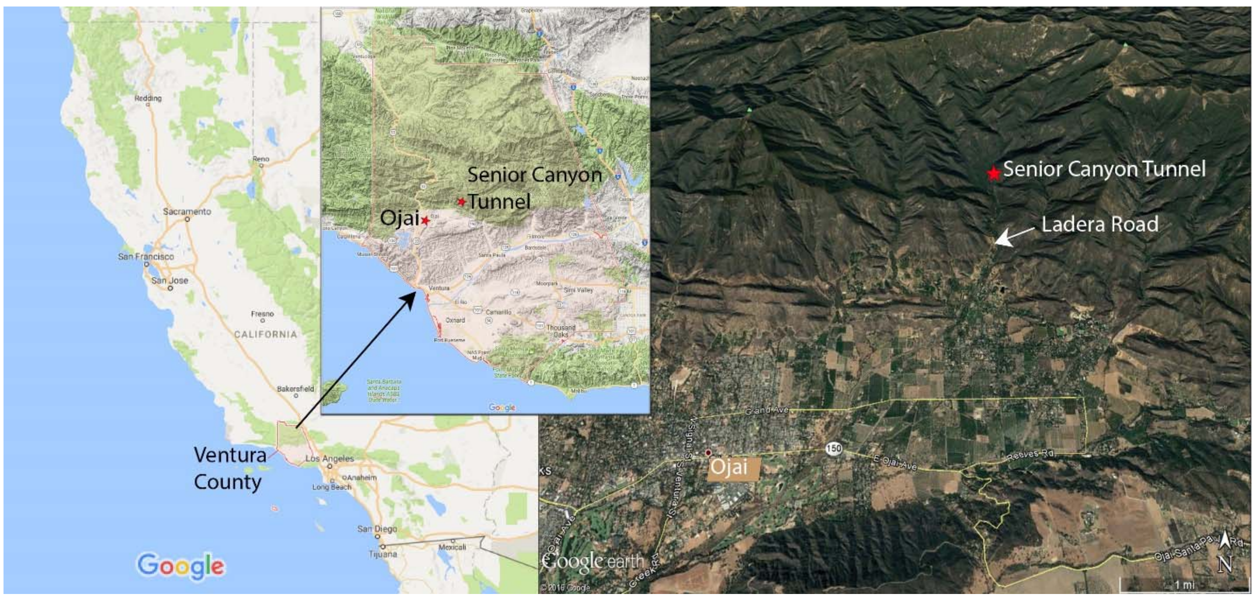


Figure 2-1: Senior Canyon Tunnel Portal Location, Ojai, California ("Ojai", 2016)

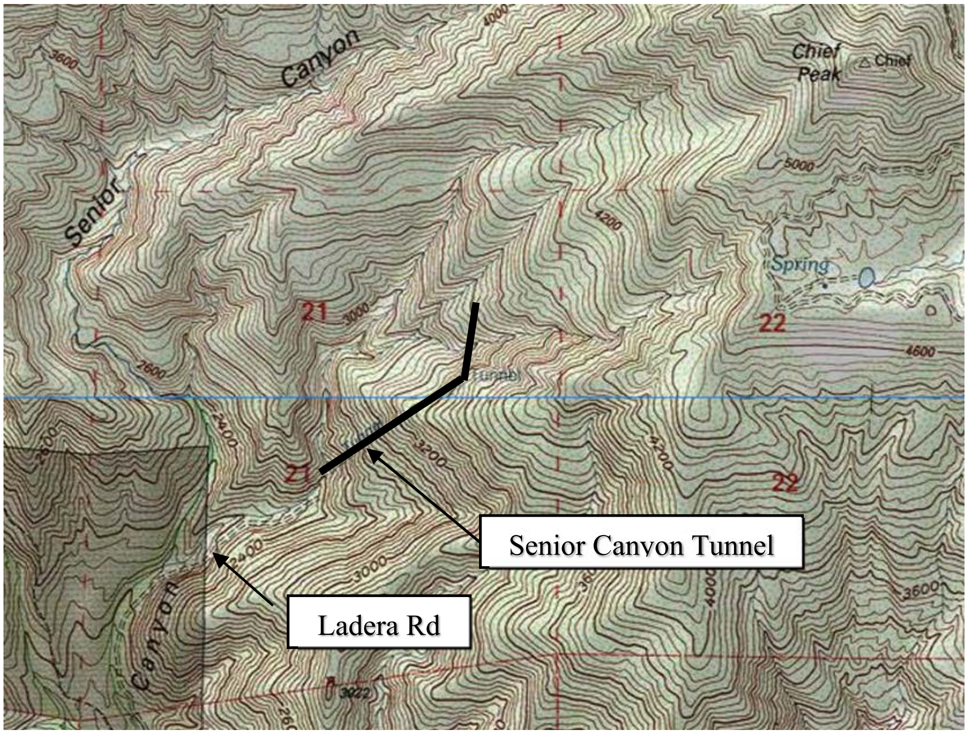


Figure 2-2: Senior Canyon Tunnel Approximate Alignment in Plan with Topography (USGS, 2015)

2.1 1929 Construction

In 1929 SCMWC began and completed the construction of the tunnel to a distance of at least 1,555-feet from the portal. On average, the width and height of the tunnel is 8-foot by 8-foot, respectively. As-built dimensions at 100-foot intervals (also referred to as Stations) are provided in this report in Section 5.

The excavation work was performed using drill and blast methods. Based on news articles written at the time of construction, the blasting loosened the rock surrounding the tunnel (see summary below). There are short stretches in the tunnel that have been supported with either timbers, concrete ribs, or cast-in-place (CIP) concrete lining. These supported sections are documented in this report in Section 5.

Insight into the construction is provided in two articles reported in the local newspaper called "The Ojai," dated December 13, 1929. The pertinent information from these articles is summarized:

- Tunneling began in May 1929.
- Very little water was encountered in the first 500-feet of excavation.
- Between 500-feet to 1,555-feet of excavation, several "little stream" inflows were encountered.
- Timber supports were added where soft shale was encountered.
- The tunnel was dry at first, but blasting shook the hillside and trickles of water began to appear often near the invert. As these flows increased it started to impede the work.
- In late November, 1929, the tunnel superintendent raised the rail that were used to haul material in and out of the tunnel, in anticipation of encountering water. Based on the lack of substantial water inflow encountered at that moment, raising the rails was considered optimistic.
- On December 9, 1929, 1,555-feet into the tunnel drive, the following was reported:

  "Then suddenly we were upon it – the gusher. Straight in front of us a diffused spray of water shot out from the shale which blocked the tunnel's end, pouring out with fire-hose

pressure from a fissure slanting upward across the face of the rock, a fissure only eight or ten inches long."(Ojai, 1929)

- On December 9, 1929, water discharging from the tunnel was reported as "50-inches of flow."
- By December 11, 1929, water discharge from the tunnel was reported as "75-inches of flow." (Note: a "miner's inch" is regional and hard to interpret).
- On December 11, 1929, a reporter from The Ojai reported the water depth as knee deep in the tunnel. The same reporter also commented that water was coming out of the ceiling, sides, and floor of the tunnel.
- One of the articles put forth the following theory on the origin of the water:
  - The nature of the geologic formation traps this water high up in the mountains.
  - The water stored in the strata is fed by favorable topography that acts as a series of catch basins which store the rainwater, but the drainage of the water is impeded such that it slowly works its way down in the channel which feeds the tunnel gusher.
- At the time of reporting, there was no intention of advancing the tunnel beyond 1,555-feet. There was plans to block off a portion of the tunnel with a concrete dam to store water and regulate the water discharges from the tunnel.

2.2 Excavation after 1929

Sometime after the 1929 construction, tunnel excavation was resumed and the heading was advanced well beyond a length of 1,555-feet. Anecdotal evidence, provided by the local residents (locals) who at one time maintained the tunnel, puts the total length to be between 3,000- to 3,500-feet. The locals described the end of the tunnel as having a wall of rock that was soft enough to push a finger into. These same locals relayed second-hand information that the excavation was stopped due to excess water being encountered at the tunnel heading. The actual length of the tunnel is unknown and due to later ground loss cannot currently be measured.

2.3 1980's Ground Loss at Station 24+00

The SCMWC stated that sometime in the 1980's material fell into the tunnel and created an obstruction. During the geometric survey, the distance to the fully obstructed tunnel was measured and determined to be at approximately 2,400-feet from the portal. By visual inspection, it appeared that the obstruction was formed by the piling of material that fell from a feature in the crown and possibly the sidewalls of the tunnel. The fallen material is consistent with the pulverized material seen in the faults located at other locations along the tunnel. The material is soil-like and has formed a natural repose that slopes downward at approximately 30° from the crown of the tunnel at Station 24+00 back to the toe of the slope at Station 23+80.

Based on SCMWC officials, at one time the stacked material at Station 24+00 did not fully seal the tunnel and could be "looked-over". It is reported that one could observe the tunnel extending well beyond the stack of fallen material. During the December 2016 geometric survey, approximately 1 gpm or less of flowing water was observed coming from the toe of the piled material.

2.4 Dr. Scott's Recommendations

In October 1994, Dr. James J. Scott (Scott, 1994), a mining consultant, visited and assessed the stability of the tunnel and recommend improvements to protect the tunnel as a water source. Dr. Scott also provided recommendations to enhance water inflows and improve water discharge from the tunnel. In general, Scott felt the tunnel was a valuable water resource, and though the rock was fractured, the fractures themselves were:

"…fundamentally tight, with fall zones occurring near where water is most prevalent." (Scott, 1994)

Scott recommended a 3-phase approach for improvements, including:

Phase 1: Improve the tunnel by hand scaling the loose material and bolt the roof as needed to stabilize slabs. Advance a small opening through the tunnel obstruction at Station 24+00. Determine if additional water resources can be captured by re-establishing the tunnel to its full length.

Phase 2: If Phase 1 is successful, continue improving the tunnel by cleaning it over its entire length.

Phase 3: Enhance the water resource capacity by drilling a fan pattern of holes within the tunnel to intercept additional groundwater inflows.

General: Investigate if sections of "dry" sandstone in the tunnel invert are absorbing water by using a series of temporary dams and weirs at strategic locations. Any areas found to be absorbing water should be sealed.

During Scott's visit in 1994 the rails were still in decent condition and he felt they could be re-used to support the work outline in Phase 1, 2, and 3 above. This is no longer the case, the ties have deteriorated substantially and can no longer be relied upon for reuse.

2.5 Current Conditions

Per discussions with the SCMWC officials:

- The tunnel has supplied water on an uninterrupted basis with current discharges being reported as 40-60 gallons per minute (gpm). A considerable amount of this water is from inflows coming through the tunnel's invert.
- During large rain events, the tunnel discharge can increase up to 450 gpm. The increase in water inflows are mainly from the sidewalls and crown of the tunnel.
- Water discharging from the tunnel are piped down the mountain from the portal and the flow rate is measured by a partial flume.

3 GENERAL SITE GEOLOGY

The following sections summarize the Senior Canyon Tunnel site conditions including regional geology, local geology and geomorphology, groundwater regime, and regional seismicity. Specific rock characteristics, rock mass discontinuities, and groundwater conditions within the tunnel are included within Section 6 of this report.

3.1 Regional Geology

The project area is located on the side of the east-west running Santa Ynez mountain range that is immediately to the North of the Ojai Valley. These mountains are composed of sedimentary rocks that were deposited approximately 36-million years ago, during the Eocene Epoch. Rock types include sandstone, shale, siltstone, and claystone. As the earth's crust squeezed together from the North and South, the ground was lifted and folded. The Santa Ynez Mountains resulted from upward folding of the crust into an arch and the Ojai Valley resulted from a downward folding of the crust into a trough, which are known as anticlines and synclines, respectively. During this process, and other geologic events, the bedrock fractured and formed discontinuities such as faults, shears, and movements along bedding planes. It should be noted, these mountains are still forming and are one of the fastest rising mountain ranges in the United States, with uplift rates as high as 0.2 to 0.4 inches per year (Ferren et al, 1990).

3.2 Local Geology and Geomorphology

The Senior Canyon Tunnel is located within the Senior Canyon Valley on the south face of the Santa Ynez Mountains. The tunnel portal was built in the valley of the canyon and the tunnel alignment cuts into the steep mountainside, southwest of Chief Peak between Nordhoff Ridge Road and the town of Ojai. Based on USGS topographic maps, the invert at the portal is at elevation 2,430 feet and ground cover ranges from 0 feet at the portal face to approximately 1,250 feet at Station 35+00. (Dibblee, 1987). The tunnel portal is located at the end of a dirt road. The steep hill side above the tunnel consists of high-desert brush vegetation rooted in loose, erodible soils and occasional intact rock outcrops.

Geotechnical borings above the tunnel are not available so the actual depth of bedrock is unknown, but it is assumed to be shallow based on observations of numerous rock outcrops. Below shows a photograph of a portion of the access area at the portal and the hillside above the tunnel alignment.

Figure 3-1: Senior Canyon Tunnel Portal Staging Area and Hillside above the Tunnel Alignment

Based on the USGS fault map, a southeast-northwest horizontal orientation of the fault was identified by Dibble, 1987. The portal and majority of the tunnel is located on the upthrown portion of the fault and the rest of the tunnel is located on the downthrown portion. In addition, the tunnel has been driven parallel to the orientation of the anticline. Figure 3-2 shows the tunnel alignment in relation to the fault and anticline.

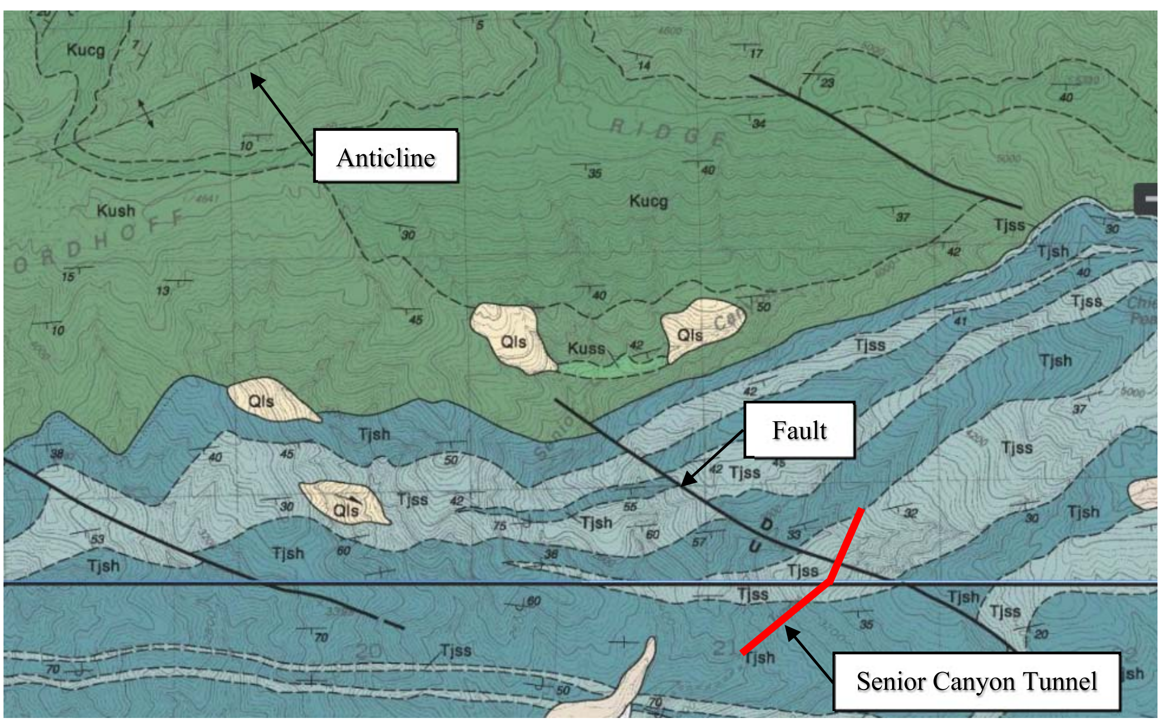


Figure 3-2: Senior Canyon Tunnel and Geologic Features Map (Dibble, 1987)

The tunnel alignment is located in sedimentary bedrock that include shales and sandstones, designated on Figure 3-2 as Tjsh and Tjss, respectively. The description of these rock types per the USGS map are:

- Shale: Dark gray micaceous shale and siltstone with minor thin interbeds of hard, gray-white to tan arkosic sandstone (Tjsh).
- Sandstone: Hard, gray-white to tan arkosic sandstone with minor interbeds of dark gray, micaceous shale (Tjss).

3.3 Groundwater Regime

The local watershed is a complex system comprised of stormwater runoff, streams, and lakes. Within Senior Canyon alone, there are multiple creeks including Senior Canyon Creek. From these surface sources, water migrates downward through the discontinuities during rain events and locally resupplies the groundwater aquifer on a seasonal basis. The aquifer may also be fed from deeper sources related to a regional groundwater flow, which is less affected by seasonal changes. The flow of water within the aquifer is controlled by fractures within the rock mass, including faults, bedding joints, and other discontinuities. The ability of water to freely flow through the rock mass is controlled by the nature of these fractures, including: their location, length, aperture (width), interconnections with other fractures, and infill material within the aperture of the fracture. Fractures packed with pulverized soil-like material may significantly impede the flow of water within the rock mass, whereas crushed rock within an open fracture aperture can easily convey water through the rock mass.

3.4 Regional Seismicity

The Senior Canyon Tunnel is located between Santa Ynez Fault and the Santa Ana Section of the Mission Ridge Fault. The Santa Ynez Fault is a late quaternary (less than 130,000 years old), left lateral strike fault that bears N88° E near the tunnel location. Per USGS, the Santa Ynez fault slip rate is between 1.0 and 5.0 mm/yr. The tunnel is located approximately 2 miles south from the Santa Ynez Fault.

The Santa Ana Section of the Mission Ridge Fault is a late quaternary, reverse fault that bears N 80° E near the tunnel location. Per USGS, the Santa Ana Section of the Mission Ridge Fault slip rate is between 0.2 and 1.0 mm/yr. The tunnel is located approximately 4 miles north from this fault.

Figure 3-3 shows the location of the faults in relation to the Senior Canyon Tunnel.

Figure 3-3: Santa Ynez and Santa Ana section of the Mission Ridge Faults ("Ojai", 2015 and USGS, 2006)

4 TUNNEL INSPECTION APPROACH

On December 8, 2016, JCK Underground assisted SCMWC personnel establish station markers along the tunnel length to Station 24+00 and helped collect basic data at 100-foot intervals, including: photographs and measurements of the tunnel cross section.

On February 2 and 3, 2017, JCK Underground returned to Senior Canyon Tunnel to conduct the inspection. The inspection work was broken into a series of passes designed to systematically gather data for the follow-on inspection. The focus of this inspection included:

- Mapping the geologic structure and collecting data on the rock mass properties.
- Locating and quantifying the sources of groundwater inflows contributing to the tunnel discharge.
- Locating where ground support improvements are needed to ensure safe access into the tunnel.
- Locating other features within the tunnel that influence the cost of improving the tunnel and enhancing the water discharge.

On the first pass, ground water inflows were located and quantified along the length of the tunnel. Sources of inflows included pinholes observed on the invert, wetness noted on tunnel walls, drips from the crown and walls, and concentrated flows from the invert and walls. The flows were estimated based on direct measurement where possible (e.g. timed filling of a 1-gallon container), comparison to known flows (e.g. tap water, garden hoses, etc.), relative comparison between inflows within the tunnel, and experience on previous projects.

The second pass of the inspection work focused on identifying areas requiring additional ground support. This was an experience-based assessment of the observed rock fracturing and wedges.

On the third pass, bedrock data was collected, including: rock type, bedding thickness, vertical and horizontal orientation, and rock mass properties. In general, the rock observed within the tunnel is predominately gray sandstone with limited features to identify the orientation of the formation. The sandstone lacks color variations and bedding planes are not readily visible by the eye. Therefore, marker beds were used to orientate geologic formations, specifically the strike (horizontal orientation) and dip (vertical orientation) of the sedimentary beds.

Marker beds are layers of sedimentary bedrock that can be easily identified within a larger geologic setting. For this tunnel, within the sandstone, there are frequently repeated sequences of very thin layers of dark gray, micaceous, shales very closely to closely interbedded with thin layers of sandstone. These sequences form easily distinguishable bands of composite materials (shale and sandstone) and served as the marker beds that helped establish the horizontal and vertical orientation of the rock. As part of mapping the marker beds, the following geologic data was gathered:

- Rock type and layer thicknesses;
- Orientation (e.g. strike and dip) of the bedrock layers;
- Joint (separation between layer) apertures and infill material;
- Weathering;
- Relative rock strength.

The fourth pass of the inspection was used to confirm the orientation and layer thicknesses of the sandstone between the marker beds, as well as gather geologic data for the marker beds.

The fifth pass was used to collect fracture data for the following: the primary fracture set, a more limited secondary fracture set, and several faults. The data collected on these discontinuities included orientation, spacing, fracture aperture, infill material and weathering of the fracture surfaces.

The sixth, seventh, and eighth passes were used to locate and/or measure the following: areas where loosened rock had fallen out of the wall and crown of the tunnel, housekeeping issues (e.g. debris, old pipes, etc.), voids above the existing ground support, and air quality along the length of the tunnel.

5 TUNNEL CONDITION

Data was collected on the physical condition of the tunnel including: alignment, internal tunnel support, tunnel geometry, the condition of the invert, location of rock falls, and air quality, which is summarized in this section. Photographs taken at 100-foot stations during the inspection are included in Appendix B.

5.1 Tunnel Alignment

The bearing of the tunnel alignment was measured from the USGS Ojai Quadrangle map (Dibble, 1987) as N 55° E. The USGS map provided no indication that the tunnel curves to the North. However, upon inspection two bend points were observed, the first at approximate Station 15+88 and the second Station 16+16. Using a crude survey method involving line of sight and offset measurements, it was determined that the direction of the tunnel changes to a bearing of about N 33° E at the first bend, and changes to bearing of about N 23° E at the second bend. No additional or obvious bends were observed past Station 16+16 to Station 24+00.

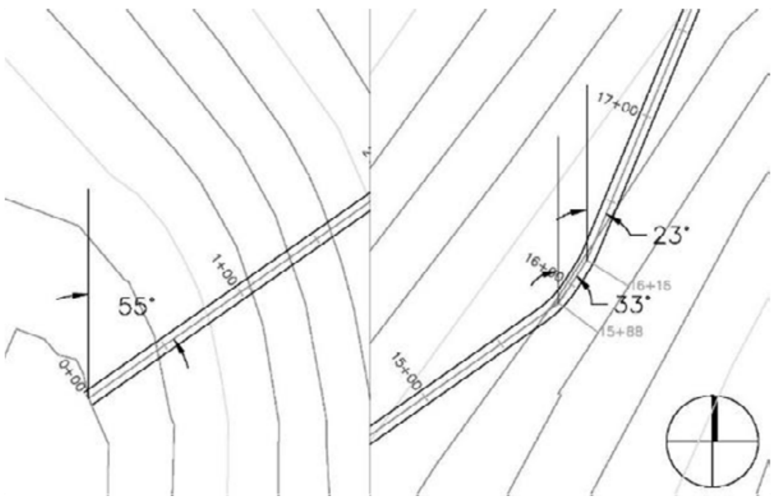


Figure 5-1: Senior Canyon Tunnel Bearings (Dibble, 1987 and Topography from USGS, 2015)

5.2 Internal Tunnel Support

The Senior Canyon Tunnel is accessible to 2,400 feet from the tunnel portal, at which point the tunnel is filled to the crown with a pile of pulverized material. To this point, the tunnel is predominately unlined, however, there are five (5) short sections of the tunnel that are supported by internal structures. Three (3) sections of tunnel are supported with cast-in-place (CIP) concrete tunnel liners ranging in length between 20 feet to 90 feet. It could not be determined if the CIP liner is reinforced with steel. One (1) 34-foot long section of tunnel is supported with timber sets. One (1) 10-foot long section of tunnel is supported with CIP concrete rib sets. Figure 5-2 shows the approximate locations of these internal tunnel supports.

