FEDERAL PROJECT NO. IM 0703-391 PCN 19036

COLORADO DEPARTMENT OF TRANSPORTATION

I-70 Twin Tunnels
Contract Package 2

Geotechnical Baseline Report

February 28, 2013

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in association with Atkins

Table of Contents

1 Introduction

1.1 Project Covered by this Geotechnical Baseline Report (GBR)

This GBR defines baseline subsurface geologic conditions for excavation and initial support activities required to enlarge the existing eastbound I-70 Twin Tunnel from its current two-lane condition to a three-lane configuration. Limits of the tunneling work and conditions addressed here extend from the defined turn-under point at the East Portal to the defined turn-under point at the West Portal.

1.2 Geotechnical Contract Documents

The Contract Documents which define the geotechnical conditions to be anticipated in excavation and support of the Eastbound Tunnel Widening are limited to the following:

(a) The Final Geotechnical Data Report (GDR) dated December 31st 2012, prepared by Yeh and Associates.

(b) This Geotechnical Baseline Report (GBR) dated February 28, 2013, prepared by Parsons Brinckerhoff, including input from Yeh and Associates.

(c) Additional Geotechnical Memoranda have been prepared by Yeh and Associates for the project and include:

- Eastbound and Westbound Twin Tunnels Liner Investigation Report: Final Memorandum – December 11th 2012
- 3D Seismic Investigation Eastbound Tunnel: Final Memorandum – November 26th 2012
- Initial Rockfall Parameters – West Portal Extension Design: Memorandum – September 26th 2012
- Final West Portal Subsurface Investigation and Portal Turn-Under Locations: Memorandum – Revised December 7th 2012

In interpretation of anticipated ground conditions, the Geotechnical Baseline Report (b above) has precedence over the Geotechnical Data Report (a), which has precedence over the Additional Geotechnical Memoranda (c).

1.3 Reference Documents

Documents prepared for CDOT's Twin Tunnels Environmental Site Assessment that are referenced in this GBR but are not Contract Documents are:

- Materials Management Plan, dated September 14, 2012, prepared for CDOT, Region 1 by Pinyon Environmental
- Twin Tunnels Environmental Assessment: Regulated Materials and Solid Waste Technical Memorandum, dated May 23, 2012, prepared for CDOT, Region 1 by Pinyon Environmental
- Memorandum – Eastbound and Westbound Twin Tunnels Liner Investigation Report: Twin Tunnels Widening Project, dated June 29,2012

- Parsons (2012), Existing Conditions Report of the Interstate 70 Twin Tunnels prepared for the Colorado Department of Transportation, Contract No. 12HA1 38233, SAP P.O. 231003175.

1.4 Purpose of this Geotechnical Baseline Report

Owner, Contractor and Designers have worked closely together during preparation of the construction contract documents developed for the excavation and initial support of the widened Eastbound Tunnel. During the course of the developing design, innumerable documents have been passed between the different parties discussing ground conditions that it was anticipated might be experienced during excavation and initial support. The purpose of this GBR is to summarize and set the baseline for the anticipated ground conditions, so that in the event that unanticipated conditions are encountered during the construction, the cost and schedule impacts, if any, can be evaluated fairly and allocated to the responsible parties.

2 Geologic Setting

In the vicinity of the Twin Tunnels, bedrock is composed of metamorphic felsic gneiss, biotite gneiss, and hornblende gneiss. Felsic gneiss is fine-to medium-grained, light gray, tan, or pink and contains quartz, oligoclase, microcline, and colorless biotite. These units are interlayered on a scale ranging from about an inch to 30 feet or more.

The rock is well foliated and trends at a regional strike of about 105 degrees (azimuth with respect to North) with a dip ranging from 35 to 65 degrees to the northeast. Locally, variations in the orientation in the rock structure are attributed to the numerous folds and minor faults along the corridor. Igneous intrusions of pink granite and pegmatite occur at various locations along the corridor.