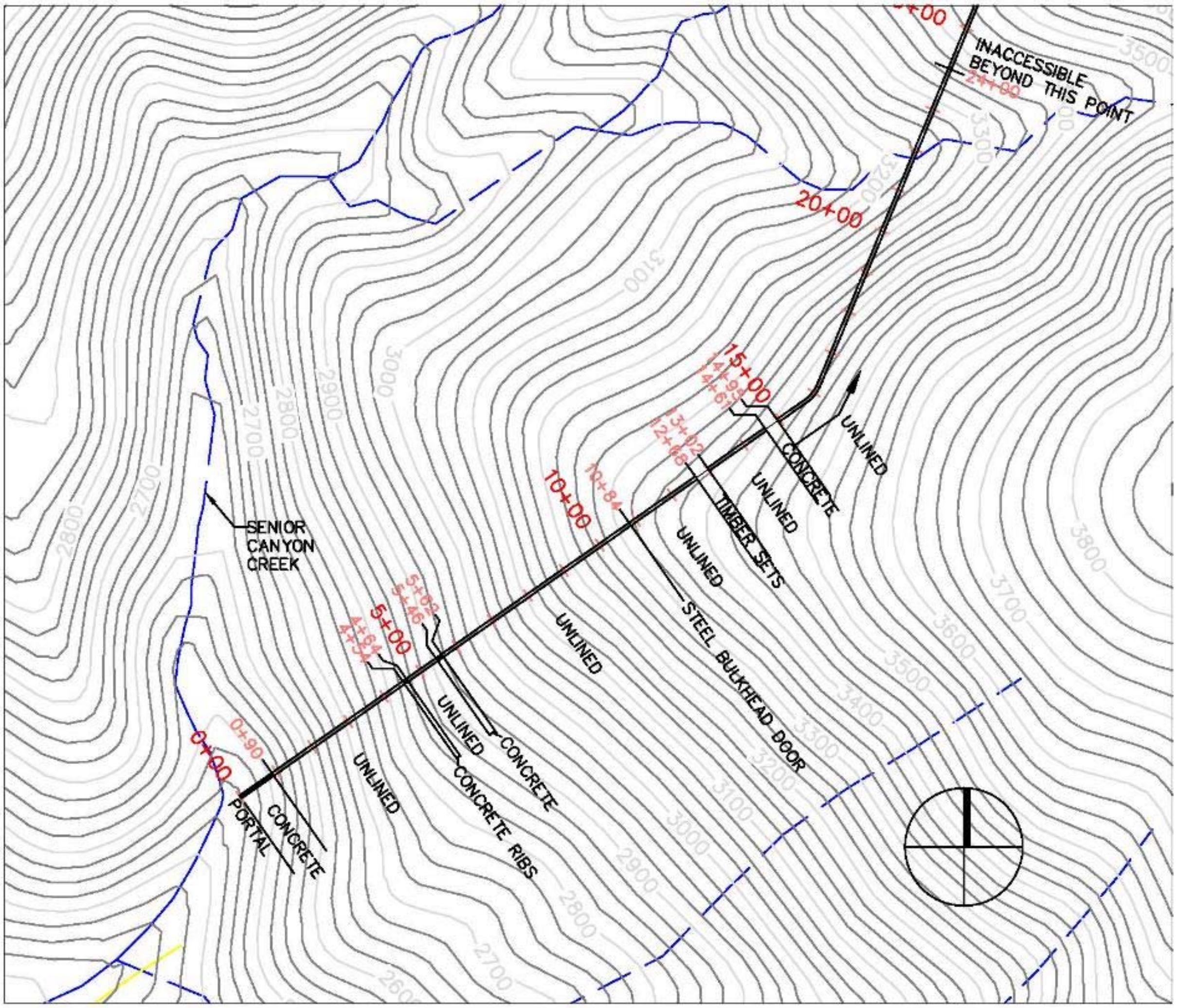


Figure 5-2: Senior Canyon Tunnel Stationing and Liner (Topography from USGS, 2015)

The concrete lined sections of the tunnel appear to be in good shape, however there is a large void above the liner at Station 5+46 to 5+62 (See Figure 5-3). Within this void is a large wedge of rock directly above the liner that could cause damage if it falls.

Figure 5-3: Horseshoe-shaped CIP Concrete Liner with Open Annulus at Crown at Station 5+46

The timber sets from Station 12+68 to 13+02 were most likely installed during the original tunnel construction and have been exposed to water conditions throughout its lifetime. The rock within this zone has a shallow dipping plane which resembles slabbing at the crown, hence the use of the timber sets as an initial support. The timber sets are 6 by 8 inches in area and are set up in a trapezoidal shape with occasional blocking to provide contact with the rock. From observation, the timbers are soft and spongy and unreliable as a support. A large pile of rock, most likely fallout from the sidewall, was noted at the left side of the invert (looking upstream). Figure 5-4 (below) shows a photograph of the trapezoidal-shaped timber sets.

Figure 5-4: Trapezoidal-shaped Timber Sets and Rock Debris at Invert at Station 12+68

5.3 Tunnel Measurements

The cross section of the unlined portions of the tunnel is predominately rectangular, often shaped by the fracture orientations in the rock mass. The CIP concrete-lined portions of the tunnel are horse-shoe shaped, as shown in Figure 5-5.

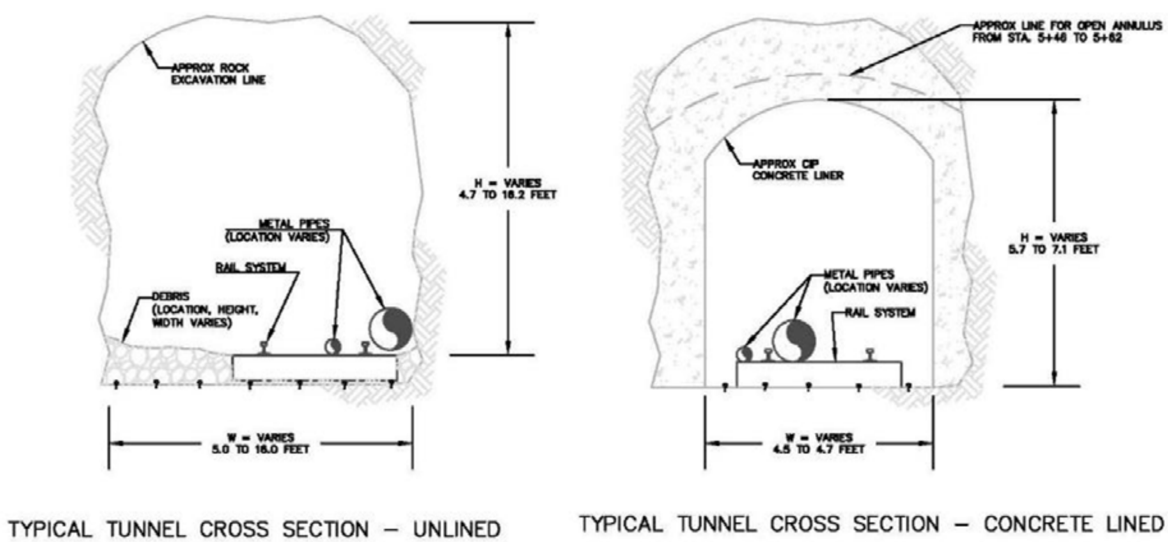


Figure 5-5: Senior Canyon Tunnel Typical Cross Sections

The cross-section dimensions were measured at 100-foot Stations and where internal tunnel support was located. The width of the tunnel was enlarged in some of the unlined portions of the tunnel. These areas are believed to have been used as laydown areas to store materials during tunnel construction operations. In addition, the tunnel was observed to reduce in height at approximate Station 17+00. Table 2 is Appendix A provides all the dimensional data collected and Table 5-1 below provides averages, maximums, and minimum widths and heights for both unlined, lined, and internal support sections.

Table 5-1: Senior Canyon Tunnel Measurements at Unlined, Lined, and Support Sections

Station	Width (feet)			Height (feet)			*Notes*
	Avg	Max	Min	Avg	Max	Min	
0+90 to 17+00	7.9	11.7	5.8	9.0	16.2	6.2	Unlined Portions
17+00 to 24+00	7.9	16.0	5.0	7.2	8.9	4.7	
0+00 to 0+90	4.5	4.5	4.6	6.3	5.8	6.7	Concrete liner
4+54 to 4+60	5.6	-	-	7.5	-	-	Concrete sets – trapezoid shape
5+46 to 5+62	4.7	-	-	7.1	-	-	Concrete liner with open annulus at crown
10+84	4.1	-	-	5.1	-	-	Bulkhead door with square concrete liner
12+68 to 13+02	5.5	-	-	6.8	-	-	Timber sets – trapezoidal shape
14+61 to 15+02	4.5	4.5	4.6	5.7	5.7	5.8	Concrete liner

5.4 Rock Fallouts

Rock fallout include material unravelling from faults and rock blocks loosening from the tunnel walls.

Faults are thin features that are fully packed with very dense pulverized material (see Figure 5-6). The infill material may loosen with time when exposed to air and fall to the invert. Given enough time, the fallout can create an obstruction, as it has at Station 24+00 (see Figure 5-7). The potential for similar fallout may exist at Stations 13+59, 14+97, 15+48, and 20+30, where faults crossing the tunnel have been identified.

Figure 5-6: Pulverized Material within a fault at Station 20+30

Figure 5-7: Obstructed Tunnel from Fallen Material at Station 24+00

Rock blocks may fall from the tunnel walls as they loosen with time. Figure 5-4 above shows rock fallout at Station 12+70 supported by the timber sets. Rock block fallout was also observed at Stations 11+50, 11+95, 12+70, 15+40, 15+50, and 15+55. The rock fallout data collected is tabulated in Table 8 in Appendix A.

5.5 General Conditions

Materials not considered essential for the operation and maintenance of the tunnel were inventoried and include: rail tees and ties, track ballast and miscellaneous materials.

The rail runs the length of the tunnel and consist of 16 pound tees, wooden ties and track ballast. The rail tees are corroded and the wood ties are deteriorated. For most of the tunnel, the tees are spaced with a narrow track gauge of approximately 2 feet. However, where the ties are broken or missing the track ballast has pushed the tees closer together. Figure 5-8 shows the rail system at approximate Station 6+50, where it appears that the track ballast on the right side of the rail has been moved to the left side in an attempt to improve water flow along the invert.

Figure 5-8: Typical Tunnel Invert with Debris, Rail System, and Flow (Photograph taken at Station 6+50)

The miscellaneous materials are inventoried in Section 9, and include:

- Three (3) metal pipes located at the invert, with diameters ranging from 2 to 10 inches.
- An abandoned, uncharged, electric wire.
- Metal rods embedded in the rock at the 2:00 and 10:00 positions.
- Long strands of "tie wire" attached to the metal rods.
- Invert pipe conveying water beneath the bulkhead door at Station 10+84.
- Wheel barrow and muck car bucket.

During the inspection, the water depth in the invert varied from 0 to 6 inches. Figure 5-8 shows the water in the tunnel invert at approximate Station 6+50. At this location, the water flow does not appear to agree with the discharge being recorded by SCMWC or the observations made by JCK Underground. A possible explanation could be that the flow was altered when the rail was raised in November 1929, in preparation for encountering water. At that time, a discharge pipe may have been buried in the track ballast to keep the work area dry.

6 GEOLOGIC MAPPING

Observations and measurements of pertinent geologic data were collected and used to assess the stability of the tunnel and to quantify the location of unstable rock and sources of groundwater inflow. The data collected is tabulated in Appendix A and summarized in this section.

6.1 Rock Units

Based on USGS geologic maps (Dibble, 1987), the bedrock is part of the Juncal Formation, which consists of sandstone and shale. Our mapping encountered predominately a gray sandstone that lacked obvious signs of bedding. However, these thicker layers of sandstone were interrupted by layers of very thin (e.g. less than 2”) dark gray shale that was interbedded with thin (e.g. 2” to 12”) layers of sandstone. These interbedded layers became the marker beds used to map the orientation (strike and dip) of the bedrock formation. There were at least 24 marker beds between Station 0+00 to 16+00 and their location is shown on Drawing 7 of Appendix C.

The marker beds, and hence the formation, generally have a horizontal orientation (strike) between S101ºE and S124ºE degrees. The vertical orientation (dip) angles of the bedding within three approximate reaches of the tunnel is as follows:

- Station 0+00 to 6+55: dip between 45º-75º
- Station 6+55 to 14+30: dip between 25º-76º
- Station 14+30 to 16+00: dip between 58º- 77º

Figure 6-1 below shows the horizontal and vertical orientation of a bedding at Station 8+50.

Figure 6-1: Horizontal and Vertical Orientation (Strike and Dip) of Bedding at Station 8+50

6.2 Rock Mass Properties

Data on the rock mass properties was collected, including: weathering, strength, faults, bedding joints, joint sets and groundwater inflows. The data summarized below is also tabulated in Appendix A.

6.2.1 Rock Mass Weathering

Weathering is the chemical and mechanical breakdown of rock. In general, the rock mass in the Senior Canyon Tunnel is unweathered (a.k.a Fresh) to slightly weathered. The unweathered rock does not show signs of discoloration or loss of strength. The slightly weathered rock is often discolored on the face of the fractures, however it does not appear to have any noticeable loss of strength.

6.2.2 Strength

Rock strength was estimated using established empirical relationships of rock behavior when struck firmly with a geologic hammer. The sandstone located near, or as part of the marker beds, generally either formed a shallow indentation when struck with the geologic hammer or fractures with a single firm blow with the hammer. These reactions is indicative of weak to moderately strong rock with an approximate uniaxial compressive strength (UCS) ranging between 700 to 7,200 psi. Where the sandstone beds become thicker, the rock would either take one or more blows to fracture, which is indicative of moderately strong to strong rock with an approximate UCS ranging between 3,600 to 14,500 psi. Results are provided on Table 4 of Appendix A.

6.2.3 Faults

Fault zones are present in the rock mass, as evidence by the presence of pulverized material filled within vertical fractures that run perpendicular to the tunnel at five (5) identified locations: Stations 13+59, 14+97, 15+48, 20+30 (see Photograph 28 in Appendix B), and 24+00 (see Figures 5-6 and 5-7). The two faults located beyond Station 16+00 (at Stations 20+30 and 24+00), were located during the geometric survey in December 2016. The faults range in thickness from 4 to 22 inches, and are filled with pulverized material (e.g. intact gravel sized rock fragments and soil-like material). As previously discussed, the pulverized material slowly unravels, falls out and piles up on the invert, as shown in Figure 5-7. The fallout does not seem to be de-stabilizing the rock mass, but it is limiting access beyond Station 24+00.

6.2.4 Bedding Joints

The bedding joints are separations between layers of sedimentary rock. Where the sandstone layers were thick, bedding joints were either non-existent or so tight that they could not be seen by the unaided eye. However, bedding joints were obvious in the marker beds, where numerous joints were observed. Most of the marker beds had at least one bedding joint that was filled with pulverized material similar to what is shown in Figure 6-2 (Note: the geologic hammer is embedded 2 inches into the pulverized material). The bedding joints are identified on Drawings 7 through 12, in Appendix C.

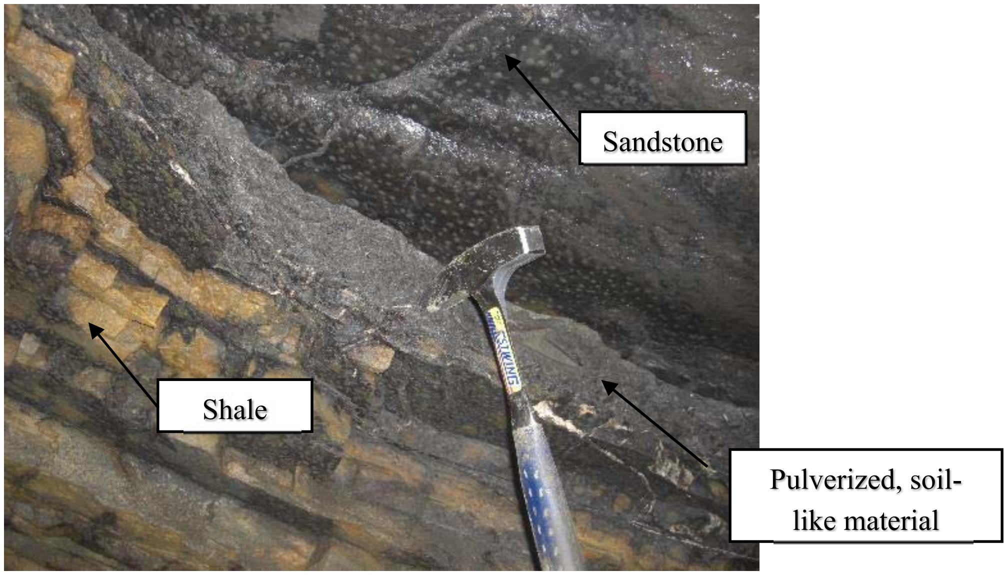


Figure 6-2: Geologic Hammer Inserted within Layer of Pulverized Material at Sandstone/Shale Contact

6.2.5 Joint Sets

Joints are natural discontinuities (fractures) along which no displacement has occurred. When numerous joints run parallel in a group they are called sets. Only one strong joint set was identified in the tunnel and it is referred to as the primary joint set, or Joint 1. Joint 1 was only observed between Station 1+00 and Station 11+00. Generally, Joint 1 strikes sub-parallel to the tunnel, dips steeply to the North, and persists over lengths that are longer than 30(+) feet.

A weaker secondary joint set, Joint 2, was identified between Station 3+00 and 7+00. Generally, Joint 2 strikes sub-perpendicular to the tunnel, undulates with a variable dip direction, and persists in lengths less than 10 feet.

The joint orientation data is summarized on Table 6-1.

Table 6-1: Discontinuity Orientations for Joint Sets 1 and 2

Station	Joint Set	Average Horizontal Orientation (Strike)/ Vertical Orientation (Dip)	Range in Horizontal Orientation (Strike)	Range in Vertical Orientation (Dip)
1+00 to 11+00	1	N 44° E / 68°	±30°	±25°
3+00 to ~7+00	2	S 128° E / 0°*	±20°	±20°*
* Joint set 2 vertical orientation varies from 20°N to 20°S, with one dip measured at 45° at Station 8+00				

Both joint sets generally are fresh to slightly weathered, slightly rough, tight aperture, and are moderately to highly fractured. Figure 6-3 illustrates the bedding joints and primary/secondary joints at Station 7+00, with their associated horizontal and vertical orientations in relation to the tunnel alignment.

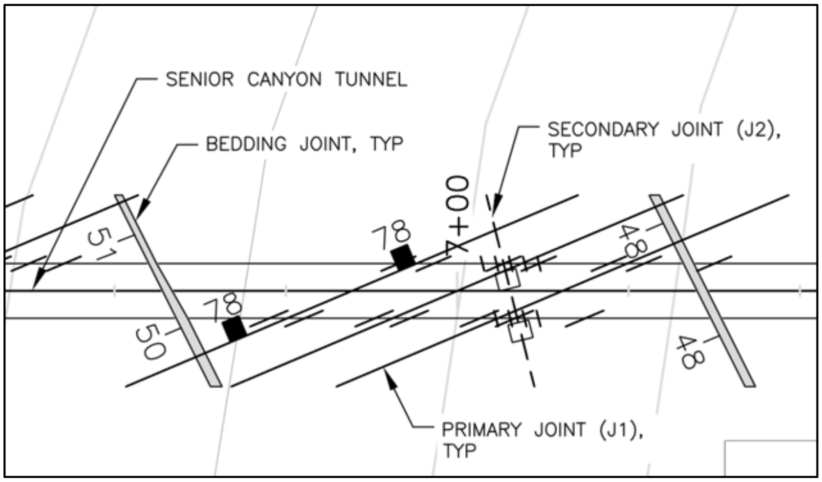


Figure 6-3: Horizontal and Vertical Orientation (Strike and Dip) of Joints at Station 7+00

The complete data for the joint sets are provided on Table 7 provided in Appendix A and shown on Drawings 7 through 12 in Appendix C.

6.3 Groundwater Inflow

Groundwater inflow data (e.g. location and estimated flow rate) was collected along the length of the tunnel. The inflow ranged from occasional drips to steady inflows up to 15 gpm. Wet tunnel walls, with no discernible flow, were also noted but was not considered for estimating inflow.

Inflows were present throughout the tunnel length, but six (6) distinct zones accounted for the majority of the inflow: Stations 5+87, 6+80, 6+96, 7+05 to 7+09, 15+72 to 15+88, and 16+66 to 16+73. The location and flow rate of each measured inflow is tabulated in Appendix A and shown on Drawings 7 through 12 in Appendix C. The following should be noted:

- Inflows coming up through the invert are difficult to see due to the track ballast. However, there is evidence that inflows are occurring. Pinholes, created by water seepage, were observed in areas where the track ballast was submerged.
- Staining and calcite deposits (see Figure 6-1 and Photographs 11 and 12 in Appendix B at Station 8+50) were observed on the sidewalls in areas producing inflows; but, there were multiple locations where calcite deposits were observed but no inflows were present (e.g. Stations 8+50(±), 9+36, 9+85, 11+47 to 11+50). Calcite deposits may have sealed the joints that were once producing water.

The total cumulative inflows into the tunnel during the inspection was estimated between 29 to 64 gpm. Figure 6-4 presents a plot of inflow locations, maximum inflow magnitudes, and the maximum cumulative discharge along the tunnel alignment.

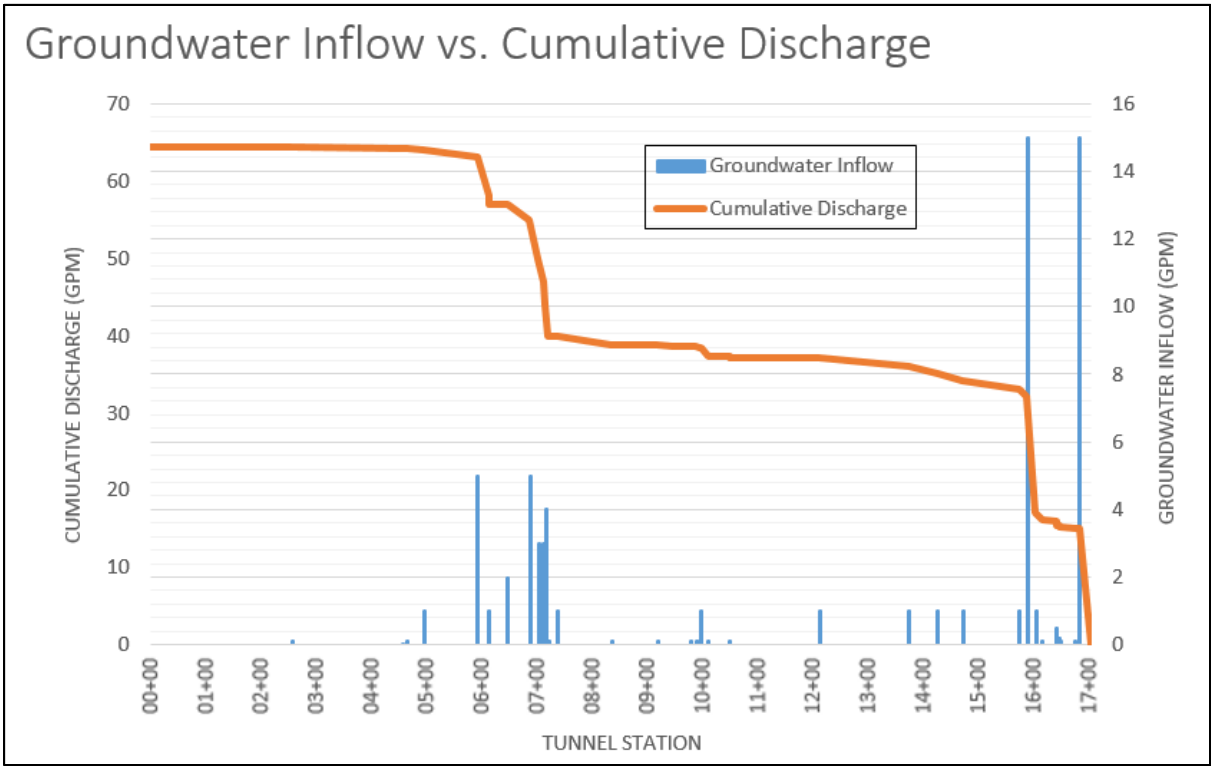


Figure 6-4: Groundwater Inflow vs. Cumulative Discharge along Tunnel Alignment

7 ROCK SUPPORT RECOMMENDATIONS

Figure 5-2 shows the areas of tunnel that are supported with either cast in place (CIP) concrete liner, timber or concrete rib sets. The remainder of the tunnel is unsupported, self-standing, rock. However, over time the timber sets have rotted and portions of the unsupported tunnel have loosened. In some cases rock blocks have come free and pulverized material has unraveled from faults. The short-term stability of the tunnel needs to be improved so that future work associated with enhancing water discharge can proceed and the long-term stability needs to be improved to assure continued use of this water resource. This can be accomplished by adding rock support, designed to withstand the loading condition and wet environment, but not to hinder water inflows. This section provides rock support recommendations.

7.1 Loading Conditions

Design loads are typically assumed to be equivalent to the weight of rock acting on the rock support system. These loads are calculated using concepts developed by Terzaghi and later modified by Deere (Proctor and White, 1968; Deere et al, 1969), and rely upon the condition of the rock and geometry of the tunnel. Using these concepts, the estimated loads were calculated for various conditions encountered in the Senior Canyon Tunnel, using the formulas provided in Table 7-1.

*Table 7-1: G*round Load Estimates

Ground Conditions	Estimated Ground Load	Recommended Design Vertical Ground Load B=8 feet, H=10 feet
Hard and intact	0	0
Massive, moderately jointed	0 to 0.25B	0 to 2 feet
Moderately blocky and seamy	0.25B to 0.35*(H+B)	2 feet to 6.3 feet (avg = 4.2 feet)
Very blocky and seamy	(0.35 to 1.10)*(H+B)	6.3 feet to 19.8 feet (avg = 13 feet)

B = Tunnel Width, H = Tunnel Height

7.2 Ground Support

Based on the loads estimated for the tunnel, five (5) different types of rock support are recommended, and are provided in Table 7-2.

Table 7-2: Rock Support Types

Type	Description	Typical Ground Conditions
I	Random rock bolt	Discrete rock blocks or slabs.
II	Three (3) bolt pattern, 4 feet on center	Zones of blocky rock, or slabs in the tunnel crown.
III	Three (3) bolt pattern, with mesh, 4 feet on center	Interbedded shales and slates, and areas with pulverized material and crushed rock in the tunnel crown.
IV	Steel ribs with mesh lagging, 4 feet on center	Replacement of Timber Sets.
V	8-inches of Shotcrete	Faults where pulverized material that are susceptible to loosening and raveling when exposed to air.
VI	Grout Fill	Void filling above CIP liner.

The recommended support type within different reaches of the tunnel is provided in Table 7-3.

Table 7-3: Tunnel Stationing with Support Type and Loading Condition

Station		Type
Start	End	
0+95	1+20	III
1+25	1+35	III
3+10	3+20	III
3+50	-	I
3+90	4+00	III
4+50	5+40	III
5+46	5+62	VI
5+70	5+90	III
6+58	6+74	II
7+31	7+35	III
8+60	8+65	III
12+68	13+02	IV
13+25	13+50	III
13+50	13+90	I
13+59	13+66	V
14+25	14+50	III
14+97	15+02	V
15+00	15+40	III
15+48	15+52	V
15+72	15+88	III
20+30	20+38	V

7.2.1 Rock Support Type I, II, III

Prior to installing Type I, Type II and Type III rock support, the tunnel crown and side walls needs to be scaled to remove loose rock blocks. After the loose material is removed, the rock support can be installed. See Drawing 4, in Appendix C, for details.

Type I rock support, consisting of non-pattern bolts or a single bolt, is recommended for supporting discrete rock blocks. These blocks can be located on the side walls and/or in the tunnel crown.

Type II rock support, or patterned bolts, is recommended for zones of the tunnel that have multiple rock blocks or a slab, in or near the crown of the tunnel, that may loosen if not systematically supported. It is suspected that these areas may loosen with time and create a condition leading to a sizable rock falling from the crown. See Drawing 4, in Appendix C, for details.

Type III rock support, consisting of pattern bolts and mesh, is recommended for areas where the shale and sandstone interbeds (e.g. the marker beds) cross over the crown of the tunnel. These are the marker beds and they typically have numerous bedding joints that loosen with time and results in small blocks of rock falling to the invert. Though these pieces are small, they pose a long-term stability issue. By bolting mesh along the crown across these interbedded materials, the smaller rocks will either be prevented from moving or be caught by the mesh should they fall. See Drawing 4, in Appendix C, for details.

A standard 8 foot long bolt is recommended for Type I, II, and III rock support. Due to the wet environment, bolts should be designed for corrosion resistance. We recommend using the M22 CT-bolts with double corrosion protection, manufactured by DSI Underground, or equivalent. The CT-bolt, shown in Figure 7-1, provides immediate support using a mechanical anchor. The first level of corrosion protection is provided by the polymer sleeve that encases the steel bolt. The second level of corrosion protection is provided by grouting in the bolt after installation. All rock bolts (e.g. Type I, II and III) should be installed perpendicular to the circumference of the tunnel. When the rock bolts are used in a pattern (e.g. Type II and Type III Rock Support), the bolts should be spaced apart no further than 4 feet on centers.

Figure 7-1: Corrosion Protected Rock Bolt (CT-Bolt) (DSI Underground, 2016)

The recommended mesh for Type III rock support shall also be corrosion resistant due to the wet environment in the tunnel. We recommend the Tensar Mining Systems high-strength polymer mining mesh, known as BX3326, or similar. This mesh is corrosion resistant and complies with MSHA CFR 30, Part 7 criteria for permanent applications. The mesh is secured to the tunnel crown from the 10:00 to 2:00 position (looking upstream) using the bolts described above. Figure 7-2 below depicts how the mesh will look once installed.

Figure 7-2: High-Strength Polymer Mesh Installed as Rock Support (Minex Rock Mesh, Tensar, 2001)

7.2.2 Rock Support Type IV

Type IV rock support, consisting of steel ribs with mesh lagging, is recommended as the replacement for the existing timber sets from Station 12+68 to 13+02. The timber sets have been compromised with rot and can no longer be relied upon to support the rock slab and fallout that bears upon the timbers. The steel ribs are typically made from I-beams, and are detailed on Drawing 4 in Appendix C.

The ribs are designed to be installed at 4-foot centers with each rib being braced to the adjacent rib using tie-rods and collar braces to prevent shifting. The ground between each rib is supported using polymer grid and bolts. The steel ribs may be epoxy coated for corrosion protection. Thicker steel sections (with a sacrificial thickness) may be used in lieu of the epoxy coating.

7.2.3 Rock Support Type V

Type V rock support is recommended for where faults cross the tunnel. As stated before, the pulverized material within the fault unravels with time when exposed to air. The use of shotcrete will prevent air from drying out the pulverized material. However, considerable material has fallen out of most of these faults, making it difficult to directly spray shotcrete on to the surface. Therefore, bolts and mesh is recommended to ensure the shotcrete stays in place and does not become a falling hazard. Details of Type V rock support are provided on Drawing 4, in Appendix C.

7.2.4 Rock Support Type VI

The concrete of the existing horseshoe-shaped CIP concrete liner, from Station 5+46 to Station 5+62, appears to be in good shape. However, there is a large void above the crown that runs the length of the liner and presents a potential hazard that needs to be addressed. With time, the rock mass above the crown may loosen, resulting in a large rock wedge falling directly onto CIP liner. The area does not appear to be generating water inflows, so it is recommended that the annulus simply be backfilled with low strength grout (e.g. minimum strength 500 psi). Alternative materials, such as foam additives or plastic fillers, may be used to reduce the cost, but only if the source is inspected and the grout performance with the fillers is laboratory tested.

8 RECOMMENDATIONS FOR FLOW ENHANCEMENT

8.1 Probe Hole Drilling

Scott (1994) recommended:

> *"…water flows can be increased into the tunnel by drilling long holes in a fan pattern at the locations were water is being produced."*

Other than knowing that water is stored in the open apertures of jointed or fractured rock mass, it is difficult to predict groundwater flow within these discontinuities. Groundwater within the rock formation surrounding the Senior Canyon Tunnel is most likely concentrated in the bedding joints and the primary joint set (Joint 1). Thus, water inflow to the tunnel may be enhanced by drilling angled probe holes that intersect as many of these joints as possible. Table 8-1 summarizes locations along the tunnel alignment where drilled probe holes may have a high probability of intersecting water bearing joints. It is recommended that each probe hole be a minimum of 30 feet long.

Table 8-1: Probe Hole Recommendations along Tunnel Alignment

Station	Probe Hole Recommendations
5+87	• Drill one (1) probe hole at 7:00 position, perpendicular to the bedding joint • Drill one (1) probe hole at 7:00 position, perpendicular to the primary fracture set
5+93	• Drill one (1) probe hole at 7:00 position, perpendicular to the primary fracture set
6+40	• Drill one (1) probe hole at 7:00 position, perpendicular to the bedding joint • Drill one (1) probe hole at 7:00 position, perpendicular to the primary fracture set
6+45	• Drill one (1) probe hole at 7:00 position, perpendicular to the primary fracture set
6+40 to 7+10	• Drill eight (8) probe holes at 4:00 position at 8-foot centers, perpendicular to the primary fracture sets • Drill eight (8) probe holes at 5:00 position, at 8-foot centers, nearly vertical (cross bedding)
15+70 to 16+80	• Drill 14 radial prove holes at the 10:00 position, at 8-foot centers • Drill 14 probe holes at the 2:00 position, at 8-foot centers, perpendicular to the bedding joint

For planning purpose, in addition to the initial fifty (50) probe holes identified in Table 8-1, we recommend including a fifteen (15) supplemental probe holes in the project budget. These extra holes shall be drilled at the discretion of SCMWC and located based on the results of the initial probe holes.

8.2 Tunnel Invert

Water inflows from wet sections of the tunnel could potentially be lost to open fractures in the drier sections of the tunnel, as suggested by Scott (1994):

> *"…I reflected on the fact that the tunnel crosses many sandstone ledges that are fundamentally dry and produce no water. I suspect that these ledges are actually absorbing some of the water flow in the tunnel, that is, water will come in at a water course, flow down the tunnel, but lose some of its volume into the dry rock. For this reason, I believe a study should be made with weirs to determine if flow of water is at the same rate at all locations in the tunnel."*

Based on observation within the tunnel, water inflow from the invert area seems non-existent between the portal and Station 4+90. The surface topography and orientation of the bedding joints may be such that this reach of tunnel gets limited recharge from storm water percolating down from above and water flowing up from deeper sources. Thus, this reach of tunnel is mostly dry and could be absorbing water flowing down the invert.

8.2.1 Weir Recommendations

The quantity of water lost to the invert can be estimated by using a weir, as recommended by Scott (1994). We recommend installing a V-notch weir downstream of Station 4+90, say Station 4+50. The flow passing over the weir can be measured and compared to the flow in the tunnel discharge pipe. If the flow over the weir is greater than what is being discharged, the invert is most likely absorbing water.

A weir (see Figure 8-1) that is applicable for flows between 4 gpm to 100 gpm should be configured as follows:

- Construct a 90° V-Notch weir (where θ = 90°) from a 8-foot long strip of ¾-inch plywood.
- The depth of the notch should allow for a H (maximum) of 6-inches.
- The shaded area on Figure 8-1 below should be chamfered at 45°.
- Install the weir so that the top of chamfer is on upstream side of the notch.
- Ensure that water flows freely to and away from the weir.
- Set weir height high enough to ensure that water falls freely.
- Secure the weir with sand bags or tunnel muck.
- Block off water from flowing around or under the weir using tunnel muck or sand bags.

After allowing the water to rise and stabilize to a steady state rate, the flow rate (Q) can be determined by measuring height (H) of water spilling over the notch as shown on Figure 8-1.

H (feet)	Q (gpm)
0.10	3.5
0.20	20.1
0.25	35.1
0.30	55.3
0.35	81.3
0.40	113.5

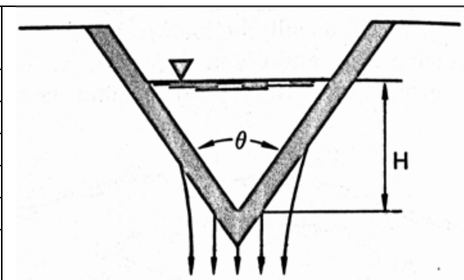


Figure 8-1: V-Notch Weir Diagram and Flow Table (Lindenburg, 1989)

8.2.2 Tunnel Discharge Enhancement

If it is determined that a significant amount of water is being lost, the invert section that is absorbing the water can be cleaned and sealed. Alternatively, a pipe can be run to by-pass water over this section.

If cleaning and sealing is chosen, the cleaning effort will require the removal of the rail tees, ties and approximately 10-inches of track ballast. After this material is removed, the invert can be pressure washed so that bedrock can be examined. If the rock is highly fractured, then the invert should be sealed with either concrete or shotcrete. If it becomes obvious that only a few fractures are responsible for the water being lost, these fractures can be locally sealed with grout.

9 TUNNEL CLEANING RECOMMENDATIONS

Tunnel cleaning falls into three categories: housekeeping, flow improvement, and tunnel discharge enhancement. These three categories are discussed in detail below.

9.1 Housekeeping

Access within the tunnel can be improved by implementing some simple housekeeping. Construction debris is found along the entire length of the tunnel, including: old vent pipes, steel rods, tie wire, uncharged electric wire, and uneven footing due to displaced ballast and rock. Table 9-1 provides a partial inventory of these type of debris items and their approximate location within the tunnel. It should be noted that diameters included in the table are estimated. The miscellaneous metal (e.g. pipe, rail tees, metal rods, wire, mining car, wheel barrel, etc.) can most likely be recycled for little to no costs.

Table 9-1: Debris Inventory within Senior Canyon Tunnel for Housekeeping

Approx. Station Location (+/- 100 feet)		Type of Tunnel Debris	Type of Hazard or Impediment
4+60	10+85	Rotten wood rail ties.	Tripping hazard and an impediment to water discharge.
1+95	18+50	10-inch thin gauge ventilation pipe (rusted), partially secured by tie wire attached to metal rods/pipe placed in drill holes at the 5:00 position of the tunnel	Tie wire and rods/pipe are an eye and head hazard. The ventilation pipe is a tripping and laceration hazard.
3+50	15+50	2- to 3-inch metal pipe	Tripping hazards
3+50	13+50	Rail ballast piled up on outside edge of rail (generally the 7:00 position of the tunnel)	Slipping hazard and potential impediment to water discharge
16+50	21+50	4- to 6-inch metal pipe	Tripping hazards
19+50	21+50	Old uncharged electric wire	Tripping hazard
General		Fallout of bedrock material from tunnel perimeter (e.g. pulverized material and rock blocks), muck car bucket, wheel barrow, etc.	Tripping and slipping hazard

9.2 Flow Improvement

Currently water flowing down the invert is not consolidated into an efficiently shaped channel. The flow is impeded by multiple obstacles created by wooden ties (ties) and uneven track ballast.

There are sections of the tunnel where the track ballast has been moved from the right side of the rail to the left side of the rail, as shown in Figure 5-8. Water in this section flows around and between the rail tees and ties, resulting in a wider and more tortuous water course. The flow can be improved if the water channel is made more efficient. One suggested improvement is to remove the rail (e.g. tee and ties) and centralize flow into a properly shaped channel. This would improve the flow rate and possibly reduce water loss through the invert (e.g. less time to be absorbed).

10 OTHER CONSIDERATIONS

The following section addresses additional considerations prior to, during, and after tunnel improvements. These considerations include: permitting and agency approvals, staging area, underground work requirements, maintenance, and future inspections.

10.1 Regulatory Agencies, Permitting, and Environmental Controls

The proposed project will be completed within the jurisdiction of the County of Ventura and the City of Ojai. As such, coordination with these entities, as well as federal, state, and local authorities and agencies is required during the design and improvements of the facilities. Table 10-1 below provides a partial list of permits that may be required to conduct the work.

Table 10-1: Permits and Approvals for the Design and Improvements of Senior Canyon Tunnel

Agency	Document Name
Cal/OSHA	Underground Classification Certificate
City of Ojai	Ground Disturbance Statement
Ventura County	Grading Permit
	Stockpiling Permit
	Discretionary Permit for Groundwater Section Review
State of California	California Environmental Quality Act (CEQA) Permit

Additional permits or approvals not provided in Table 10-1 may be required; such as, from U.S. Army Corps of Engineers for Clean Water Act Section 404 Permit, US Fish and Wildlife Service, California Department of Fish and Game, California Department of Parks and Recreation, Office of Historic Preservation. These agencies need to be contacted to determine if additional permits or approvals are necessary for the tunnel improvements.

The California Department of Industrial Relations, Division of Occupational Safety and Health (Cal/OSHA) Mining and Tunneling (M&T) Unit will require an Underground Classification Certificate prior to the start of tunnel improvements. California Labor Code Section 7955 and Title 8 California Code of Regulations Section 8422 require classification of all tunnels, underground chambers and excavations. Cal/OSHA differentiates between permits issued for access and for construction of underground facilities. Underground Classification Certificates are issued for all underground construction activities, and Confined Space Permits are issued for all underground operation and maintenance work. The M&T Unit typically schedules a pre-job safety conference prior to issuing the certificate.

10.2 Staging Area Preparation

10.2.1 Access Road

Access to the tunnel and staging area is at the end of Ladera Road on the north-east side of Ojai. The main cross street to Ladera Road is Thacher Road. Ladera Road is a two-way, asphalt-paved, relatively-flat, public road for the first 0.8 miles, providing access to orchards and private residences. At mile 0.8 there is a security gate requiring a code to provide access beyond this point. At this juncture, Ladera Road becomes a private road owned by SCMWC, with private residence easement within the first mile. After roughly mile 1.8, the road narrows into a one-lane, mountainous-terrain, unpaved road that follows Senior Canyon Creek. The tunnel and staging area is approximately 2.1 miles from and 1,200 feet higher in elevation than the security gate.

The unpaved road leading into the Senior Canyon is best accessed with a pick-up truck with 4-wheel drive. There are three (3) concrete-paved river crossings which may be unpassable during heavy rain events. Rock and soil debris and vegetation is present along the access road. Figure 10-1 shows the access route from Thacher Road to the tunnel portal.

Figure 10-1: Access Road from Thacher Road to Senior Canyon Tunnel ("Ojai", 2016)

Due to the granted easement after the security gate, it is recommended that prior to the work, a survey of the road condition, including video log, be conducted. Once tunnel improvements are complete, a final survey of the road conditions shall be conducted. Any damage caused by the contractor will need to repaired.

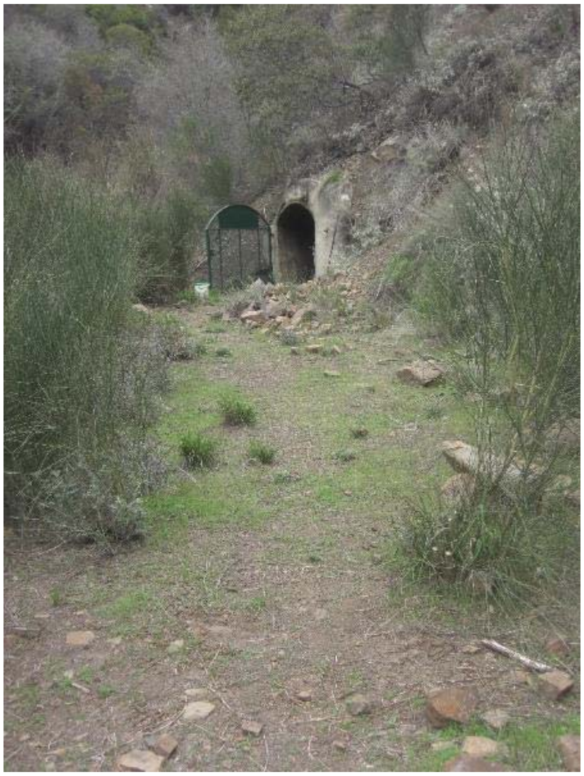
10.2.2 Staging Area

The existing staging area in front of the tunnel portal is approximately 3,000 square feet, on an approximately 3% slope, and is long and narrow. The site is constrained by the narrow access at the end of Ladera Road, which is a one lane dirt road. The south side of the staging area consists of a rocky hillside with loose boulders. The north side of the staging area consists of a ravine formed by the Senior Canyon Creek.

The staging area may be used to store equipment and materials needed to complete the work, including:

- Parking and turn-around for three vehicles (three point turn at the base of the staging area);
- Maintenance and tool container;
- Generator, compressor, water storage, and ventilation fan;
- Skid steer, excavator, fork lift, loader, shotcrete and group pumps, drilling equipment, and other surface support equipment;
- Material stockpile (e.g. ground support materials, cement bags, tunnel muck);
- Portable toilets.

Figure 10-2 shows the staging area, looking north and south.



Looking North ***Looking South***

Figure 10-2: Staging Area Looking North and South

Key constraints considered for the staging area layout include:

- Maintaining access to the tunnel portal;
- Protecting the Senior Canyon River;
- Avoiding impacts to the slope;
- Safety requirements for the loose blocks on the north slope; and,
- Clearing and grubbing of the vegetation.

The actual site layout will be determined by to the contractor and will depend on the equipment used and means and methods employed. The contractor may choose to grade the site to provide a flatter working area which may warrant permitting described previously.

The slope south of the staging area contains loose rocks and boulders which may be a safety hazard. During the February 2017 inspection, multiple small rocks were observed rolling down the slope and onto the staging area, as shown in Figure 10-3. It is recommended to include improvements of the south slope as part of the contractor mobilization requirements. Improvements may include removal of large blocks from the slope, and constructing a temporary barrier to prevent smaller rocks and boulders from entering the staging area.

Figure 10-3: Portal Staging Area South Slope with Loose Rocks and Boulders

It is unlikely that the contractor will need a trailer at the staging site; however, a small trailer located offsite may be needed to serve as an office to complete paperwork, provide storage for project documents, and to provide the workers a clean and private space to change clothing. Since space is limited, the contractor may have to carpool the project team to the tunnel portal with one or two trucks.

Additionally, the contractor will need room for parking, material storage, equipment storage, and stockpiled material. It is recommended that SCMWC identify several laydown areas to be made available to the contractor during the work.

10.2.3 Tunnel Muck Storage

If the tunnel is fully cleaned/cleared, an estimated 375 cubic yards of material will be generated, including ballast, pulverized material, and fallen rock block from Station 0+00 to 16+00. However, the majority of the ballast will likely remain in place, and will only be removed if the invert is suspected of absorbing water. The actual volume that will be generated is closer to 20 cubic yards, consisting of pulverized material (hereafter known as muck) and fallen rock. Any muck removed from the tunnel should be tested for contaminates prior to stockpiling, disposal, or reuse. The final disposition of tunnel muck must conform to government regulations and permits with respect to stockpiling, reuse, hauling, and disposal.

Muck removal and disposal may be the responsibility of the Contractor. If left to the contractor, it is expected that the overall tunnel improvement cost will be higher than if conducted by SCMWC, due to potentially high disposal fees. To keep costs down, SCMWC may consider locating a muck storage site and managing disposal of the material. Small volumes may be stored temporary at the staging area and then transported down to the pre-determined muck storage site. If SCMWC elects to reuse the tunnel muck for alternate purposes, some uses may include: road paving, backfill for slope remediation, or filling a nearby quarry.

10.2.4 Temporary Erosion and Sediment Control Best Management Practices

Source control measures and best management practices (BMPs) will be required during tunnel improvement activities to control erosion and sediment-laden runoff, per the County of Ventura. The following BMP's taken from the State of California Stormwater BMP Handbooks and Manuals (Caltrans, 2003), may be applicable to this project:

- Erosion Control
    - EC-1 or SS-1: Scheduling for sequence of construction
    - EC-2 or SS-2: Preservation of existing vegetation
- Temporary Sediment Control
    - SE-1 or SC-1: Silt fence
    - SE-8 or SC-8: Sandbag barrier
- Temporary Tracking Control
    - TC-1: Stabilized construction entrance/exit
- Non-Stormwater Management
    - NS-1: Water conservation practices
    - NS-2: Dewatering operations
- Waste Management & Materials Pollution Control
    - WM-1: Material delivery & storage
    - WM-3: Stockpile management
    - WM-4: Spill prevention & control
    - WM-5: Solid waste management
    - WM-8: Concrete waste management
    - WM-9: Sanitary/septic waste management

The purpose of implementing BMPs is to effectively prohibit pollutants generated from the work activities from entering the storm drain system. BMPs for wind erosion and dust control may also be required. The implemented BMPs shall be in accordance with the National Pollutant Discharge Elimination System (NPDES) Ventura Countywide Stormwater Municipal Permit No. CAS004002 dated July 8, 2010.

10.2.5 Noise Controls

The City of Ojai has established a noise ordinance for noise generating activities. See Table 10-2.

Table 10-2: Exterior Noise Level Limits (City of Ojai, 2015)

Zones	Noise Standard		15 Minutes/ Hour		5 Minutes/ Hour		1 Minute/ Hour	
	Day	Night	Day	Night	Day	Night	Day	Night
Residential	55db	45db	60db	50db	65db	55db	70db	60db
Commercial & Industrial	65bd	55db	70db	60db	75db	65db	80db	70db

SCMWC should confirm with the city of Ojai, if the tunnel improvement work will be required to comply with the tolerable noise limits for residential or commercial & industrial, or neither. If noise ordinances apply, SCMWC should seek a waiver for weekend work and potential noise variances, even if not anticipated.

10.3 Underground Tunnel Improvements

10.3.1 Tunnel Classification

Based on the February 2017 inspection, no hazardous gases in concentrations that impact human health and safety are expected within the tunnel; however, air quality monitoring shall be required throughout the tunnel improvements. The tunnel is considered non-gassy with respect to toxic and combustible gases. Refer to Cal/OSHA, Subchapter 20, Article 8, Section 8422. Tunnel Classifications, for definitions, limitations and testing requirements.

10.3.2 Communications

Per OSHA standards, SCMWC must maintain lines of communication with the contractors at the worksite to ensure rapid and complete exchange of information concerning events or situations that may impact worker safety. Currently, the Senior Canyon valley has no cellular phone communication; thus in an emergency situation, the only way to contact someone outside the site is by driving to a cell phone service location, which may vary depending on the service provider. Communications between personnel at the tunnel site and those within phone access should be conducted using assigned 900 MHz radios. This would allow information to be radioed from the tunnel site designated personnel with phone capabilities outside of the tunnel site, who can then contact emergency personnel. Satellite-based communication systems may also meet OSHA standards.

10.3.3 Emergency Personnel

Work activities in underground settings, such as tunnels, are inherently dangerous and require ample coordination and communication between the owner, contractor, and emergency personnel. Establishing protocols in case of an emergency is essential and each site differs, so it is important to create a safety program specific to this project. Identifying emergency personnel onsite and offsite is necessary for a project of this scope.

The emergency personnel who remains onsite is typically trained in CPR/first aid, has communication lines to outside emergency personnel, ensures a check-in/check-out procedure to account for underground personnel, and can identify existing and predictable hazards in the surroundings or working conditions. This person tends to be the designated individual on duty above ground, while employees are working underground, and is trained to respond to an emergency situation.