According to mapping conducted for the north (westbound) tunnel pilot bore for the Twin Tunnels (Colorado Department of Highways, 1959), the rock encountered within the first 200 feet of the tunnel from the west and approximately the first 500 feet of the tunnel from the east consisted of weathered schist to schistose gneiss. The strike of the foliation was mapped as 65 degrees with a dip ranging from 60 to 70 degrees to the north. Two possible fault zones were mapped by Colorado Department of Highways (CDOH) in this area, one with a strike of 100 degrees and the other with a strike of 145 degrees. The remaining 500 feet of rock to the east was mapped as felsic gneiss to schistose gneiss with a foliation strike of approximately 75 degrees and a dip ranging from 31 to 61 degrees to the north.

One of the possible fault zones identified during the original Twin Tunnels construction may be exposed at the surface above the west portals. Previous mapping indicated that a zone containing fault gouge, soft seams, platy crushed rock and some veins of pyrite was encountered in the first 100 to 150 feet of the tunnels. Recent mapping above the west portals has confirmed that a zone of weaker mineralized rock is present in the area. The mineralized zone appears to continue along a plane striking approximately northeast and dipping to the northwest and was exposed in the area of the power line tower.

Three systematic joint sets were noted in the rock mass comprising the Twin Tunnels host rock. Discontinuities (joints and fractures) observed in the tunnel core samples and in televiewer borehole images show a moderate to high spacing frequency depending on location within the tunnel. The intensity of the discontinuities with respect to position in the tunnel has limited predictability. Generally the quality of the rock improves from west to east, as indicated by the Q and RMR values. The area around the west portal is lower quality than the rock comprising the east portal. The rock encountered during the investigation was highly variable in terms of the degree of observed discontinuities and in terms of the local orientation of the foliation. The thickness of biotite bands parallel to the foliation also showed significant variation from location to location.

Further geological and geomechanical information can be found in the Final Geotechnical Data Report – CDOT I-70 Twin Tunnels Widening Project, December 31st 2012 (GDR).

3 Previous Construction Experience.

This section summarizes the construction of the original tunnels and documents relevant ground behavior and groundwater information observed during that original construction

A geologic reconnaissance of the tunnel area was performed by Colorado Department of Highways (CDOH) between August and October of 1958. A pilot bore was completed the summer of 1959, and the following December it was geologically mapped by CDOH. As described in the 1959 map, the “mica schist and gneiss bedrock exhibits a distinct stratification dipping 30 to 45 degrees to the north, with joint planes intersecting this at right angles.” Bedrock was observed to be “quite sound” except for the west portal where possible “faulting” had resulted in “highly fractured, folded rock that exhibits fault gouge, ground to a clayey mass.”

An undated map of the pilot bore indicated the presence of flowing water and faults in the rock. The pilot bore followed the centerline of the north tunnel and was destroyed when the tunnel was further excavated. The map indicates that approximately 100 feet east from the west portal water seepage from the roof was estimated at “1 to 2 gallons per minute.” Further east into the tunnel, water was estimated coming out of the base of the north wall at 1 gallon per minute. The documents indicates the water flowing out of the tunnel contained very little acidity or presence of sulfates as tested by CDOH.

A geologic map, complete with plan and cross section, was developed circa 1960, after investigation of the outcrop and surrounding area. The entire bedrock outcrop was mapped as quartz-monzonite gneiss transected by a single large mineralized vein. A high tension tower shown at the top of this vein is still present and is a reliable reference point. The vein was mapped as dipping toward the tunnel alignment at 70 degrees from horizontal, but it was not mapped in its entirety. There was a large talus slope shown covering the entire west portal area and part of the slope above. Some pegmatites were mapped above the talus slope.

There are eight photographs of the tunnel construction showing the north tunnel and pilot bore looking east, the east portal of the south tunnel prior to the concrete facing and six views of the south tunnel. Photographs taken inside both tunnels show steel sets with extensive wood blocking between steel and rock. There are eight black and white photographs of the tunnel showing various stages of construction. One photo is of the pilot bore through the north tunnel, looking east. The pilot bore is free standing and does not have any timbers or supports visible. One photo is of both north and south tunnel construction entrances, looking to the west. Both tunnels have steel sets extending out and tied into the rock face.