Offsite emergency personnel are the local fire department, emergency medical technicians, and police department, and 911 responders. In case of an emergency, one of the team members would call 911 to request assistance and the Ojai first responders will respond on site (typically the fire department). It is important to perform an onsite meeting with Ojai first responders, SCMWC personnel, and the contractor to review tunnel emergency procedures and protocol, in addition to site access. Note that Ojai first responders are most likely not trained to enter into these conditions and will need guidance on required emergency procedures and evacuation requirements. If the fire department declines to be the first responders, the contractor will have to provide alternative resources at an extra cost to the project (e.g. increase labor costs).

10.3.4 Ventilation and Air Monitoring

Future entries will likely require positive means of entraining air into the tunnel. A reversible ventilation system must be provided to ensure that each employee working underground has at least 200 cubic feet of fresh air per minute. Per OSHA standards, when work is being performed that is likely to produce dust, fumes, mists, vapors, or gases, the linear velocity of air flow in the tunnel must be at least 30 feet per minute.

Air quality monitoring shall be conducted by a competent person authorized to test for air contaminates throughout the duration of the work. The atmosphere within the tunnel should be monitored for the following parameters:

- Carbon monoxide concentration;
- Combustible and toxic gas (hydrogen sulfide) presence;
- Oxygen levels; and
- Dust and smoke (exhaust fumes) levels.

10.3.5 Power Requirement

The contractor will likely power water pumps, lights, and ventilation with a diesel generator. Drills and hauling equipment used inside the tunnel will likely be air powered by a compressor.

10.3.6 Water Management, Handling, and Disposal

All sources of water associated with improvements of the tunnel shall be handled, treated, and disposed of in accordance with applicable laws, regulations, and permits. There are three identified sources of water associated with improvements of the tunnel: groundwater, water used for tunnel improvements, and stormwater runoff from the portal and staging areas.

Tunnel water inflow and water used for improvements of the tunnel will most likely mix together and drain by gravity to the portal, where it shall be collected and pumped to a holding tank. The water will be stored in the tank for some time before being hauled offsite to be treated and discharged. The water may be turbid and could be contaminated with suspended solids particles, small amounts of oil, grease, and fuel, as well as pH fluctuations due to cement in concrete grout and shotcrete operation. The treatment requirements for this water will depend on the standards established as part of the permitting process. SCMWC should plan and prepare for additional water resources, since the tunnel will provide limited to no water collection during the time of tunnel improvements.

10.4 Maintenance and Future Inspections

After the tunnel improvements and enhancement are complete, we recommend tunnel inspection and maintenance be continued on a yearly basis. The inspections shall be completed by a tunneling design firm or by trained SCMWC personnel. Information obtained from the inspections should include at a minimum:

- Overall condition of the tunnel;
- Air monitoring along the length of the tunnel;
- Station locations and sizes of rock falls within the tunnel;
- Station locations of rock within the tunnel walls and crown that appear to be loose;
- The condition of the ground support (e.g. stone accumulating on the mesh, shotcrete falling to the invert, bolts secured tightly to the face of the rock, etc.);
- Station locations of water inflow sources and productivity of the probe holes;
- Weir measurements (if applicable).

The inspection reports and documentation shall be kept in the company records for future reference.

In addition to tunnel inspections, ongoing maintenance is recommended. Maintenance may include, but is not limited to, access road grading, removal of obstructions along the access road and tunnel portal, and periodic removal of rock fall from within the tunnel.

11 COST ESTIMATE

A cost estimate was prepared for activities to improve the tunnel and enhance the water inflow and discharge capacity. The tasks include:

1. Mobilization;
2. Preparation of the construction staging area;
3. Improving the rock support and enhancing the water inflow;
4. Improving the invert to enhance the water discharge; and
5. Site restoration

The cost of each task includes labor, equipment, materials, overhead and profit, contractor contingencies, and owner contingencies. Durations for each task are based on production rates taken from previous projects and experience. The estimate does not include the cost for preparing procurement documents, obtaining permits and management of the work.

Task Description

Mobilization includes cost associated with mobilizing equipment and material to the site and the storage thereafter. There also are additional costs within mobilization that are related to the logistics, permitting, and planning the work.

Preparation of the construction staging area includes clearing and grubbing approximately 2,250 square feet, grading the access road, backfilling approximately 10 cubic yard of uneven surfaces and establishing approximately 200 linear feet of environmental controls.

Activities to improve the rock support and enhance the water inflow, includes:

- Installation of ventilation and lighting for the 1,600 linear feet of the tunnel.
- Installation of 306 CT-bolts for the Type I, II, III and V Rock Support.
- Installation of 4,160 square feet of Minex Rock Mesh for the Type IV and V Rock Support.
- Installation of 10 sets of steel ribs for the Type IV Rock Support.
- Placement of 23 cubic yards of concrete or grout backfill for the Type VI Rock Support.
- Drilling 1,950 linear feet Probe Holes for Water Inflow Enhancement.

Improvements to the invert to enhance the water discharge, includes:

- Removal of 3,200 linear feet of 16 pound rail tee.
- Installation and monitoring of a weir placed at Station 4+48.
- Removal of 105 cubic yards of track ballast and ties from Station 0+00 to 4+48.
- Pressure washing 448 linear feet of tunnel.
- Placement of 23 cubic yards of crushed stone.
- Placement of 66 cubic yards of 4,000 psi concrete to seal the invert from Station 0+00 to 4+48.

Site restoration includes removal of temporary construction facilities and re-grading of the site with track ballast removed from the tunnel.

11.1 Cost Estimate Assumptions

11.1.1 Resource Rates and Other Costs

This section summarizes the assumptions used for determining resource rates (e.g. hourly labor and equipment rates, material unit prices) and other costs, including overhead and profit, contingency and escalation. For a detailed cost breakdown per task refer to Appendix D.

11.1.2 Labor Costs

Labor cost include both the fully built hourly labor rate and living expenses.

The fully built hourly rate includes: the Davis-Bacon standard rate, overtime premiums, Davis-Bacon Fringe and payroll burdens. The standard rates and overtime premiums are based on labor classifications, for the work needed at the Senior Canyon Tunnel this would include: Miner Group I, Lead Miner Group IV and Operator Power Equipment Group 6. The standard rates for these classification range from $38.09/hour to $43.34/hour. Overtime premiums are an additional 50% of the standard rates for overtime hours. Davis-Bacon Fringe is an additional $19.74/hour. The following payroll burdens are based on percentages of standard rates and overtime premiums and include:

- Workers Compensation at 25% of the Standard Rate
- FICA (Social Security) at 6.2%
- FICA (Medicare) at 1.45%
- Federal Unemployment Tax Act (FUTA) at 1%
- State Unemployment Insurance at 5%
- Unemployment Training Fund at 0.1%

Taking into consideration the fringe and payroll burdens, the fully built standard (hourly) rate ranges from $72.59/hour to $113/hour. It is likely that one (1) hour of overtime will be worked each day, thus the fully built overtime rate for that hour will range from $99.01/hour to $113.55/hour.

Underground construction, like what is required for Senior Canyon Tunnel, will likely be performed by out-of-town labor. Per the General Services Administration (GSA) government portal: Lodging in the nearby area (Santa Barbara) would average about $173/day, and Meals & Incidental Expenses are $74/day.

The labor rates, work hours, and corresponding costs per task are provided in detail in Appendix D. The labor cost per task are summarized on Table 11-1.

11.1.3 Equipment Rates

The equipment hourly cost is based on a combination of sources, including:

- Rates quoted from local equipment rental companies (e.g. United Rental, Griffin Rental and SunBelt Rental).
- Rates published by California Department of Transportation.
- Experience working on claims using Army Corp Rates.

The detailed equipment list per task, the hours, and the source used for pricing is provided in detail in Appendix D. The equipment cost per task are summarize on Table 11-1.

11.1.4 Material Cost

Material cost for ground support include pricing from:

- DSI Underground for the CT-bolts used for Type I, II, III and V rock support, $100/bolt.
- Tensar for the Minex Rock Mesh used for the Type III and Type V rock support, $7.81/sf
- Bay City Fabrication, Ventura, CA, for the steel ribs used for Type IV rock support, $1,800/rib.
- National Ready Mix Concrete, Moorpark, CA, was quoted for a 4,000 pound concrete mix for the invert seal at $112/cy.
- Shotcrete prices were difficult to pin down for this area; therefore, we used a blended rate (e.g. equipment and materials)of $1,600/cy. This was conservatively built up from unit pricing taken from other projects. *Note: the shotcrete material costs are only $3,520.*
- Materials that have only a minor cost implication (e.g. less than $1,000) were estimated based on experience from past project for:
  - Backfill used for access road improvements: $10/cy
  - Crushed Stone used for improving the work surface of the tunnel invert: $25/cy
  - Environmental Control (silt fence) used around tunnel staging area: $2/linear foot.

The quantities and corresponding cost per task are summarize in Table 11-1 and broken down in detail in Appendix D.

11.1.5 Work Hours

The cost for labor and equipment is based on nine (9) hours per day, five (5) days per week. Typically, the hours of work are between 7:00 am to 4:00 pm.

11.1.6 Utilities and Water Treatment Facilities

Power components (i.e. electricity) and fuel is to be supplied by the contractor. We are assuming that stand-alone diesel generators and compressor will be used and they are covered in the equipment costs.

Construction water will be needed to drill probe holes, wash down equipment and work areas, and general use. The cost of the water is in the “500 Gallon Water Trailer” included in the equipment cost provided in Appendix D. We assumed that SCMWC would supply water at no additional cost. If water will not be supplied to the contractor this cost would have to be added into the cost estimate.

Water treatment of construction related operations is covered in the equipment cost, see the “600 Gallon Metal Tank for Water Treatment” in Appendix D. The unit price assumes a skimmer will be used for oil and residence in the tank will be adequate for sediments. The skimmer adds an additional $4.48/day to the cost of the tank for a total of $10/day.

11.1.7 Disposal

Per SCMWC, disposal costs were not considered. The cost estimate is based on the following assumptions:

- Miscellaneous metals removed from the tunnel (e.g. pipe, rail tees, metal rods, wire, mining car, wheel barrel, etc.) can be recycled at cost.

- Track ballast removed from the tunnel can be stored at SCMWC facilities and re-used during site restoration to regrade the staging area. *Note: it is recommended that the track ballast be tested for contamination prior to removal form the site or storing on SCMWC property.*

- Water is assumed to be treated at the site and put back into the discharge pipe for treatment.

11.1.8 Overhead and Profit

The following overhead and profit was carried on the labor, equipment and materials:

- Labor: 25%
- Equipment: 10%
- Materials: 10%

11.1.9 Contingency

Contingency is typically included to cover design and construction issues that are still undefined at this preliminary design stage. Relatively small contingencies have been added to the bottom of the cost estimate. Although the scope of work is relatively well defined, bidders may still include up to 10% contingency in their cost proposals to account for unanticipated expenses.

As indicated earlier, the Workers Compensation percentage can vary significantly between companies. The cost estimate is based on Workers Compensation of 25% of the labor rate, but if a company must use 55%, this will add approximately 5% to the cost estimate. Therefore, we recommend that SCMWC carry at least 10% contingency in their budget to account for potentially higher labor rates and other unexpected conditions.

11.1.10 Escalation

The cost is based on 2017 dollars. If the work is not started until the middle of 2018, SCMWC should expect the costs to escalate by approximately 3%.

11.2 Cost Estimate and Summary

The estimated total project construction cost and schedule for the work to be performed under the contract is summarized in Table 11-1 below.

Table 11-1: Tunnel Improvement Cost Estimate

A. Mobilization	Direct Cost	OH&P	Indirect Cost	Total Cost
Labor	$ 9,513	25%	$ 2,378	$ 11,891
Equipment	$ 925	10%	$ 92	$ 1,017
Material	$ -	10%	$ -	$ -
B. Preparation of Construction Staging Area				
Labor	$ 15,855	25%	$ 3,964	$ 19,819
Equipment	$ 5,439	10%	$ 544	$ 5,982
Material	$ 715	10%	$ 72	$ 787
C. Improving Rock Support & Enhancing the Water Flow				
Labor	$ 325,941	25%	$ 81,485	$ 407,426
Equipment	$ 75,439	10%	$ 7,544	$ 82,983
Material	$ 95,564	10%	$ 9,556	$ 105,120
D. Improving the Invert to Enhance Water Discharge				
Labor	$ 146,480	25%	$ 36,620	$ 183,100
Equipment	$ 34,946	10%	$ 3,495	$ 38,441
Material	$ 8,764	10%	$ 876	$ 9,640
E. Site Restoration				
Labor	$ 26,062	25%	$ 6,516	$ 32,578
Equipment	$ 4,269	10%	$ 427	$ 4,696
Material	$ -	10%	$ -	$ -
Total Cost				
Labor	$ 523,852	25%	$ 130,963	$ 654,815
Equipment	$ 121,018	10%	$ 12,102	$ 133,120
Material	$ 105,042	10%	$ 10,504	$ 115,547
Total	$ 749,912		$ 153,569	$ 903,481
Mobilization/Demobilization	$ 22,497	10%	$ 2,250	$ 24,747
Grand Total - Construction Bid	$ 772,409		$ 155,819	$ 928,228

Contingencies Cost	
Contractor	$ 92,823
Owner	$ 92,823
Other Costs	
Environmental Permitting	Performed by Owner
Procurement Preparation	Performed by Owner
CM Services	Performed by Owner
Total Project Cost for 2017	**$ 1,113,874**
Escalation if constructed 2018	$ 33,416.21
Total Project Cost for 2018	**$ 1,147,290**

12 CONCLUSIONS

Based on a historical review of the project, inspection results, and data analysis the following conclusions are drawn from this report and are summarized as follows:

- On December 8, 2016, an initial geometric survey of the tunnel was conducted. The tunnel was found to be on average 8 feet wide by 8 feet high. The tunnel was obstructed at Station 24+00 by a pile of pulverized material that fell out from the tunnel walls, most likely from a fault, and obstructs the full height of the tunnel (see Figure 5-6). Inspection beyond this point is impossible. Locals, who at one time assisted in maintaining the tunnel, reported that the majority of the water inflows historically have come from a source upstream of Station 24+00. They also report that the tunnel is somewhere between 3,000 feet to 3,400 feet long. We could not confirm this, but we did notice about 1 gpm, or less, of water flowing from the toe of the obstruction (see Figure 5-6).
- The majority of the tunnel that was inspected is unlined and unsupported to Station 24+00. Three (3) short sections of the tunnel have been lined by a CIP concrete liner, for a cumulative length of 141 feet. Six (6) feet of the tunnel is support by concrete sets. Timber sets support 34 feet of the tunnel.
- The tunnel was mined in the Juncal Formation, a sedimentary rock consisting of shales and sandstone. The majority of the tunnel is in sandstone that is frequently crossed by zones of interbedded layers of very thin shale and thin layers of sandstones beds.
- The rock mass discontinuities that govern the rock behavior includes numerous bedding joints in the interbedded materials, a primary joint set that strikes sub parallel to the tunnel from Station 1+00 to 11+00, and five (5) faults strike sub-perpendicular across the tunnel. The bedding joint and Joint 1 are the main conduits of water. The faults are packed with pulverized material that acts as a geologic impediment to groundwater movement within the rock mass (see Figure 5-6). Similarly, slippage along the bedding joint has pulverized some of the bedding joints which also acts as a geologic impediment.
- During the inspection, on February 1 to 2, 2017, water inflows into the tunnel were estimated to be in the range of 29 gpm to 64 gpm. The majority of the water inflow came into the tunnel at Stations 5+87, 6+80, 6+96, 7+05 to 7+09, 15+72 to 15+88 and 16+66 to 16+73. The water downstream of Station 5+00 was insignificant (e.g. less than 0.5 gpm). Note: Water upstream of Station 16+73 could not be mapped due to reduced oxygen levels.
- On February 2, 2017, the air quality was monitored from Station 00+00 to 19+00. The oxygen content remained at 20.9% to Station 10+00 and then steadily declined to 16.4% at Station 19+00. The air was also monitored for H2S, CO and LEL; but no levels were registered (e.g. 0 ppm, 0%).
- We recommend the following:
  - Remove and possibly recycle all miscellaneous metals from the tunnel (e.g. pipe, rail tees, metal rods, wire, mining car, wheel barrel, etc.).
  - Scale loose rock from the tunnel walls and crown prior to installation of Type I, II, and III rock support.
  - Improve the stability of the jointed rock and fallout with Type I, II, III and Type V rock support. This includes installation of (306) CT-Bolts, 4,160 square feet of Minex Mesh and 2 cubic yards of shotcrete. The bolts and mesh are both designed to resist corrosion and provide

long service life. The details for Type I, II, III and IV rock support are provided in Appendix C and Table 7-3.

- The existing CIP concrete liners are in good shape, but there is a large void above the liner between Station 5+46 and Station 5+62. Within this reach, the liner could be damaged by rock fallout so the crown of the liner needs to be protected. We recommend placement of 23 cubic yards of concrete or grout within the void over the liner.
- The timber sets (see Figure 5-4) used between Station 12+68 and Station 13+02 have rotted and need to be replaced with Type IV rock support (e.g steel ribs and mesh). The details of the Type IV rock support are provided in Appendix C.
- Water inflow into the tunnel can most likely be improved by drilling multiple probe holes into the water bearing joints in the rock mass. Drawing 6 in Appendix C, and Table 8-1 summarizes the areas, numbers and orientation of recommended probe holes.
- A water discharge pipe may have been buried in the track ballast in 1929. SCMWC should investigate whether a buried pipe exists, and whether it is still conveys water.
- Based on the topography, bedrock orientation, and reports from "The Ojai", the tunnel is more or less dry from Station 0+00 to 4+50. If water is being lost to the invert, the first 450 feet of the tunnel is the likely cause. We recommend installing a weir at Station 4+50 to confirm if water is being lost to the invert. If water flow is not sufficient at this location, move the weir upstream.
- If water is being lost to the invert, consider either piping invert flows to bypass the first 450 feet of the tunnel or sealing the tunnel invert with concrete. If a concrete seal is used, the invert must be prepared and cleaned down to the top of rock by removing the tunnel ballast and power washing the rock surface. If only a few joints are absorbing the water, consider grouting only the joints instead of sealing the entire invert.
- Water discharge can be enhanced by improving the invert channel. This would require removing all miscellaneous metals and reshaping the track ballast and channel.

- Other considerations have been included in Section 10 of this report and include the following:
  - Permitting
  - Cal/OSHA requirements
  - Staging preparation
  - Tunnel muck storage
  - Noise consideration
  - Tunnel classification
  - Tunnel communication and emergency personnel
  - Ventilation and power requirements
  - Handling of construction water
  - Maintenance and future inspections
- The cost estimate for the work is summarized on Table 11-1. The estimates is broken down by task. The tasks include: mobilization, preparation of construction staging area, improving the rock support and enhancing the water inflow, improving the invert to enhance the water discharge, and

site restoration. The cost for each task include labor, equipment, materials and overhead and profit. The total cost for the work is estimated to be $928,228; however, we recommend adding a 10% contingency for contractor bidding and an additional 10% contingency for the Owner to cover unanticipated conditions. The total cost for the work in 2017 dollars, including contingencies, is $1,113,874. This estimate does not include costs for permitting, preparation of procurement documents and construction management services.

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APPENDIX A – DATA TABLES

Data Tables Index

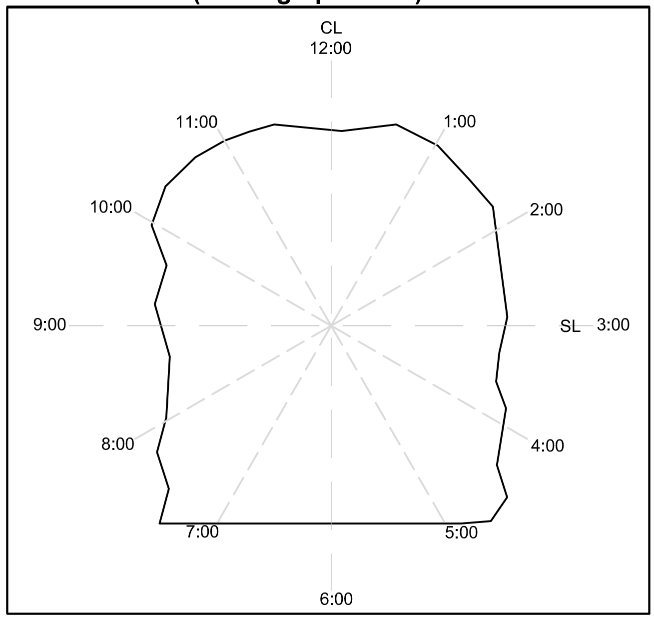
Table	Description
1	Liner and General Geology Notes
2	Geometry – Initial Support and Rock Excavation Dimensions
3	Water Inflow Conditions
4	Bedrock Characteristics
5	Fault Zone Data
6	Bedding Joint Data
7	Primary and Secondary Joint Data
8	Fallout Material

Glossary of Terms

Rock Type

SS	Sandstone
SH	Shale

Clock Position (looking upstream)



CL = Centerline
SL = Springline

Discontinuity Types

J	Joint
B	Joint along bedding
F	Fault

RQD Designation

	Description	Range
E	Excellent	90-100
G	Good	75-90
F	Fair	50-75
P	Poor	25-50
VP	Very Poor	<25

Rock Weathering/ Alteration

FR	Fresh / Unweathered - Rock shows no discoloration, loss of strength, or other effect of weathering or alteration
SW	Slightly Weathered - Rock is slightly discolored, but not noticeably lower in strength than fresh rock
MW	Moderately Weathered - Rock is discolored and noticeably weakened, but less than half is decomposed
HW	Highly Weathered - More than half of the rock is decomposed
CW	Completely Weathered - Almost entirely decomposed to secondary minerals; material can be granulated by hand
R	Residual Soil - Entirely decomposed to secondary minerals ; material can be easily broken by hand

Surface Roughness

VR	Very Rough
R	Rough
SR	Slightly Rough
S	Smooth
SLK	Slickensided

Aperture Width

T	Tight (<0.004")
PO	Partly Open (0.004"-0.04")
O	Open (.04"-0.2")
W	Wide (0.2"-1")
VW	Very Wide (>1")

Rock Strength

	Description	Recognition	Uniaxial Compressive Strength (psi)
EW	Extremely Weak Rock	Can be indented by thumbnail	30 to 150
VW	Very Weak Rock	Crumbles under firm blows with point of hammer	150 to 700
W	Weak Rock	Shallow indentations made by firm blow with point of hammer	700 to 3,600
MS	Moderately Strong Rock	Fractures with single firm blow of hammer	3,600 to 7,200
S	Strong Rock	Requires more than one blow of hammer to fracture	7,200 to 14,500
VS	Very Strong Rock	Requires many blows of hammer to fracture	14,500 to 36,000
ES	Extremely Strong Rock	Can only be chipped with hammer blows	>36,000

Persistance

VL	Very Low (<3.3')
L	Low (3.3'-9.8')
M	Medium (9.8'-32.8')
H	High (32.8'-65.6')
VH	Very High (>65.6')

Bedding Thickness

	Description	Range
M	Massive	>10'
VTK	Very Thickly	3'-10'
TK	Thickly	1'-3'
MO	Moderate	4"-1'
T	Thinly	1.2"-4"
VT	Very Thinly	0.4"-1.2"
L	Laminated	<0.4"

Rock Fracturing

IF	Intensely Fractured	Fractures spaced less than 2 inches apart
HF	Highly Fractured	Fractures spaced 2 inches to 1 foot apart
MF	Moderately Fractured	Fractures spaced 1 foot to 3 feet apart
SF	Slightly Fractured	Fractures spaced 3 feet to 10 feet apart
MA	Massive	Fractures spacing greater than 10 feet

TABLE 1. LINER AND GENERAL NOTES		
Station		Liner Notes
To	From	
00+00	00+90	CIP concrete horseshoe- shaped liner
00+90	04+54	Unlined
04+54	04+60	Unlined with (2) 8"x8" trapezoidal-shaped concrete sets
04+60	05+46	Unlined
05+46	05+62	CIP concrete horseshoe-shaped liner with large open annulus with variable void dimensions
05+62	10+84	Unlined
10+84	10+85	CIP Concrete square-shaped liner with steel bulkhead door
10+85	12+68	Unlined
12+68	13+02	Unlined with (8) 6"x8" trapezoidal-shaped wood sets
13+02	14+61	Unlined
14+61	14+95	CIP concrete horseshoe-shaped liner
14+95	15+88	Unlined, first obvious bend point in tunnel alignment
15+88	23+90	Unlined
23+90		Unlined

TABLE 2. GEOMETRY - INTERNAL SUPPORT AND ROCK EXCAVATION DIMENSIONS					
Station		Internal Support Dimension		Rock Excavation	
To	From	Width (ft)	Height (ft)	Width (ft)	Height (ft)
00+00	00+90	4.5	5.83-6.67	-	-
00+90	-	-	-	8.50	9.50
01+00	-	-	-	8.67	10.17
02+00	-	-	-	9.91	8.67
03+00	-	-	-	6.91	10.08
04+00	-	-	-	7.42	9.08
04+54	04+60	5.58	7.42	9.33	10.50
05+00	-	-	-	7.42	8.17
05+46	05+62	4.67	7.08	-	-
05+62	-	-	-	9.83	16.17
06+00	06+10	-	-	6.83	8.25
06+58	06+74	-	-	11.67	12.33
07+00	-	-	-	10.75	9.58
08+00	-	-	-	6.58	9.75
09+00	-	-	-	8.67	10.00
10+00	-	-	-	7.58	8.67
10+84	-	4.08	5.08	-	-
10+85	-	-	-	7.83	7.25
11+00	-	-	-	7.25	7.83
12+00	-	-	-	6.25	6.33
12+68	13+02	5.50	6.75	7.25	8.00
14+00	-	-	-	5.75	7.50
14+61	14+95	4.5-4.58	5.75-5.83	6.91	7.25
14+95	15+72	-	-	7.50	7.75
15+00	15+40	-	-	6.25	6.17
16+00	-	-	-	6.33	6.75
17+00	-	-	-	6.42	6.75
17+45	-	-	-	10.33	8.17
17+95	17+99	-	-	16.00	8.33
18+00	-	-	-	7.83	7.83
19+00	-	-	-	6.17	7.25
19+80	19+90	-	-	10.08	7.42
20+00	-	-	-	5.58	7.33
21+00	-	-	-	6.00	7.33
22+00	-	-	-	5.00	7.83
22+55	-	-	-	11.91	6.08
22+90	-	-	-	5.33	4.67
23+00	-	-	-	6.50	6.91
23+15	-	-	-	7.08	6.91
23+25	23+50	-	-	8.91	8.91
24+00	-	-	-	5.50	6.00

TABLE 3. WATER INFLOW CONDITIONS

Station		Clock position (Looking Upstream)	GPM		Water Flow (GPM)	Frequency	Notes
To	From		Low	High			
02+54	04+50	10:00 to 2:00	0.0	0.1	Dripping	Occasional	< 0.1 gpm entire region, damp surface, iron oxide, calcite, mica
04+51	06+07	10:00 to 2:00	0.0	0.1	Dripping	Continual	Steady drip, damp surface, iron oxide, calcite, mica
04+61	-	4:00	0.1	0.1	Dripping	Occasional	Small drip
04+90	05+02	6:00	0.0	1.0	Invert boils	Continual	Invert boils in muck and under water, difficult to determine gpm
05+87	-	7:00	2.0	5.0	Flow	Continual	Flow coming from clean rock fracture, beneath water in pond, estimated gpm
06+07	-	5:00	0.0	1.0	Invert boils	Continual	Invert boils in muck and under water, difficult to determine gpm
06+07	-	12:00	0.1	0.1	Dripping	Occasional	Occasional, slow drips
06+40	-	7:00	1.0	2.0	Flow	Continual	Flow coming from clean, south dipping rock fracture
06+80	-	4:30	2.0	5.0	Flow	Continual	Flow coming from clean, calcite rock fractures
06+96	-	4:30	1.0	3.0	Flow	Continual	Flow coming from multiple clean, calcite rock fractures
07+05	-	4:00	1.0	3.0	Flow	Continual	Flow coming from multiple clean, calcite rock fractures
07+09	-	3:30	2.0	4.0	Flow	Continual	Flow coming from multiple clean, calcite rock fractures
07+14	-	4:00	0.0	0.1	Dripping	Occasional	< 0.1 gpm, damp surface, calcite
07+31	07+35	4:00	0.1	1.0	Flow	Periodic	<1 gpm slight flow, damp surface, calcite
08+27	08+63	7:00-5:00	0.0	0.1	Dripping	Occasional	Calcite deposits prominent at sidewalls and crown, occasion drip at crown
09+09	09+13	12:00	0.0	0.1	Dripping	Occasional	0.0
09+36	-	3:00	0.0	0.0	Wet	-	Shows signs of previous flow with thick calcite covering over rock, and iron oxide
09+70	-	7:00	0.0	0.1	Wet	Occasional	Small hole in rock with no flow but water present, iron oxide
09+79	-	7:00	0.0	0.1	Wet	Occasional	
09+85	-	7:00	0.0	0.1	Wet	Occasional	
09+87	10+00	7:00-3:00	0.5	1.0	Dripping	Continual	Large feature, wet dripping at crown and sidewalls
10+00	10+21	7:00 to 3:00	0.0	0.1	Wet	Continual	Wet crown and sidewalls
10+39	-	12:00	0.0	0.1	Dripping	Continual	Drip with soil-like and organics attached to crown
10+39	10+84	7/10:00 to 2/5:00	0.0	0.1	Dripping	Occasional	Wet walls with occasional drips
11+47	11+50	7:00-5:00	0.0	0.0	Wet	-	Shows signs of previous flow with thick calcite covering over rock and wet walls
11+83	12+07	5:00-7:00	0.0	0.0	Invert boils	-	Invert boils in muck and under water, no flow, maybe from drips from crown instead of flow, limited to no drips from crown observed
12+00	13+15	7:00-5:00	0.5	1.0	Dripping	Occasional	Wet rock, occasional dripping at sidewall and crown at timber sets
13+60	14+11	7:00-5:00	0.5	1.0	Dripping	Occasional	Fracture at crown, slight occasional dripping, wet sidewalls
14+11	14+31	7:00-5:00	0.5	1.0	Dripping	Continual	Drip and slight wet walls
14+57	15+72	7:00-5:00	0.5	1.0	Wet	Continual	Wet crown and sidewalls, invert boils in muck and under water, no flow, maybe from drips from crown instead of flow
15+58	17+00	7:00-5:00	0.5	1.0	Dripping/Wet	Occasional	Occasional dripping and wet walls and crown
15+72	15+88	10:00 to 2:00	10.0	15.0	Flow	Continual	Continual flow from crown, very wet
15+88	-	9:00 & 3:00	0.5	1.0	Dripping	Occasional	Wet walls and crown
16+00	-	3:00	0.1	0.1	Dripping	Continual	Wet wall
16+25	-	4:00	0.5	0.5	Dripping	Continual	Wet wall
16+26	-	9:00	0.1	0.1	Flow	Continual	Wet wall
16+30	-	3:00	0.2	0.2	Flow	Continual	Flow coming from same south dipping feature as 16+31
16+31	-	10:00	0.1	0.1	Flow	Continual	Flow coming from same south dipping feature as 16+30
16+58	-	7:00-5:00	0.1	0.1	Wet	Continual	Wet crown and sidewalls
16+66	16+73	9:00 to 3:00	5.0	15.0	Flow	Continual	Wet walls and crown
16+87	16+95	Full perimeter	0.0	0.0	Wet	Continual	Wet walls and crown

TABLE 4. BEDROCK CHARACTERISTICS

Station		Dip (degrees)	Dip direction (N or S)	Apperture Width	Bedding Description	Rock Type	Estimated RQD Descriptor	Weathering	Compressive Strength of SS	Compressive Strength of Shale	Compressive Strength of Pulverized Material	Notes
To	From											
00+92	01+00	63	S	T	Medium thin SS interbedded with very thin Shale	SS/Shale	F	FR	MS-S	W-MS	-	-
01+00	01+18	67	S	PO	Medium to thin SS interbedded with very thin shale	SS/Shale	E	FR	W-MS	W-MS	-	SS covered with calcite, potential water source at one time. Apperture goes to tight after 1+18
01+25	01+62	61	S	T	Massive SS surrounding thin/medium SS bedding interbedded with occasional very thin layer of shale with pulverized mixed material (at 1+60 12" thick)	SS/Shale	G	FR	W-MS	W-MS	EW	Occasional partly open apperture, may be from blasting operations.
01+62	02+00	61	S	T	Massive SS surrounding thin/medium SS interbedded with occasional very thin layer of shale	SS/Shale	F	FR	W-MS	W-MS	-	-
01+88	01+93	60	S	T	Thin SS interbedded with very thin shale with pulverized mixed material every 4'-6' (approx)	SS/Shale	VP	SW	W-MS	W-MS	EW	-
02+00	02+14	66	S	T	Thin SS interbedded with very thin shale with pulverized mixed material	SS/Shale	VP	SW	W-MS	W-MS	EW	SS covered with calcite, potential water source at one time
02+14	03+00	66	S	T	Thin SS interbedded with 9 equidistant zones of very thin layers	SS/Shale	F	SW	W-MS	W-MS	EW	Calcite at 2+23 for 5', then slightly weathered
03+00	03+10	77	S	T	Thin to very thin SS interbedded with one zone of very thin pulverized mixed material	SS/Shale	P	SW	W-MS	W-MS	EW	Pulverized mixed material is clayey with pieces of shale intermixed
03+13	03+76	79	S	T	Thin to thick SS interbedded with 8 equidistant zones of very thin shale with pulverized mixed material	SS/Shale	G	SW	W-MS	W-MS	EW	Occasional partly open apperture, may be from blasting operations. Shale interbeds are between 8
03+81	04+00	75, 69, 64, 68	S	T	Thin SS interbedded with 4 equidistant zones of very thin shale with pulverized mixed material	SS/Shale	VP	SW	W-MS	W-MS	EW	Calcite and iron oxide, potential water source at one time
04+00	04+36	76, 77, 70-75	S	T	Thin SS interbedded with 3 zones of very thin shale	SS/Shale	P	SW	MS-S	W-MS	-	Occasional calcite observed
04+36	04+44	75	S	T	Thin SS interbedded with very thin shale with trace presence of pulverized mixed material	SS/Shale	VP	SW	W-MS	W-MS	EW	-
04+45	04+54	72	S	T	Thin SS interbedded with thin shale	SS/Shale	VP	SW	W-MS	W-MS	0.0	Calcite and iron oxide observed
04+54	04+60	65	S	T	Very thin SS interbedded with very thin shale with occasional pulverized mixed material	SS/Shale	VP	SW	MS-S	W-MS	EW	Calcite deposits from 1:00 to 3:00 position
04+62	04+95	-	-	T	Medium to thin SS interbedded with equidistant 6 zones of very thin shale with trace presence of pulverized mixed material	SS/Shale	F	SW	W-MS	W-MS	EW	-
05+05	05+37	-	S	T	Very thin to thin SS interbedded with very thin shale with pulverized mixed material	SS/Shale	VP	SW	W-MS	W-MS	EW	Vegetation (roots) present at crown
05+35	00+00	70	S	T	Medium to thin SS	SS	G	FR	W-MS	-	-	-
05+66	06+55	-	S	T	Thin to thick SS	SS	G	FR	W-MS	-	-	-
06+55	08+50	49, 41, 45, 40, 51, 42	S	T	Thin to thick SS interbedded with 5 equidistant very thin shale and trace pulverized mixed material	SS/Shale	G	SW	W-MS	W-MS	EW	Calcite observed. Pulverized material contains clay, sand, shale fragments.
07+33	-	43	S	T	Pulverized material at crown, 16" thickness	SS/Shale	G	-	W-MS	EW	-	-
08+31	-	42	S	T	More massive thick SS interbedded with 9" thick layer of shale with pulverized mixed material	SS/Shale	G	FR	W-MS	EW	EW	-
08+58	12+00	42	S	T	Thin to medium SS interbedded with 8 zones of very thin shale with pulverized mixed material	SS/Shale	G	FR	W-MS	W-MS	EW	Layers of shale bedding has thicknesses 6" @ 9+90, 2.5"-11" @ 10+31, and 8" @ 11+75
12+00	13+07	-	-	T	Thin to medium SS interbedded with very thin shale with pulverized mixed material	SS/Shale	F	FR	W-MS	W-MS	EW	-
13+07	13+32	-	-	T	Thin SS interbedded with thin shale with pulverized mixed	SS/Shale	G	SW	W-MS	W-MS	EW	-
13+35	13+73	24-26	S	T	Thin SS interbedded with thin shale with pulverized mixed	SS/Shale	F	SW	W-MS	W-MS	EW	-
14+00	15+02	29	S	T	Massive SS, med to thick with 1 layer of pulverized mixed material at Sta. 14+50	SS	E	FR	MS-S	-	-	Slightly weathered SS at edges of pulverized mixed material edges
15+02	15+48	80, 76	S	T	Very thin to thin SS interbedded with very thin shale	SS/Shale	VP	SW	W-MS	W-MS	-	-
15+50	15+75	76-90	S	T	Medium to thin SS interbedded with very thin shale	SS/Shale	P	SW	MS-S	W-MS	-	-

TABLE 5. FAULT ZONE DATA									
Station									
To	From	Strike (degrees)	Dip (degrees) (12:00 position)	Apperture Width (in)	Apperture Classification	Depth of Fallout (in)	Nature of filling	Compressive Strength of Infilling	Notes
13+59	13+66	145	90	11	VW	36	Pulverized material	EW	11" wide opening, up to 3' high opening from 10:00 to 2:00.
14+97	15+02	145	90	8	VW	36	Pulverized material	EW	8" wide opening, up to 3' high opening
15+48	15+52	145	90	4	VW	24	Pulverized material	EW	4" wide opening, up to 2' high opening
20+30	20+38	NA	90	22	VW	NA	Pulverized material	EW	Starts at 9:00 to 3:00 position.
24+00	-	NA	NA	NA	VW	NA	Pulverized material	EW	material obstructing tunnel excavation

TABLE 6. BEDDING JOINT DATA

Station		Strike (degrees)	Dip (degrees) (9:00 position)	Dip (degrees) (3:00 position)	Dip direction (N or S)	Persistance	Apperture Width (Note 1)	Nature of filling	Weathering	Spacing of Bedding Joints				Notes
To	From									Shale	Sandstone (in) (9:00 position)	Sandstone (in) (12:00 position)	Sandstone (in) (3:00 position)	
00+92	00+97	113	66	69	S	Full	T	Two very thin layers of shale with pulverized material at outside edges	FR	IF	156	-	156	Pulverized material in a few joints; Shale & SS
01+18	01+25	106	67	66	S	Full	PO	Very thin layers of shale with pulverized material at outside edges	FR	IF	120	120	120	Pulverized material in a few joints; Shale & SS
03+10	03+13	124	66	60	S	Full	T	Thin SS with very thin layers of shale with pulverized material	SW	IF	96	96	96	Pulverized material in a few joints; Shale & SS
03+76	03+81	113	69	70	S	Full	T	Med and thin layers of SS with very thin layers of shale	SW	IF	216	216	216	Shale & SS
04+95	05+01	108	65	64	S	Full	T	Thin SS with very thin layers of shale	SW	IF	72	-	72	Shale & SS
05+01	05+05	118	69	75	S	Full	T	Thin SS with very thin layers of shale	-	IF	72	-	72	Shale & SS
05+66	05+71	113	45	45	S	Full	T	Thin SS with very thin layers of shale	-	IF	72	-	72	Shale & SS
06+55	06+59	118	51	50	S	Full	T	Thin SS with very thin layers of shale	-	IF	12	-	18	Shale & SS
07+33	-	NA	48	48	S	Full	T	Thin SS with 16" thick, very thin shale with pulverized mixed material at crown	SW	IF	16	16	16	-
08+31	-	NA	42	42	S	Full	T	Thin SS with 9" thick, very thin shale with pulverized mixed material at crown	SW	IF	9	9	9	Pulverized material
08+50	08+58	101	42	42	S	Full	T	Thin SS with multiple 10" thick, very thin layers of shale	SW	IF	60	60	60	Shale & SS
09+90	09+96	108	43	43	S	Full	T	Thin SS interbedded with very thin layer of shale	SW	IF	6	6	6	-
10+31	10+37	108	32	32	S	Full	T	Thin to medium SS interbedded with 4 zones of very thin shale with highly pulverized mixed material	SW	IF	11	11	11	Layers of shale bedding has thicknesses 11", 2.5", 10" and 5". Highly pulverized mixed material.
11+75	11+81	108	32	32	S	Full	T	Thin SS interbedded with 8" very thing shale and full pulverized mixed material	SW	IF	8	8	8	Pulverized material
12+29	12+37	101	35	36	S	Full	T	Med and thin layers of SS with 6-10" thick layers of very thin shale very thin layers of shale (4 beds total)	-	IF	78	78	78	Shale & SS
12+86	13+07	88	25	30	S	Full	PO	Thin SS with very thin layers of shale	-	IF	16	-	16	Shale & SS - shallow, slightly rough
13+32	13+35	124	28	25	S	Full	T	Thin SS with very thin layers of shale with pulverized material	SW	IF	48	48	48	Shale & SS, pulverized material growing calcite minerals
13+59	13+66	104	76	64	S	Full	T	Tight thin SS with very thin layers of shale below SL on both sides. Fault observed to not follow bedding plane from 10:00 to 2:00	HW	IF	2	11	2	-
13+73	13+80	104	27	27	S	Full	T	Thin SS with very thin layers of shale with pulverized material	SW	IF	22	22	22	-
14+21	14+27	108	30	30	S	Full	T	Thin SS with very thin layers of shale	SW	IF	120	120	120	Fractures show signs of partly open aperatures; however, most likely from blasting and excavation operations rather than in situ conditions. Bedding thickness 120"+
14+97	15+02	113	70	69	S	Full	VW	Tight thin SS with very thin layers of shale below SL on both sides. Fault observed to not follow bedding plane from 10:00 to 2:00.	HW	IF	4	8	5	-
15+19	15+24	113	80	76	S	Full	T	Very thin layers of shale with pulverized material	SW	IF	36	36	36	-
15+48	15+52	118	65	77	S	Full	T	Thin SS with very thin layers of shale with pulverized material	SW	IF	27	27	27	Shale & SS
15+74	15+80	108	58	60	S	Full	T	Thin SS with very thin layers of shale	SW	IF	9	8	7	Shale & SS

Note 1. Aperature was generally tight; however, the interbedded layers typically had 1 to 2 bedding joints that were partly open and filled with pulverized material.

TABLE 7. PRIMARY AND SECONDARY JOINT DATA

Station To	Primary or Secondary (P or S)	Strike	Dip (degrees) (9:00 position)	Dip (degrees) (3:00 position)	Dip direction (N or S)	Joints per Width of Tunnel	Spacing (ft)	Apperture Width Designation	Nature of filling	Weathering	Roughness	Persistance	Notes
01+13	P	37	80	60	N	3	3	T	None	FR	SR	H-VH	-
01+50	P	41	66	62	N	12	1	T	None	FR	SR	H-VH	-
02+00	P	40	65	70	N	7	1	T	None	FR	SR	H-VH	-
02+50	P	49	52	70	N	7	1	T	None	FR	SR	H-VH	Horizontal joint starts to show up
02+50	S	134	19	5	N	4	2	T	None	FR	SR	L	Low angle and various secondary joints range between N and S dipping
03+00	P	55	51	45	N	5	2	T	None	FR	SR	H-VH	-
03+00	S	140	20	20	N/S	8	1	T	None	FR	SR	L	Low angle and various secondary joints range between N and S dipping
03+50	P	40	79	70	N	6	1	T	None	FR	SR	H-VH	-
03+50	S	125	17	15	S/N	6	1	T	None	FR	SR	L	Low angle and various secondary joints range between N and S dipping
04+50	P	35	NA	57	N	6	1	T	None	FR	SR	H-VH	Difficult to measure dip degrees at 9:00 position
04+50	S	120	20	20	N/S	7	1	T	None	FR	SR	L	Low angle and various secondary joints range between N and S dipping
04+78	P	24	60	63	N	9	1	T	None	SW	SR	H-VH	-
04+78	S	109	10	20	S/N	4	2	T	None	SW	SR	L	Low angle and various secondary joints range between N and S dipping
05+00	P	-	-	-	-	-	-	-	-	-	-	-	Similar primary joints at 4+78 but more joints per width of tunnel
05+00	S	-	-	-	-	-	-	-	-	-	-	-	Similar secondary joints at 4+78 but more joints per width of tunnel
06+00	P	32	78	88	N	8	1	T	None	FR	SR	H-VH	Near vertical dip at 3:00 position
06+00	S	140	30	19	S/N	6	1	T	None	FR	SR	L	Strike observed to be perpendicular to tunnel alignment. May be new set, but similar to previous set but maybe starting to rotate
07+00	P	32	78	88	N	16	-	T	None	FR	SR	H-VH	Near vertical dip at 3:00 position. Difficult to locate secondary joint.
07+00	S	-	-	-	-	-	-	-	-	-	-	-	Difficult to locate secondary joint - no persistance
08+00	P	55	90	90	N	NA	-	T	None	FR	SR	H-VH	Trace of joint observed, parallel to tunnel, approx. 2-3 feet long.
08+00	S	-	45	-	S	-	-	-	-	-	-	-	Hints of very short <2' secondary joints but difficult to locate.
08+70	P	75	61	57	N	4	2	T	None	FR	SR	H-VH	Backsight due to strike of joint away from tunnel alignment.
08+70	S	-	-	-	-	-	-	-	-	-	-	-	Difficult to locate secondary joint - no persistance
09+00	P	55	80	79	N	2	4	T	None	FR	SR	H-VH	No bedding joint within massive SS, High persistance from 9+00 to 9+80
09+00	S	-	-	-	-	-	-	-	-	-	-	-	Difficult to locate secondary joint - no persistance
10+00	P	-	68	54	N	9	1	T	None	FR	SR	H-VH	Strike difficult to determine as rock starts to fan out
10+00	S	-	-	-	-	-	-	-	-	-	-	-	Difficult to locate secondary joint - no persistance. Possible 3rd steep set but little to no persistance (~1') and dips to south
11+00	P	44	68	54	N	8	1	T	None	FR	SR	H-VH	-
11+00	S	-	-	-	-	-	-	-	-	-	-	-	Difficult to locate secondary joint - no persistance. Possible 3rd steep set but little to no persistance (~1') and dips to south

TABLE 8. FALLOUT MATERIAL					
Station		Fallout Material	Volume (CY)	Block Size	Notes
To	From				
00+92	10+84	Stockpiled material blocks, fragments, and soil, SS and Shale	NA	NA	Generally tunnel much was cleaned from 5:00 position and stockpiled
03+05	-	Stockpiled material at 7:00 position	2.1	3"-1' dia	Fallout potentially from crown but may be from
04+75	-	Rock blocks mixed with 3-6" dia rock and pulverized	3.3	1'x2'x1'	Approx. 15 feet beyond concrete rib supports
05+30	-	7:00 stockpiled SS/Shale and pulverized material	1.8	NA	May be from cleaning invert. Roots observed
05+40	-	7:00 stockpiled SS/Shale	0.1	NA	May be from cleaning
09+55	-	Stockpiled SS/Shale	2	NA	May be from cleaning
11+50	-	Blocks of slightly weathered	0.1	NA	Fallout of crown
11+95	-	Mixture SS/Shale blocks and pulverized material at 5:00	0.5	NA	Soil-like material from sidewall
12+70	-	Mixture of SS/Shale blocks and pulverized material at	5	NA	Fallout at timber sets
15+00	16+00	Small 3-6" pieces of	NA	3-6" dia	May be from cleaning
15+40	-	Mixture of SW Shale and SS	0.3	NA	Material from fault that
15+50	-	Blocks of SS	0.1	12" dia	Blocks fell out at fault
15+55	-	and soil-like material piled, SS/Shale	0.5	2-3' dia max	Material from fault that opened up

APPENDIX B – PHOTOGRAPHIC RECORD

(Photographs taken in January 2017 and February 2017)

Photograph Index

Photograph	Station	Description
1	Sta. 0+00	Looking north - Tunnel portal
2	Sta. 0+00	Looking upstream - Tunnel portal and gate
3	Sta. 0+50	Looking upstream - Concrete liner
4	Sta. 1+50	Looking upstream
5	Sta. 2+50	Looking upstream
6	Sta. 3+50	Looking upstream
7	Sta. 4+50	Looking upstream - Concrete trapezoidal sets
8	Sta. 5+50	Looking upstream - Concrete liner
9	Sta. 6+50	Looking upstream
10	Sta. 7+50	Looking upstream
11	Sta. 8+50	Looking upstream
12	Sta. 8+50	Looking upstream
13	Sta. 9+50	Looking upstream
14	Sta. 10+50	Looking upstream
15	Sta. 10+84	Looking upstream - Bulkhead door and concrete frame
16	Sta. 11+50	Looking upstream
17	Sta. 12+50	Looking upstream
18	Sta. 12+68	Looking upstream - Wood sets
19	Sta. 13+50	Looking upstream
20	Sta. 14+50	Looking upstream
21	Sta. 14+61	Looking upstream - Concrete liner
22	Sta. 15+50	Looking upstream
23	Sta. 16+50	Looking upstream
24	Sta. 17+50	Looking upstream
25	Sta. 18+50	Looking upstream
26	Sta. 19+50	Looking upstream
27	Sta. 20+30	Looking upstream - Fault
28	Sta. 20+30	Looking at crown - Fault
29	Sta. 20+50	Looking upstream
30	Sta. 21+50	Looking upstream
31	Sta. 22+50	Looking upstream
32	Sta. 23+50	Looking upstream
33	Sta. 24+00	Looking upstream - Obstructed location
34	Sta. 24+00	Looking upstream - Water at invert at obstructed location
35	Sta. 24+00	Looking upstream - Obstructed location

Photograph 1. Tunnel portal at Sta. 0+00 (looking north)

Photograph 2. Tunnel portal and gate at Sta. 0+00 (looking upstream)