The remaining six photos show the interior of the south tunnel, taken facing both east and west. Photographs of the tunnel interior also show vertical steel sets stabilized by collar braces made from horizontal threaded bar and wood spacers. An extensive amount of wood cribbing is visible between the steel sets and rock surface. The floor of the tunnel appears damp in some areas. The origin of this dampness is unknown.

Detailed information related to the visual evaluation of the liner is presented in the Existing Conditions Report of the Interstate 70 Twin Tunnels (Parsons Transportation, 2012)

According to the as-built drawings of the twin tunnels (circa 1961) that are available as part of the historical documentation, steel arch sets were placed at 3 to 5 foot intervals through large parts of the tunnel though not continuously throughout. The recent ground penetrating radar (GPR) survey of the tunnel liner (Eastbound and Westbound Twin Tunnels Liner Investigation Report, Yeh & Associates, December 11' 2012), however, indicates that sets at this spacing were used the entire length of the tunnel. It should be anticipated that for the full length of the tunnel, any holes drilled through the existing lining and parallel to the existing tunnel may encounter steel elements embedded in the lining and rock including steel ribs, steel angles used as collar braces, and rock bolts. As-built Sheet 2 for the original construction (Project I-70-3 (2) 251) indicates 10"x 8" WF 39 lb/ft steel sets on 4-ft centers with 4" angle spreaders at 6 ft maximum spacing. Reinforcing steel within the concrete lining consists of longitudinal #5 rebar at 18 inches, and transverse reinforcement #6 at 8 inch spacing.

For baseline purposes, assume that 131 steel sets and associated steel collar braces will be encountered over the entire length of the Eastbound tunnel, with miscellaneous steel reinforcement, timber cribbing and lagging, and rock bolts placed radially from between the steel sets.

4 Surface Cuts to Establish Portals for Tunneling

4.1 West Portal Area

The area surrounding the west portal is steep and high with bedrock exposure on the north side of the proposed tunnel becoming less steep and covered with talus south of the tunnel. Unlike the east portal area where the position of the turn under point is well defined by the topography, the west portal turn under point will be established based on inspection and mapping as part of the initial slope stabilization and grading. For purposes of this GBR, plan preparation and quantity estimates, the west portal turn under point has been established at Sta. 142+30 based on analysis of visual inspection, drilling and seismic data.

An interpolation of seismic and visual data has been used to generate bedrock contours for those areas to the south of the center-line of the new tunnel which are covered by talus or scree at the western end of the tunnel. The talus stretches from the projected turn under point a few hundred feet up the slope and while this does not impact tunnel performance it creates a tunnel construction need that the upper part of talus slope be temporarily shored while the lower part of the slope is excavated to bedrock to allow portal establishment at the turn-under.

Since the thickness of bedrock over the brow of the excavation at the turn-under appears to be thicker and steeper over the north side of the tunnel and may be considerably thinner and less steep over the south side of the heading it is concluded that slope reinforcement in the form of soil nails, rock dowels and shotcrete will be required to stabilize cut slopes within and surrounding the excavation limits of the portal. Rock reinforcement effectiveness will depend on the thickness of the rock brow available.

Excavations made in the area of the west portal under Contract Package 1B identified timber and steel members that had been placed above and outside the steel sets installed as support of excavation for the original eastbound tunnel construction. At the west portal and extending to the East within the limits of the tunnel to be supported with steel sets and shotcrete (Support Class TT-P), it is expected that the gneiss over the existing tunnel will be extremely weathered. The liner and initial support from the existing tunnel can be expected to contain wood lagging and various forms of steel bars or rail used as lagging or forepoles. Based on the material encountered, it is assumed that the wood cribbing and lagging encountered will be almost completely deteriorated.

For baseline purposes, this condition will be considered to extend over the original tunnel excavations for the length of the new tunnel construction in Ground Class TTP at the west portal where steel sets are to be installed, and will have to be removed in the course of the tunnel excavation.