Photograph 3. Sta. 0+50 at concrete liner (looking upstream)

Photograph 4. Sta. 1+50 (looking upstream)

Photograph 5. Sta. 2+50 (looking upstream)

Photograph 6. Sta. 3+50 (looking upstream)

Photograph 7. Sta. 4+50 at concrete trapezoidal sets (looking upstream)

Photograph 8. Sta. 5+50 at concrete liner (looking upstream)

Photograph 9. Sta. 6+50 (looking upstream)

Photograph 10. Sta. 7+50 (looking upstream)

Photograph 11. Sta. 8+50 (looking upstream)

Photograph 12. Sta. 8+50 (looking upstream)

Photograph 13. Sta. 9+50 (looking upstream)

Photograph 14. Sta. 10+50 (looking upstream)

Photograph 15. Sta. 10+84 at bulkhead door and concrete frame (looking upstream)

Photograph 16. Sta. 11+50 (looking upstream)

Photograph 17. Sta. 12+50 (looking upstream)

Photograph 18. Sta. 12+68 at wood sets (looking upstream)

Photograph 19. Sta. 13+50 (looking upstream)

Photograph 20. Sta. 14+50 (looking upstream)

Photograph 21. Sta. 14+61 at concrete liner (looking upstream)

Photograph 22. Sta. 15+50 (looking upstream)

Photograph 23. Sta. 16+50 (looking upstream)

Photograph 24. Sta. 17+50 (looking upstream)

Photograph 25. Sta. 18+50 (looking upstream)

Photograph 26. Sta. 19+50 (looking upstream)

Photograph 27. Sta. 20+30 at fault (looking upstream)

Photograph 28. Sta. 20+30 at fault (looking at crown)

Photograph 29. Sta. 20+50 (looking upstream)

Photograph 30. Sta. 21+50 (looking upstream)

Photograph 31. Sta. 22+50 (looking upstream)

Photograph 32. Sta. 23+50 (looking upstream)

Photograph 33. Sta. 24+00 at obstructed location (looking upstream)

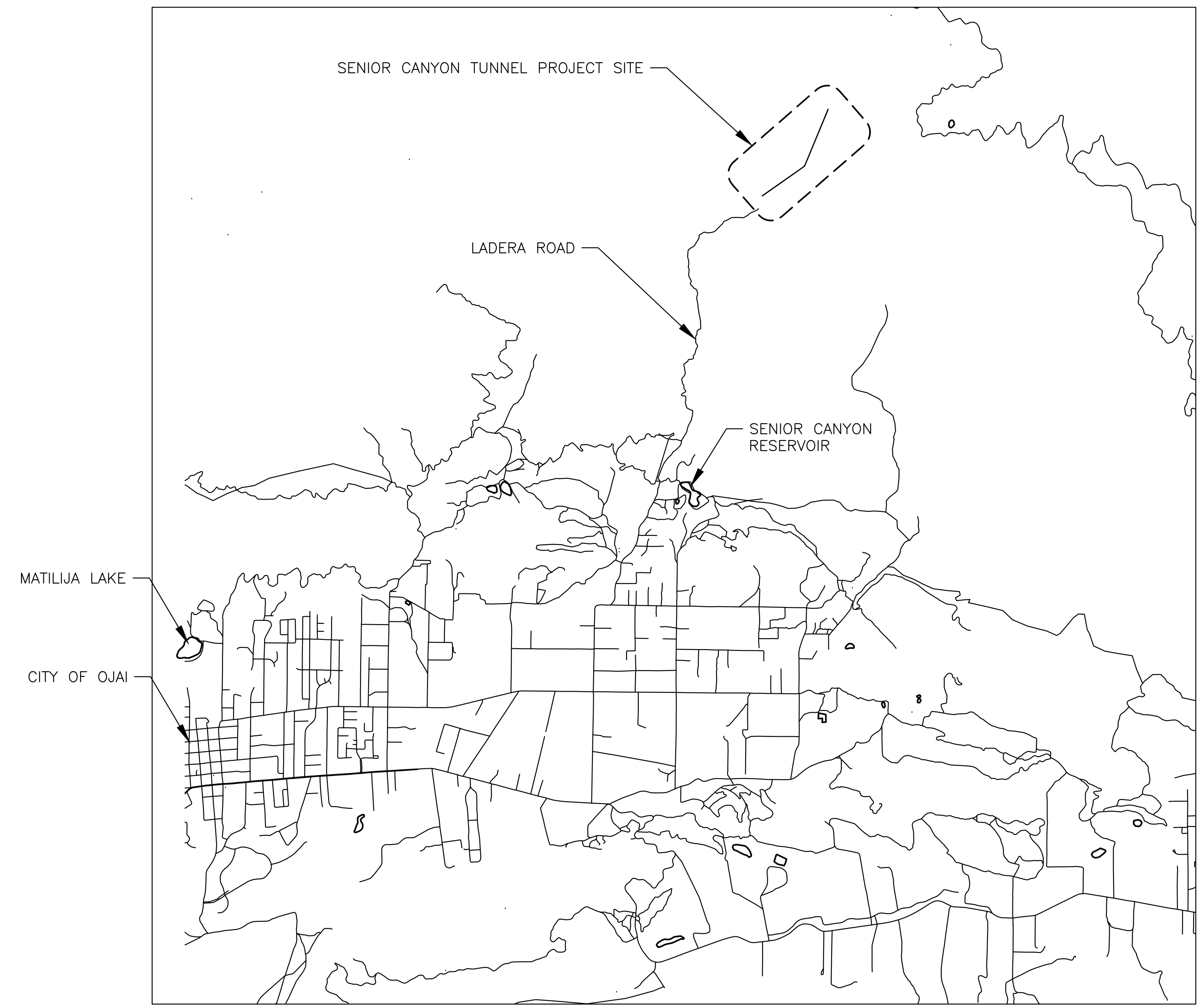
Photograph 34. Sta. 24+00, water at invert at obstructed location (looking upstream)

Photograph 35. Sta. 24+00 at obstructed location (looking upstream)

APPENDIX C – TUNNEL PLANS

Tunnel Plans Index

Drawing No. #	Drawing Name
1	Location Map
2	Tunnel Plan and Profile
3	Existing Conditions
4	Ground Support
5	Ground Support Details
6	Probe Hole Details
7	Discontinuity/Inflow Map from Station 0+00 to 24+00
8	Discontinuity/Inflow Map from Station 0+00 to 4+00
9	Discontinuity/Inflow Map from Station 4+00 to 8+00
10	Discontinuity/Inflow Map from Station 8+00 to 12+00
11	Discontinuity/Inflow Map from Station 12+00 to 16+00
12	Discontinuity/Inflow Map from Station 16+00 to 24+00



VICINITY MAP

SCALE: 1"=5000'

JCK UNDERGROUND

SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT

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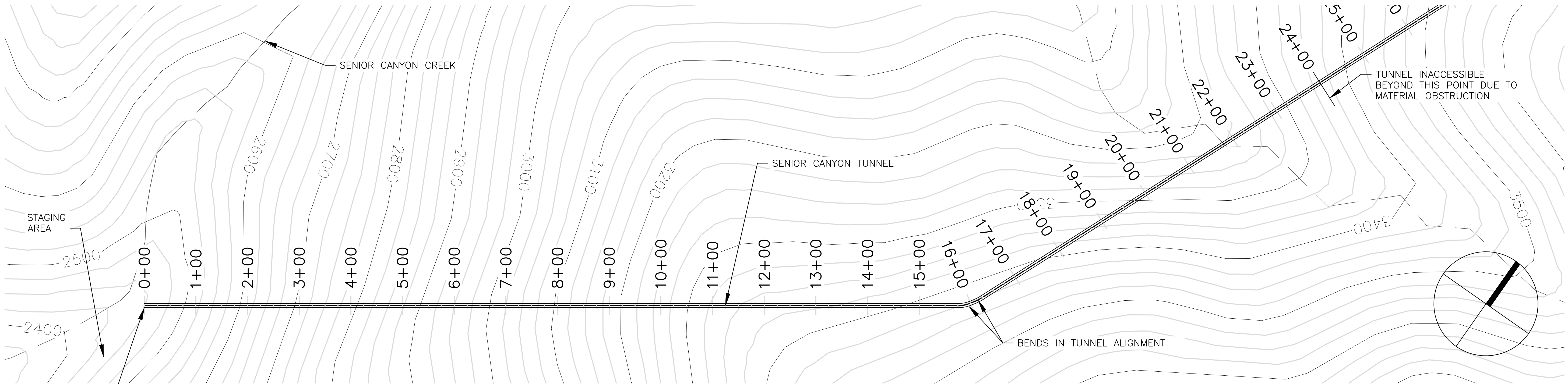
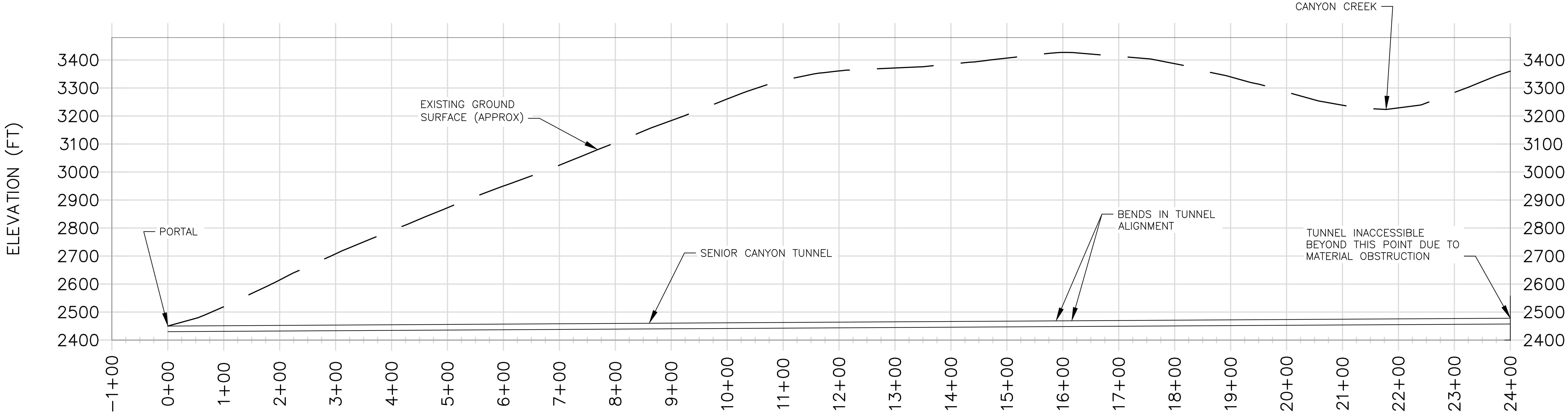
DRAWING 1 - LOCATION MAP

SCALE: AS NOTED



TUNNEL PLAN

SCALE: HORIZ = 1"=200',

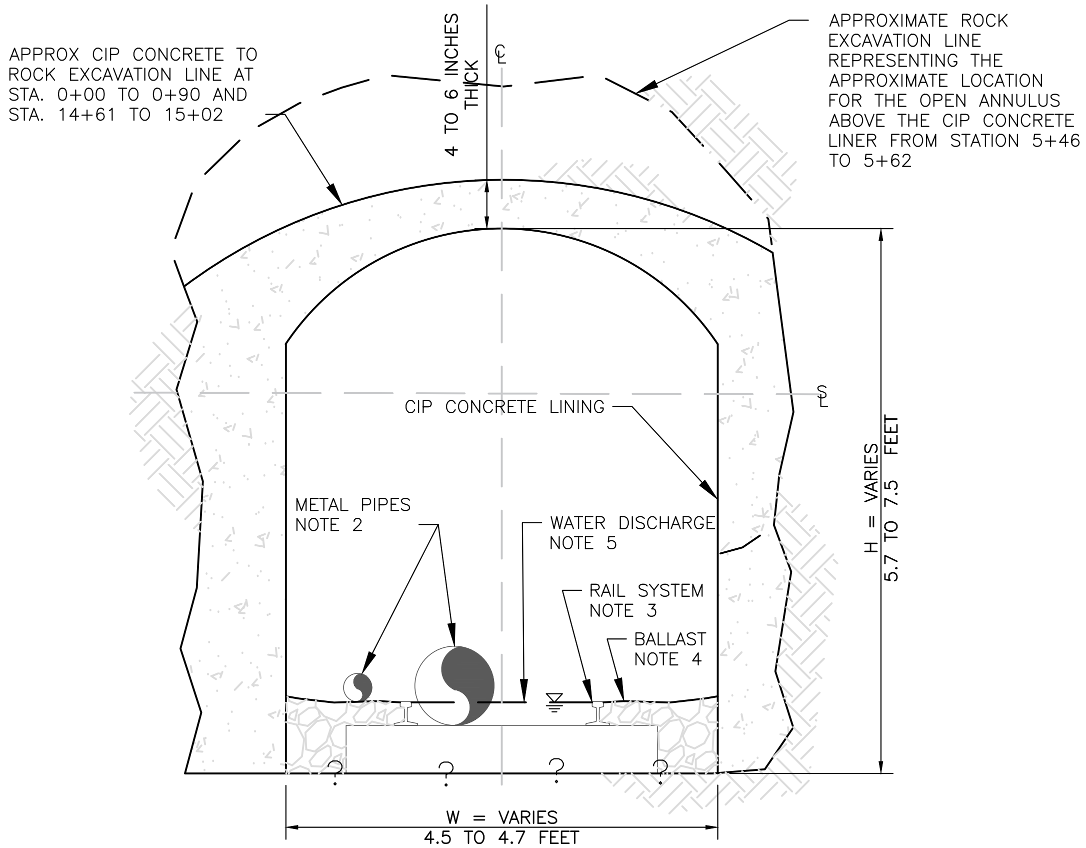


TUNNEL PROFILE

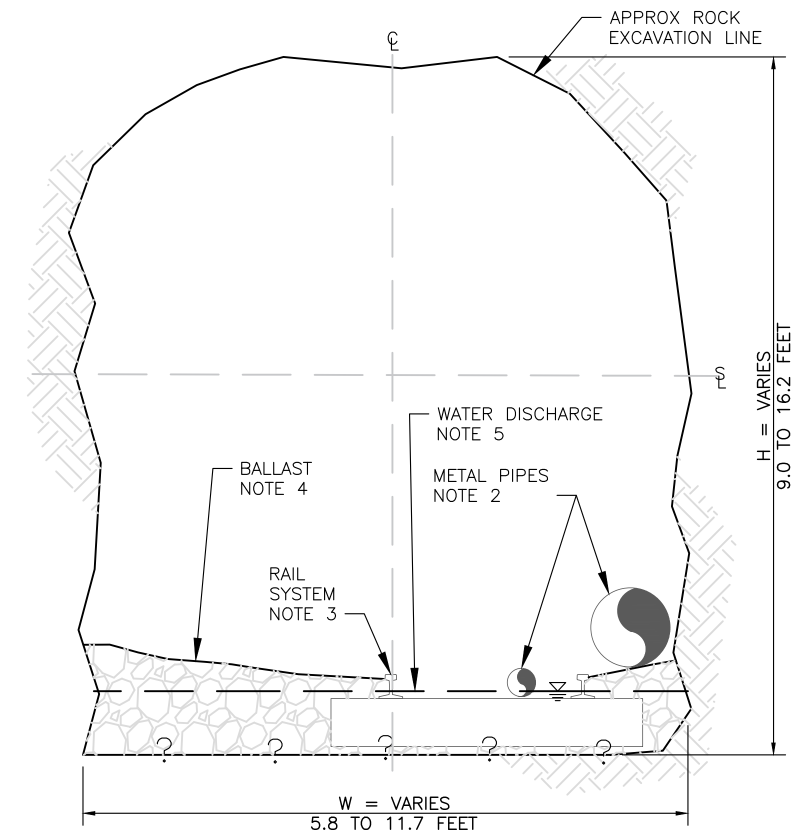
SCALE: HORIZ = 1"=200',
VERT = 1"=400'

JCK UNDERGROUND

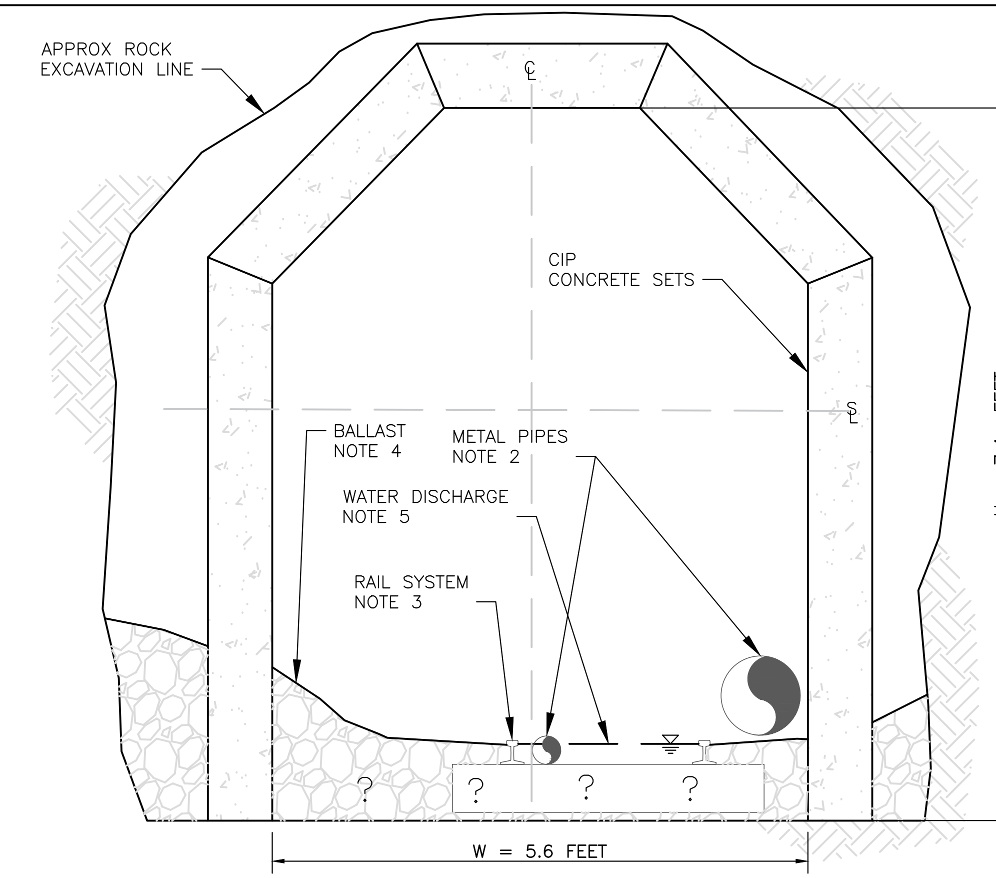
SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
DRAWING 2 - TUNNEL PLAN AND PROFILE	SCALE: 1"=200', 1"=400'



SECTION A - CIP CONCRETE



SECTION B - UNLINED



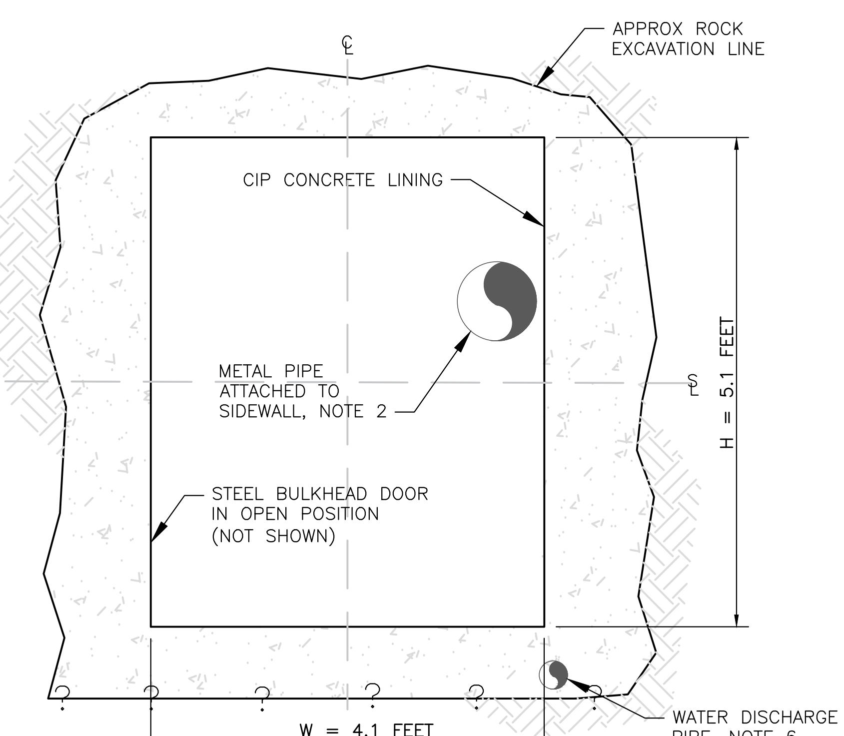
SECTION C - CONCRETE SETS

NOTES:

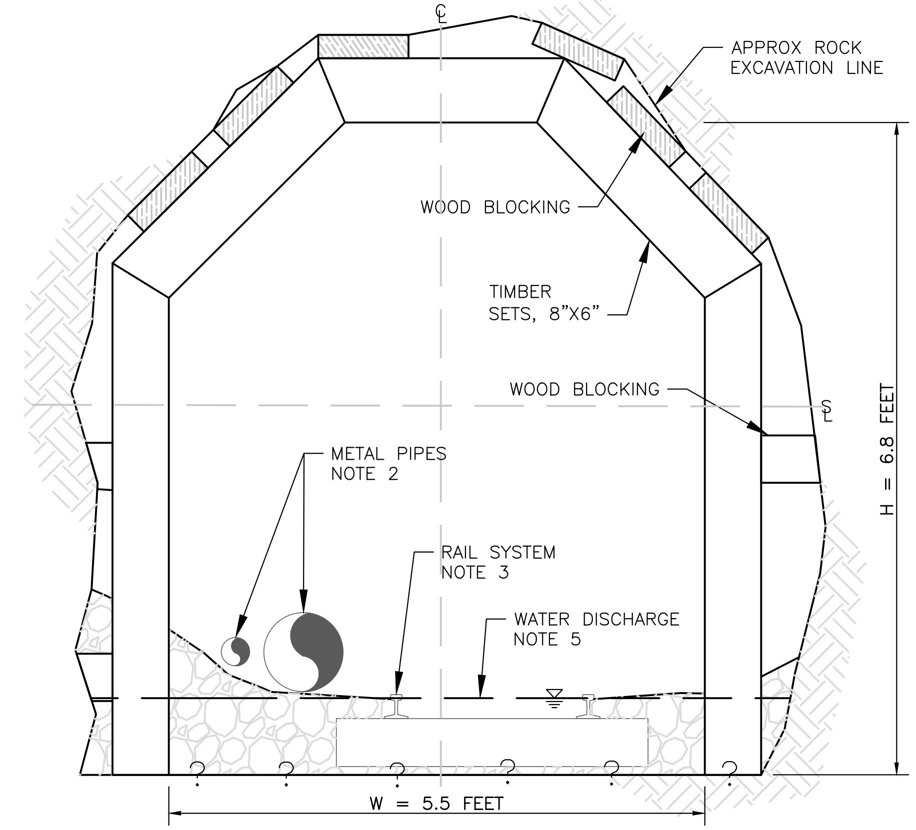
1. ROCK EXCAVATION LINES ARE NOT INTENDED TO REPRESENT GROUND CONDITIONS..
2. METAL PIPES AT INVERT MAY VARY IN SIZE, LOCATION, AND CONDITION ALONG THE TUNNEL ALIGNMENT.
3. RAIL SYSTEM CONSISTS OF RAIL TEES AND WOOD TIES.
4. BALLAST CONSISTS OF PILED DEBRIS AT THE TUNNEL INVERT. LOCATION, HEIGHT, WIDTH VARIES.
5. WATER DISCHARGE LEVEL VARIES THROUGHOUT THE TUNNEL ALIGNMENT.
6. WATER DISCHARGE PIPE EMBEDDED IN CIP CONCRETE LINER AT STEEL BULKHEAD AT UNKNOWN LOCATION.
7. STATION 17+00 TO 24+00 MEASUREMENTS ARE SIMILAR TO SECTION B; HOWEVER, REDUCES IN HEIGHT TO 4.7 FEET AT VARIOUS LOCATIONS.

EXISTING LINER CONDITIONS

STATION		LINING	SECTION
FROM	TO		
0+00	0+90	CIP CONCRETE LINER (SEE PHOTOGRAPH 3)	A
0+90	4+54	UNLINED	B
4+54	4+60	CONCRETE SETS (SEE PHOTOGRAPH 7)	C
4+60	5+46	UNLINED	B
5+46	5+62	CIP CONCRETE LINER (SEE PHOTOGRAPH 8)	A
5+62	10+84	UNLINED	B
10+84	–	BULKHEAD CIP (SEE PHOTOGRAPH 15)	D
10+84	12+68	UNLINED	B
12+68	13+02	TIMBER SETS (SEE PHOTOGRAPH 18)	E
13+02	14+61	UNLINED	B
14+61	15+02	CIP CONCRETE LINER (SEE PHOTOGRAPH 21)	A
15+02	24+00	UNLINED, NOTE 8	B



SECTION D - BULKHEAD CIP



SECTION E - TIMBER SETS

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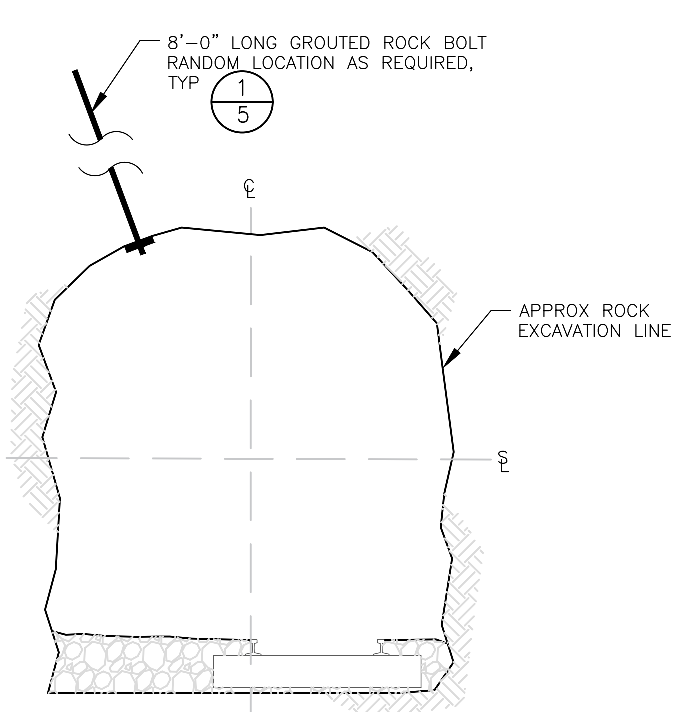
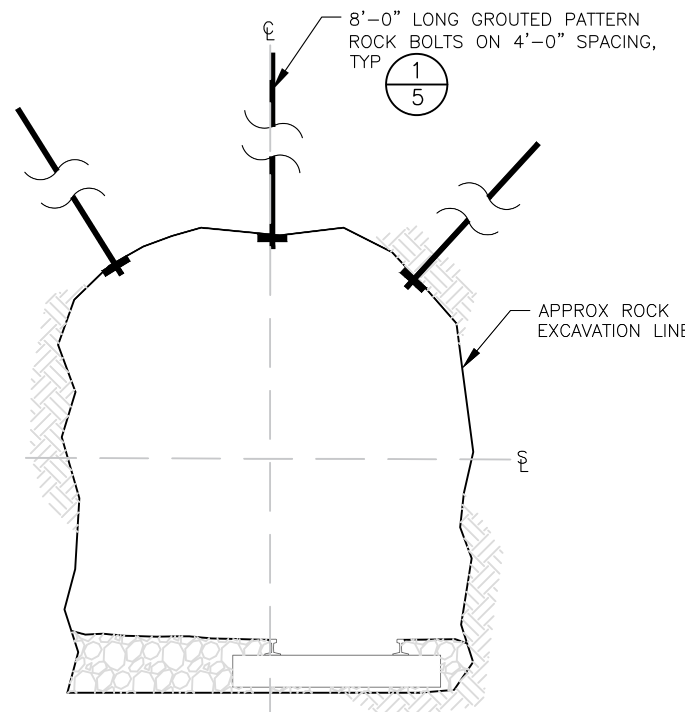
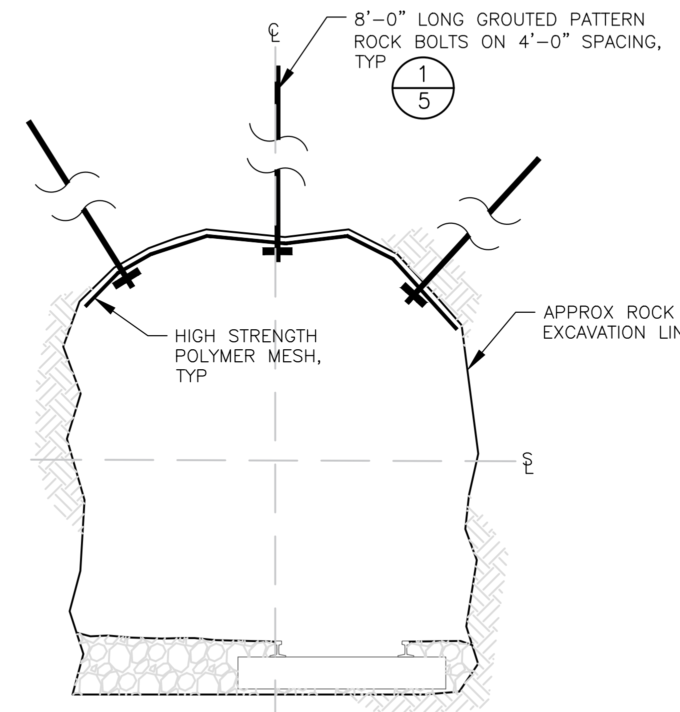
JCK UNDERGROUND	SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
	DRAWING 3 - EXISTING CONDITIONS	SCALE: 1" = 2'-0"



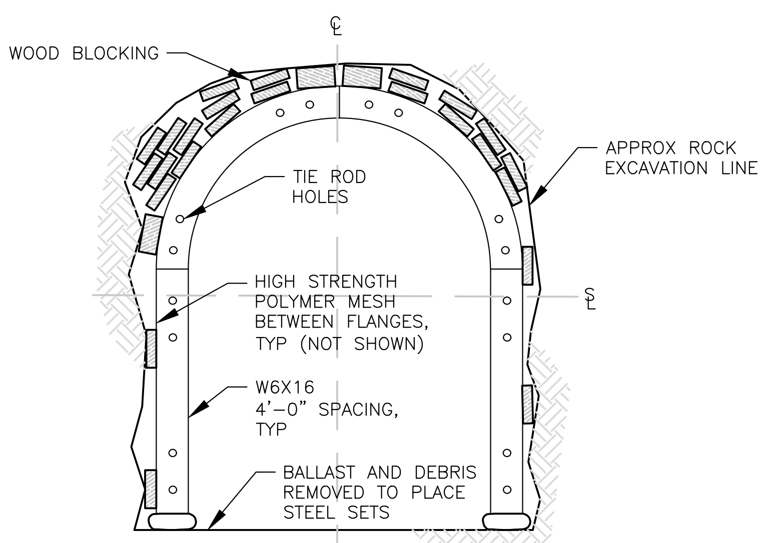
TYPE I - ROCK BOLT (RANDOM)



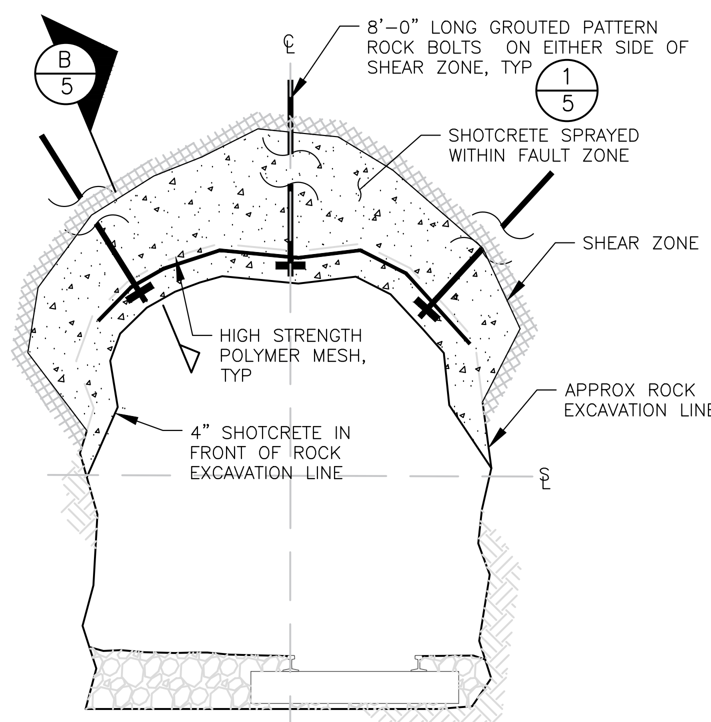
TYPE II - PATTERN ROCK BOLT



TYPE III - PATTERN ROCK BOLT WITH MESH



TYPE IV - STEEL SETS WITH MESH LAGGING



TYPE V - SHOTCRETE

NOTES:

1. ROCK EXCAVATION LINES ARE NOT INTENDED TO REPRESENT GROUND CONDITIONS..
2. METAL PIPES AND DEBRIS NOT SHOWN WITHIN GROUND SUPPORT TYPES.
3. ALL ROCK BOLTS IN THE TUNNEL ARE CT BOLT M22, 75,000 PSI, 8'-0" LONG FULLY GROUTED AND HAND TENSIONED COMPLETE WITH DOMED FACE PLATE WITH CAST ANCHOR NUT. SEE DRAWING 5 FOR DETAILS.
4. HIGH STRENGTH POLYMER MESH TO BE TENSAR MINING SYSTEM, BX3326 ROOF MATS. MESH TO BE SUPPORTED TO ROCK FACE WITH ROCK BOLTS TIGHTENED TO FACE PLATES, UNLESS DIRECTED OTHERWISE.
5. FAULT ZONE WIDTH AND DEPTH VARIES. SEE REPORT FOR DETAILS.

GROUND SUPPORT TYPE

STATION		TYPE
FROM	TO	
0+95	1+20	III
1+25	1+35	III
3+10	3+20	III
3+50	–	I
3+90	4+00	III
4+50	5+40	III
5+70	5+90	III
6+58	6+74	II
7+31	7+35	III
8+60	8+65	III
12+68	13+02	IV
13+25	13+50	III
13+50	13+90	I
13+59	13+66	V
14+25	14+50	III
14+97	15+02	V
15+00	15+40	III
15+48	15+52	V
15+72	15+88	III
20+30	20+38	V

JCK UNDERGROUND

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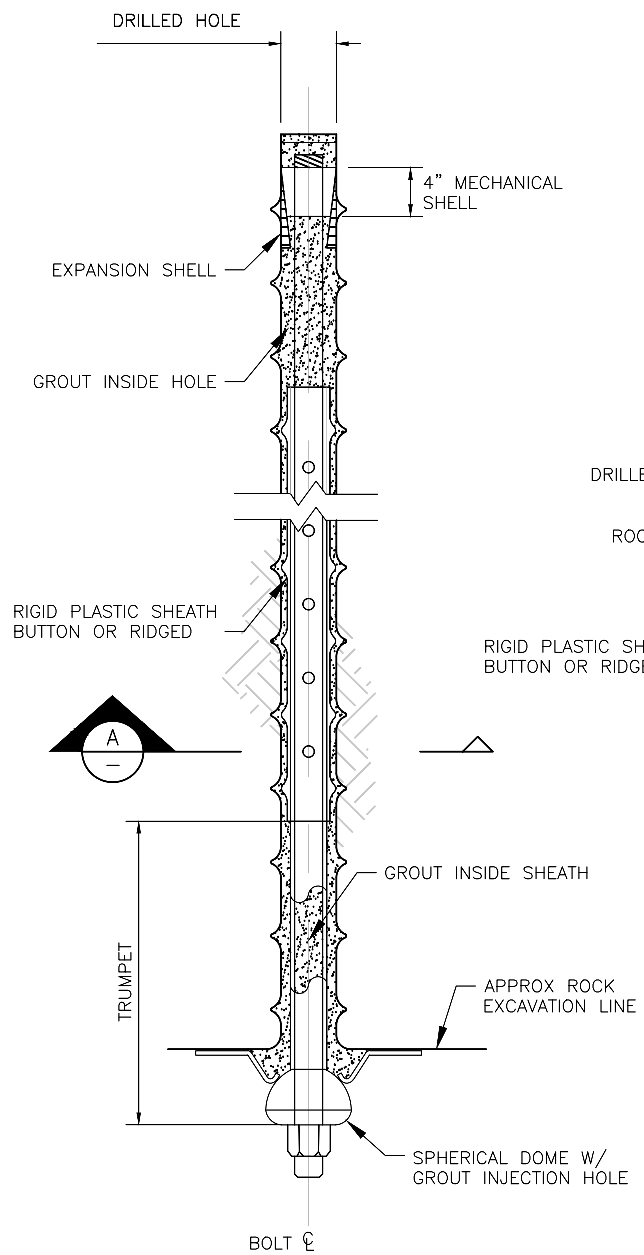
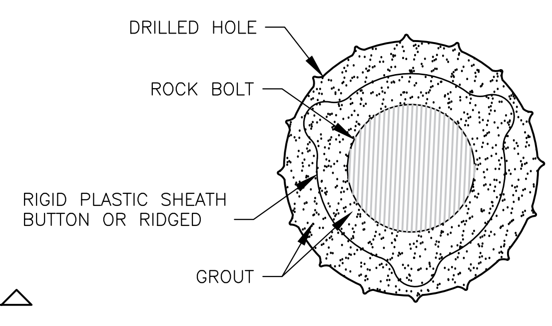
DRAWING 4 - GROUND SUPPORT

SCALE: 1" = 3'-0"

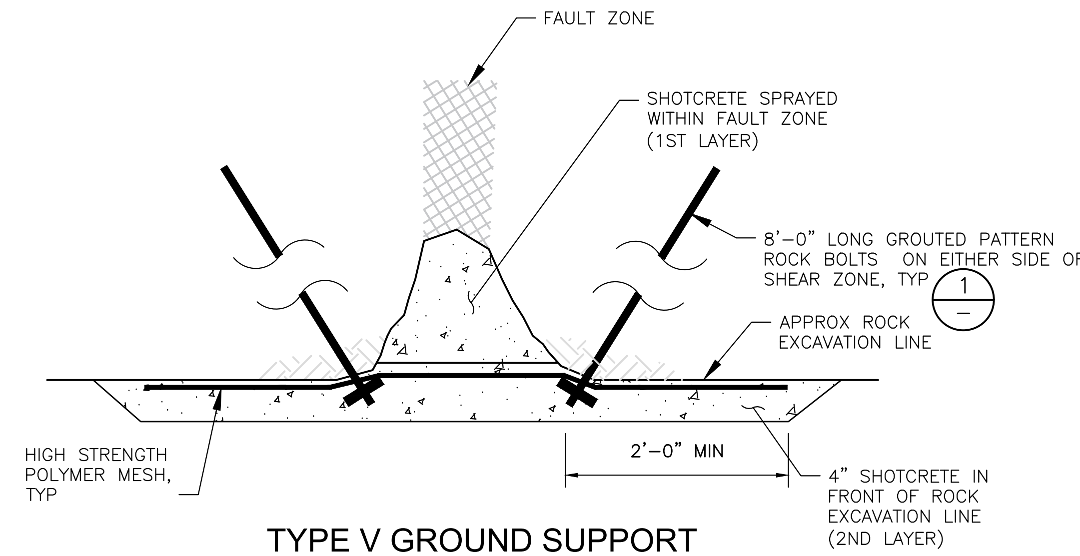


CORROSION PROTECTED ROCK BOLT

DETAIL 1/4
SCALE: NTS



SECTION A/–
SCALE: NTS



TYPE V GROUND SUPPORT

SECTION B/5
SCALE: NTS

NOTES:

1. ROCK EXCAVATION LINES ARE NOT INTENDED TO REPRESENT GROUND CONDITIONS..
2. ALL ROCK BOLTS IN THE TUNNEL ARE CT BOLT M22, 75,000 PSI, 8'-0" LONG FULLY GROUTED AND HAND TENSIONED COMPLETE WITH DOMED FACE PLATE WITH CAST ANCHOR NUT. SEE DRAWING 5 FOR DETAILS.
3. GROUT FOR GROUND SUPPORT ROCK BOLTS SHALL HAVE A MINIMUM STRENGTH OF CLASS 4000.
4. HIGH STRENGTH POLYMER MESH TO BE TENSAR MINING SYSTEM, UX3340 ROOF MATS. MESH TO BE SUPPORTED TO ROCK FACE WITH ROCK BOLTS TIGHTENED TO FACE PLATES, UNLESS DIRECTED OTHERWISE.
5. FAULT ZONE WIDTH AND DEPTH VARIES. SEE REPORT FOR DETAILS.
6. SHOTCRETE WITHIN FAULT ZONE SHALL HAVE THE FOLLOWING CONSTRUCTION STAGING: REMOVE AS MUCH MATERIAL AS DIRECTED BY RESIDENT ENGINEER. BACKFILL FAULT ZONE WITH SHOTCRETE TO THE TUNNEL ROCK EXCAVATION LINE. ATTACHED THE MESH TO THE SHOTCRETE AND ROCK EXCAVATION LINE WITH ROCK BOLTS AND SPRAY AN ADDITIONAL LAYER OF SHOTCRETE TO COVER BOLTS AND MESH (MINIMUM 4 INCHES).

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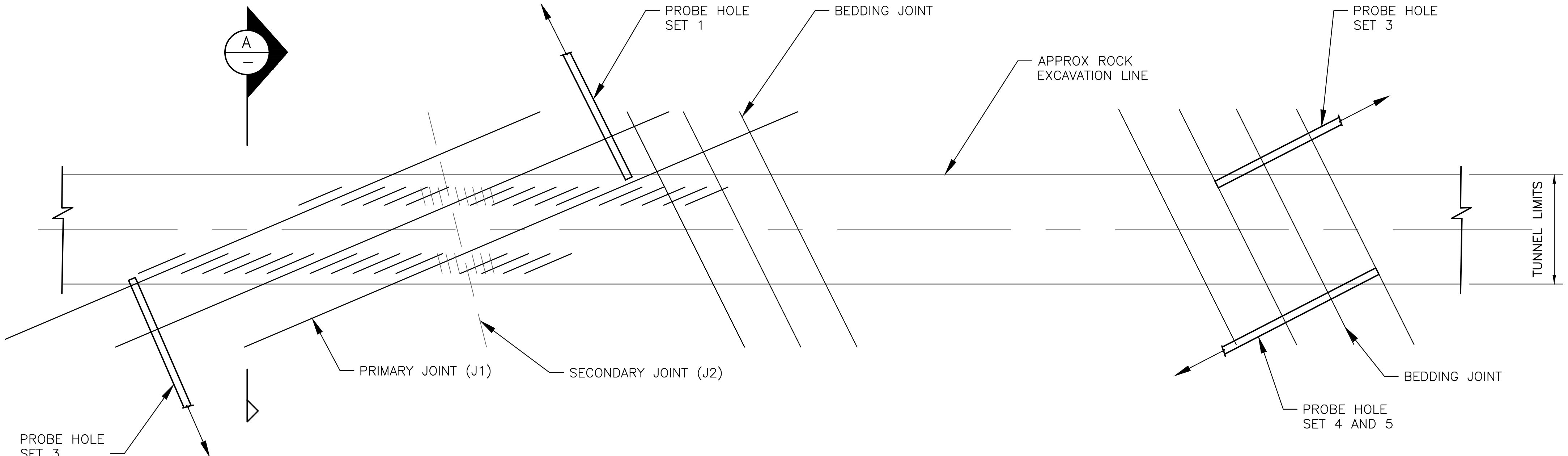
DRAWING 5 - GROUND SUPPORT DETAILS

SCALE: NTS



PLAN VIEW - PROBE HOLE LAYOUT WITH BEDDING JOINTS AND PRIMARY JOINTS

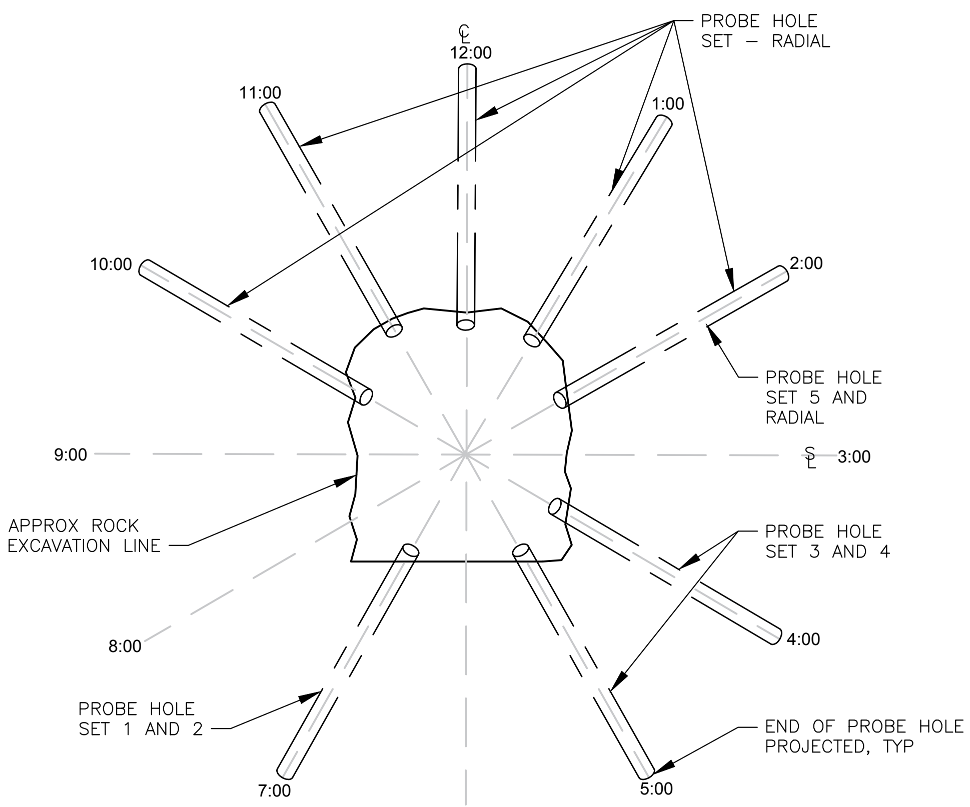
SCALE: NTS

NOTES:

1. ROCK EXCAVATION LINES, BEDDING JOINTS, PRIMARY AND SECONDARY JOINTS ARE NOT INTENDED TO REPRESENT GROUND CONDITIONS.
2. MODIFY LOCATIONS OF PROBE HOLES AT THE TUNNEL BASED ON INFLOW AND EXISTING TUNNEL CONDITIONS AS DIRECTED BY RESIDENT ENGINEER.
3. PROBE HOLES LOCATED AT THE INVERT (BETWEEN 5:00 TO 7:00 POSITIONS) USE GROUT PACKER AND PVC STANDPIPE TO RESTRICT WATER DISCHARGE FROM ENTERING PROBE HOLES. ENSURE PVC STANDPIPES AND GROUND PACKERS DO NOT INTERFERE WITH SAFETY CONDITIONS.

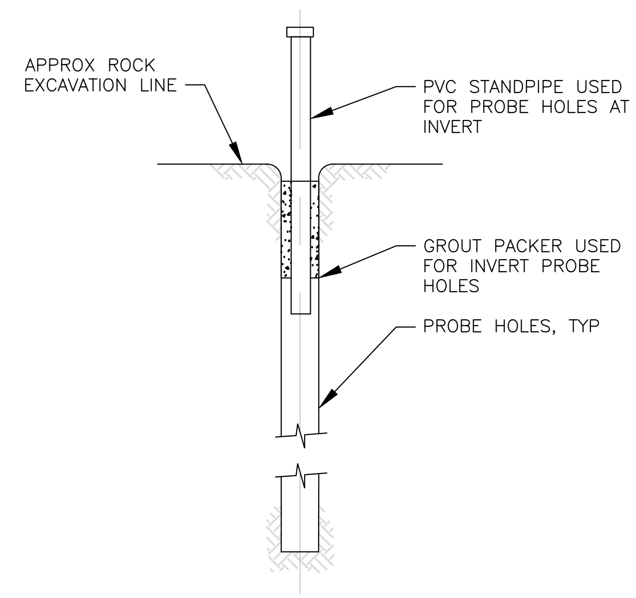
PROBE HOLE SCHEDULE

STATION	LOCATION RECOMMENDATION	PROBE SET
5+87	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO BEDDING JOINT	1
5+87	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO PRIMARY JOINT	1
5+93 (APPROX)	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO PRIMARY JOINT	1
6+40	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO BEDDING JOINT	2
6+40	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO PRIMARY JOINT	1
6+45 (APPROX)	(1) PROBE HOLE AT 7:00 POSITION PERPENDICULAR TO PRIMARY JOINT	1
6+40 TO 7+10	(8) PROBE HOLES AT 4:00 POSITION AT 8-FOOT CENTERS, PERPENDICULAR TO PRIMARY JOINT	3
6+40 TO 7+10	(8) PROBE HOLES AT 5:00 POSITION AT 8-FOOT CENTERS, NEARLY VERTICAL (CROSS BEDDING)	4
15+70 TO 16+80	(14) PROBE HOLES RADIALLY AT 8-FOOT CENTERS	RADIAL
15+70 TO 16+80	(14) PROBE HOLES AT 2:00 POSITION AT 8-FOOT CENTERS, PERPENDICULAR TO BEDDING JOINT	5
RESIDENT ENGINEER DIRECTED	(15) PROBE HOLES AS DIRECTED	IN FIELD



PROBE HOLE LAYOUT

SECTION A
SCALE: NTS



STANDPIPE AT INVERT PROBE HOLES

DETAIL 1
SCALE: NTS

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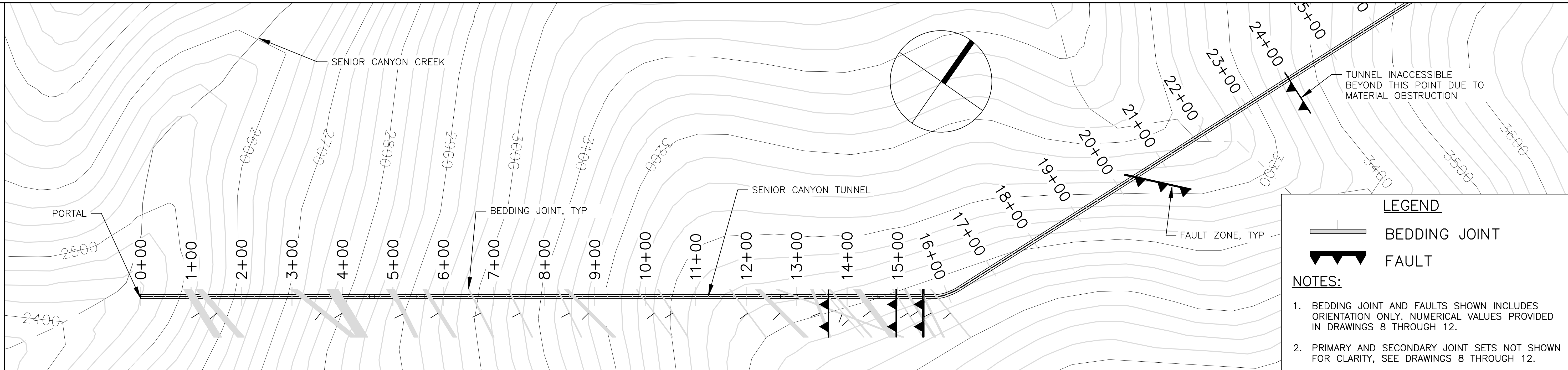
DRAWING 6 - PROBE HOLE DETAILS

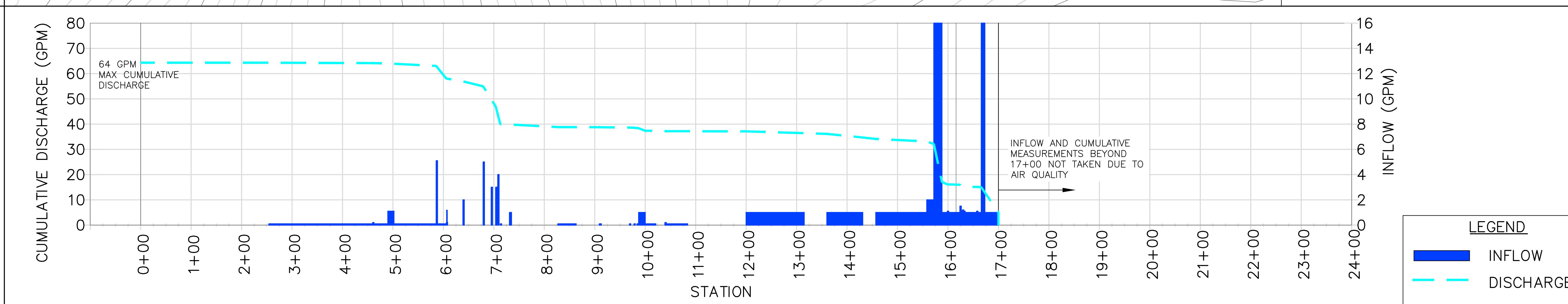
SCALE: NTS

TUNNEL PLAN - DISCONTINUITY MAP

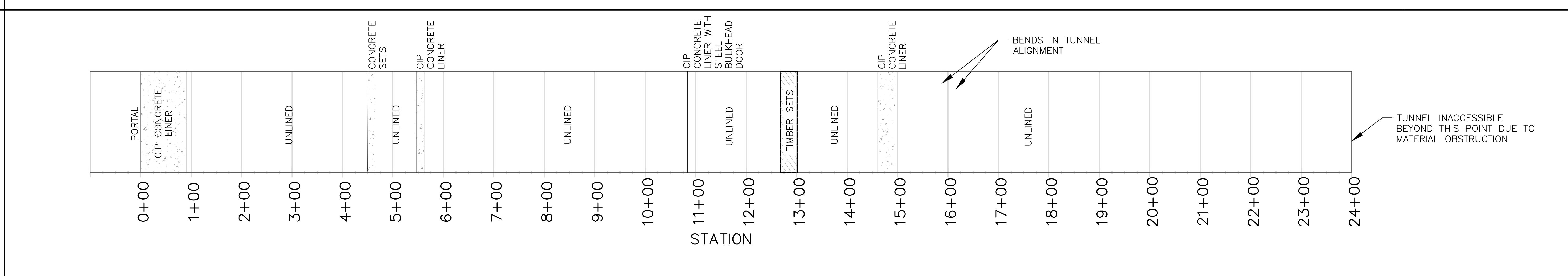
SCALE: 1"=200'



INFLOW VS. DISCHARGE

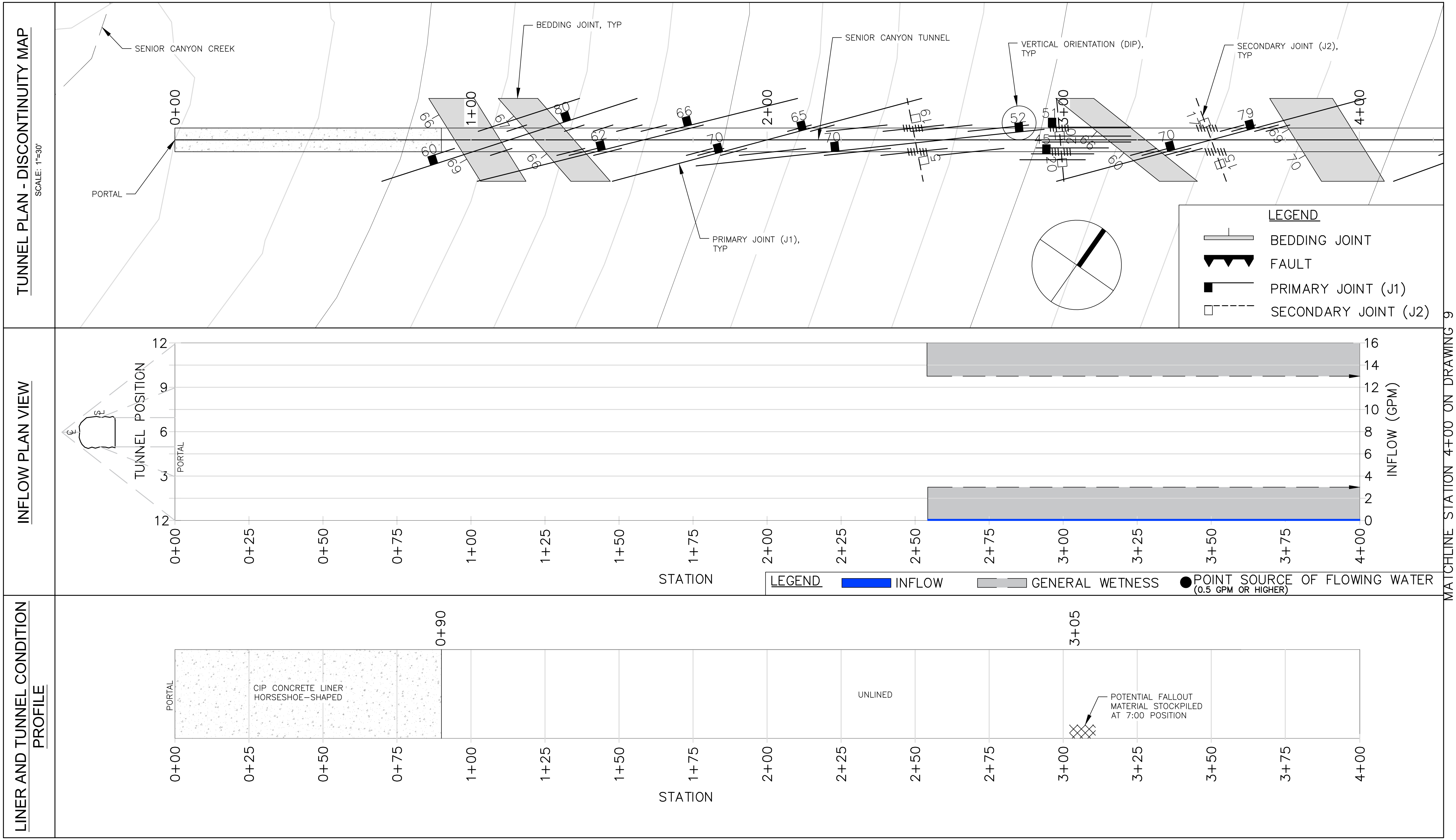


LINER AND TUNNEL CONDITION PROFILE



JCK UNDERGROUND

SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
DRAWING 7 - DISCONTINUITY/INFLOW MAP FROM STATION 0+00 TO 24+00	SCALE: 1"=200'



JCK UNDERGROUND

SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT

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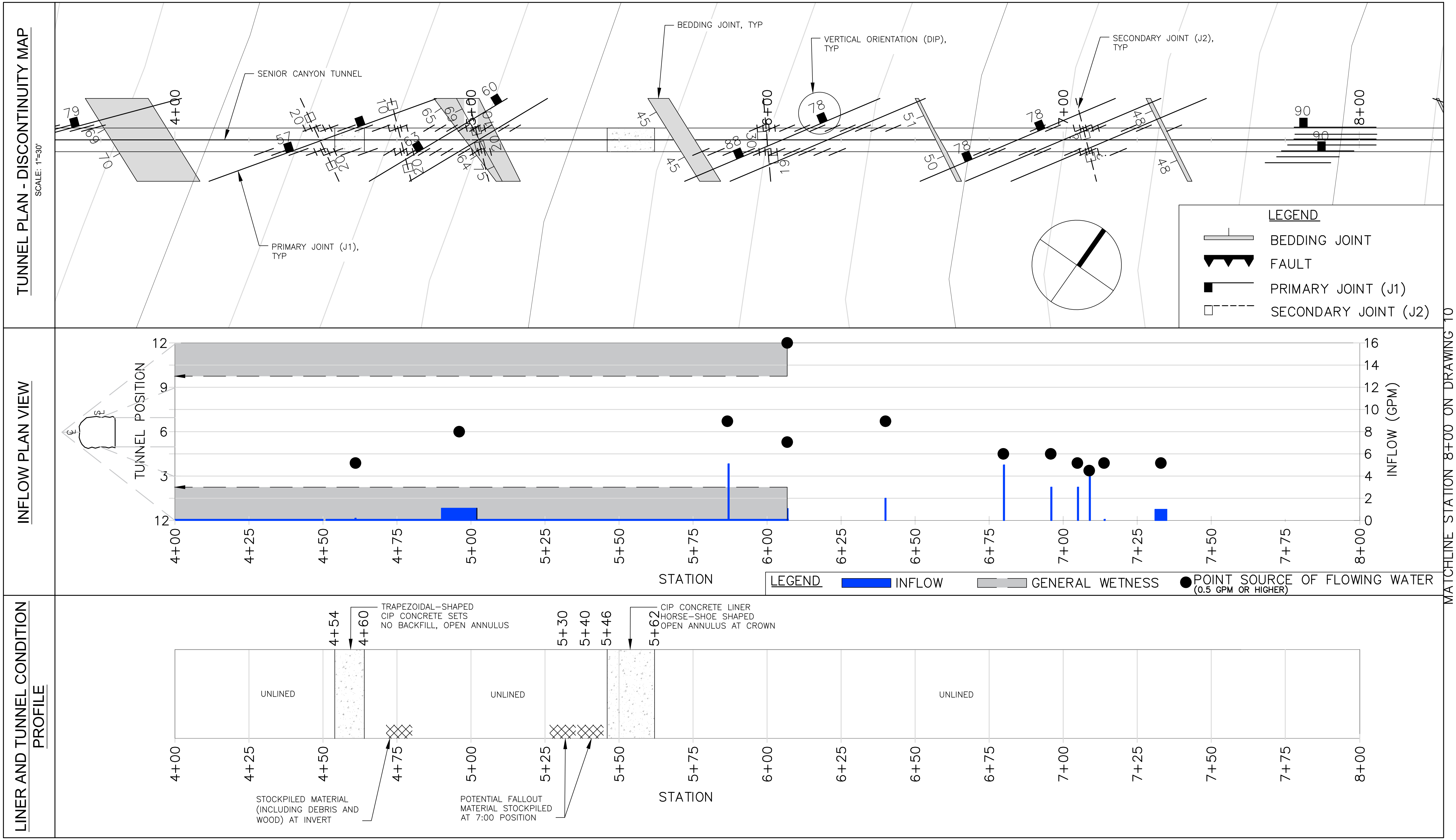
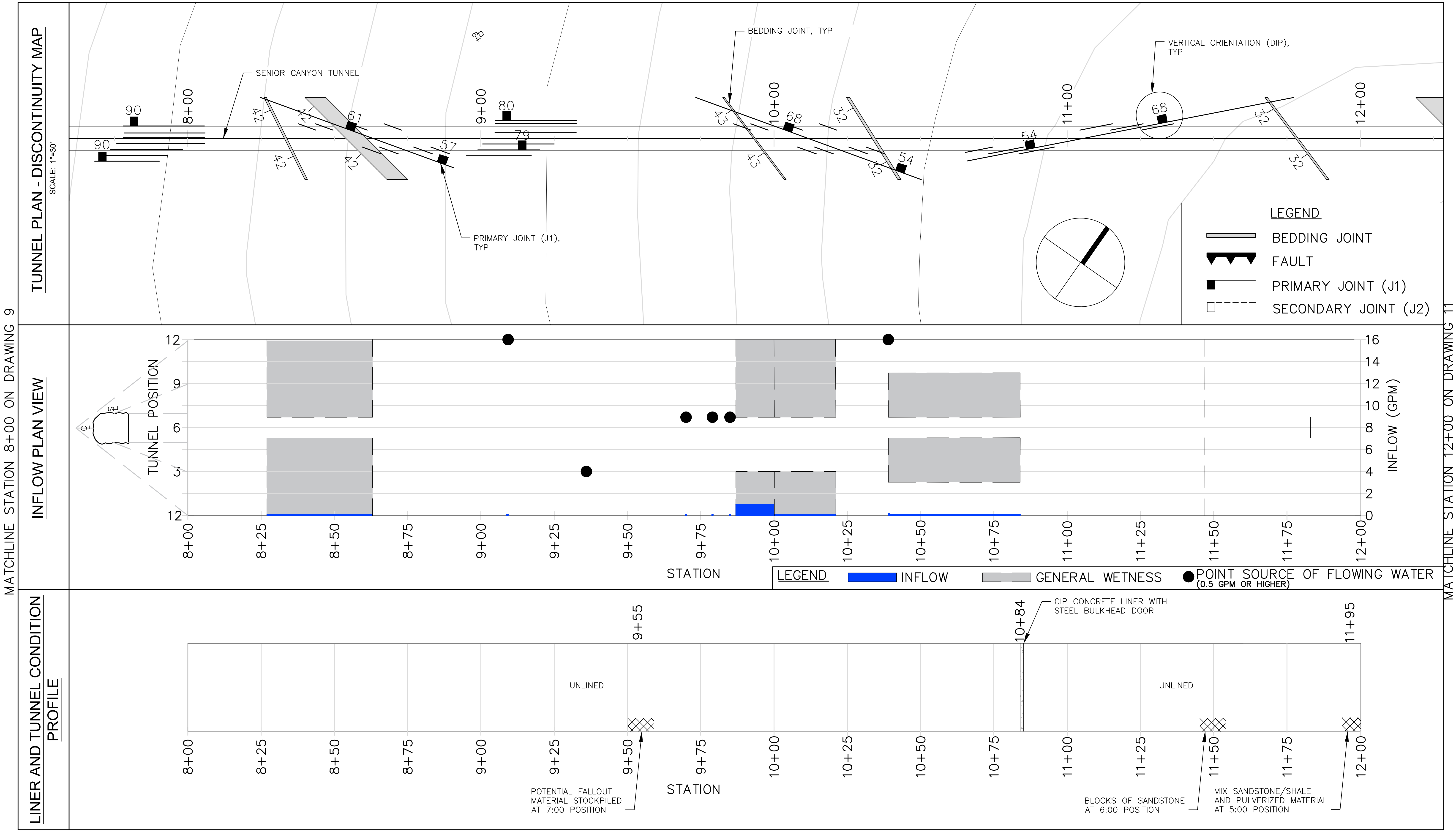
DRAWING 8 - DISCONTINUITY/INFLOW MAP FROM STATION 0+00 TO 4+00

SCALE: 1"=30'



JCK UNDERGROUND

SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
DRAWING 9 - DISCONTINUITY/INFLOW MAP FROM STATION 4+00 TO 8+00	SCALE: 1"=30'



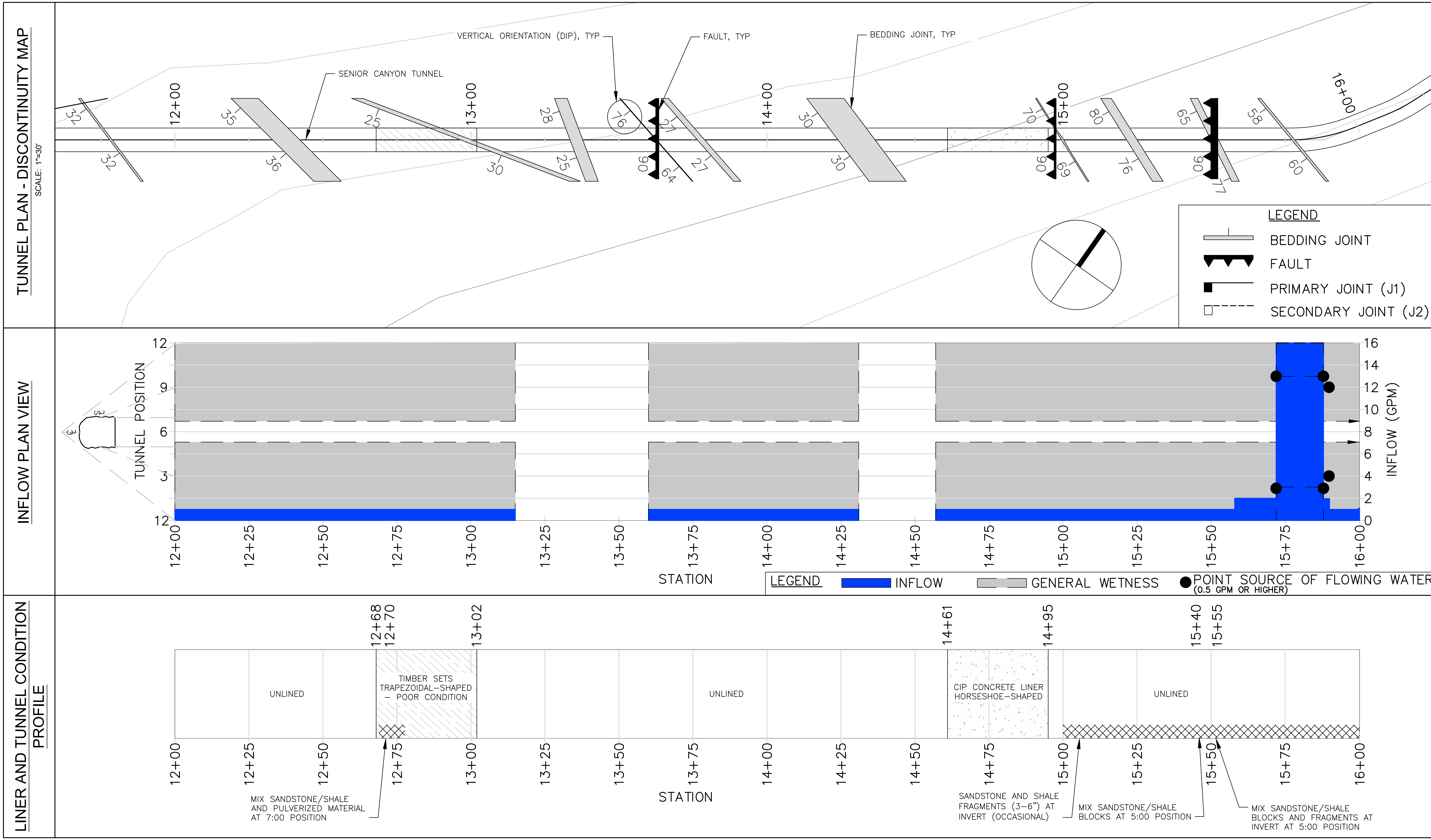
JCK UNDERGROUND

SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT

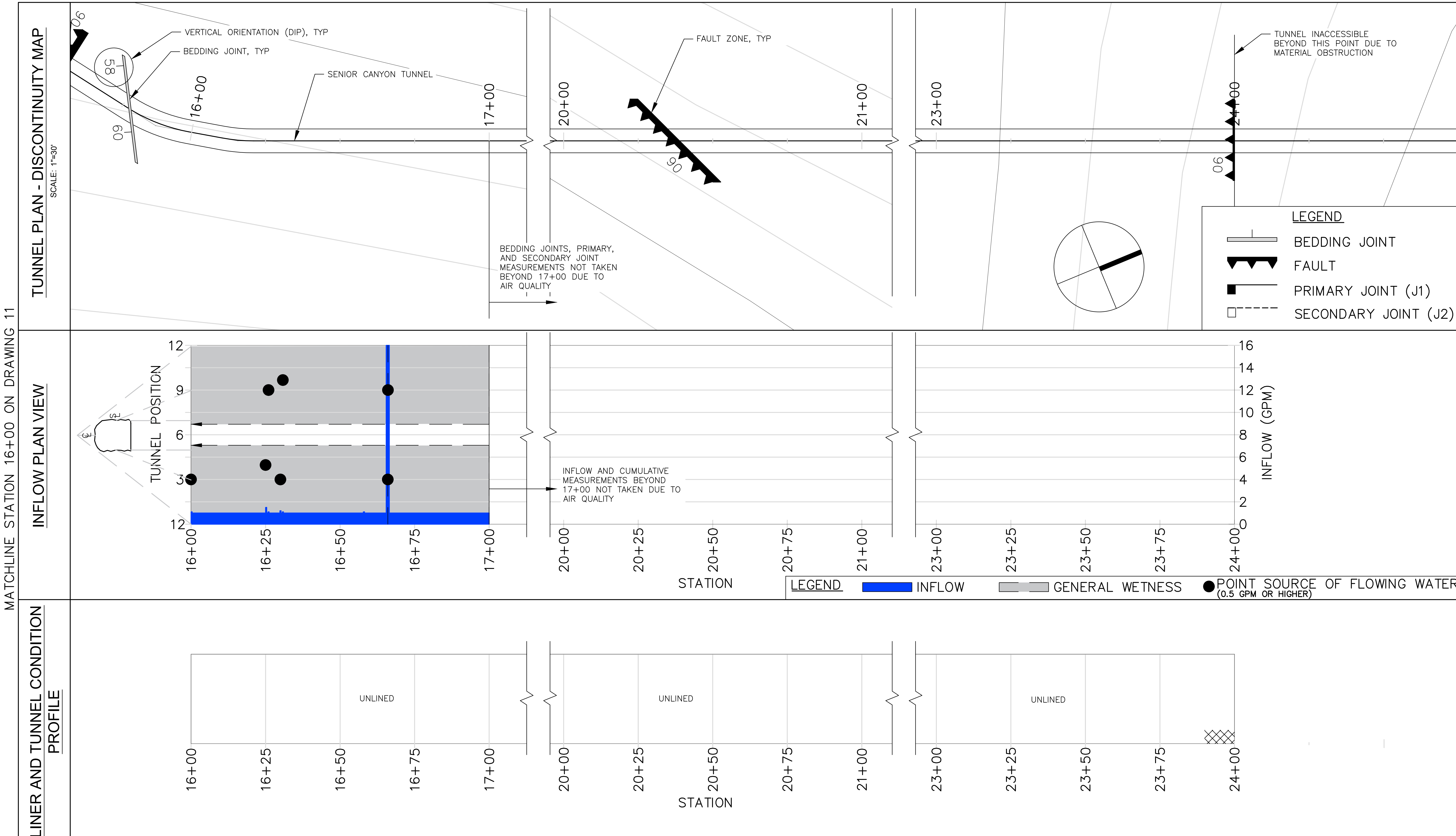
DRAWING 10 - DISCONTINUITY/INFLOW MAP FROM STATION 8+00 TO 12+00

MAY 2017

SCALE: 1"=30'



JCK UNDERGROUND	SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
	DRAWING 11 - DISCONTINUITY/INFLOW MAP FROM STATION 12+00 TO 16+00	SCALE: 1"=30'



SENIOR CANYON TUNNEL CONDITION ASSESSMENT REPORT	MAY 2017
DRAWING 12 - DISCONTINUITY/INFLOW MAP FROM STATION 16+00 TO 24+00	SCALE: 1"=30'

JCK UNDERGROUND