Further information is presented in the Portal Grading and Portal Development subset of the Twin Tunnel Construction Package 1B drawings and in the geotechnical memorandum “Final West Portal Subsurface Investigation and Portal Turn-Under Locations, Yeh and Associates,” November 26, 2012.

4.2 East Portal Area:

The existing east portal rock face will be extended southward requiring a cut into the rock to the south of the existing tunnel portal. The gneissic rock at this location is strongly foliated and discontinuities that follow this plane dip at approximately 55 degrees into the road cut. This angle dictates the most reasonable angle for the slope cut in order to control planar rock failures which are the most prevalent failure type at this specific location. Where transitions between slope angles occur or where existing blocks of rock must be stabilized rock reinforcement such as rock bolting will be required. This information is presented in the Portal Grading and Portal Development subset of the Twin Tunnel Construction Package 1B drawings and in the geotechnical memorandum “Final West Portal Subsurface Investigation and Portal Turn-Under Locations, Yeh and Associates,” November 26, 2012..

The turn-under face will likely parallel a large discontinuity which is overhung slightly, requiring the rock face immediately surrounding the entry to be stabilized using rock reinforcement such as rock dowels and spiles. This would also apply to any other wedges or blocks of rock at the turn-under face location deemed to require support.

5 Baseline Conditions and Anticipated Behavior during Construction

5.1 Portal Baseline Conditions and Excavation Support

The rock-cover interface and supporting information as determined from borings, as-built drawings and field observation are presented in the following tables. Estimated turn-under points for both east and west portal establishment are presented here.

5.1.1 West Portal

Based on discussion at the November 26, 2012 project meeting it was concluded that an "average" west portal turn-under point at station 142+30 would be used for planning and quantity purposes with the understanding that the actual position will be based on the talus and bedrock conditions encountered as the portal slopes are established.

The turn-under may be skewed from northwest to southeast with respect to the axis of the tunnel. The degree of skew is not clear but estimated bedrock profiles largely interpreted from seismic survey information indicate that the southern edge of the portal may be laterally offset with respect to the northern edge by a distance of approximately 10 feet to possibly 20 feet. Bedrock cover over the southern extent of the tunnel portal is likely to be thinner than that over the northern extent.

For **baseline** purposes, the turn-under point at the West Portal shall be considered at station 142+30 at the centerline of the enlarged tunnel. The actual face may be slightly west at the northern edge and slightly east at the southern end.

5.1.2 East Portal

The portal data at the east portal show less range than those for the west portal and an "average" east portal value of 148+65 is selected with the understanding there may be slight (1 to 5 foot) variations in this position. The rock face is slightly skewed with respect to the longitudinal axis of the proposed tunnel. For **baseline** purposes, the turnunder point for the East Portal will be considered at station 148+65

5.2 Tunnel Baseline Conditions and Ground Support

The following information is a summary of the conditions expected for the enlargement/excavation of the Eastbound tunnel and is intended to be read and applied in conjunction with the Contract Package 2 specifications and plans.

5.2.1 Ground Support

Recommended initial support systems for the expected range of ground conditions are depicted in Contract Drawings T9 through T14 and further summarized and described below in Table 1.

Table 1 Initial Ground Support Systems – By Ground Class

Ground Class	Ground Description	Initial Support System
TT1	TT1: Typically fresh, intact, dark gray gneiss with a joint/fracture spacing in excess of 6 feet. Joints/fractures are very widely spaced, with very widely spaced clusters of very closely to closely spaced fractures. Slickensided fractures are rare. Mineralization along joints/fractures is rare and few in-filled joints/fractures are observed. Joint surfaces range from planar, rough and irregular, undulating, smooth; to undulating, rough or irregular Stand-up time is expected to be good to moderately good with minimal raveling except in the localized zones of severe fracturing.	Excavation will be sequenced in two headings; the first over the existing tunnel and the second comprising the remainder of the tunnel towards the south. In each heading, a maximum round length of 15 feet is recommended. Initial support in this class before placement of final lining will consist of welded wire fabric installed above springline and pattern dowels. The rock in the center pillar (north sidewall) will also be stabilized by dowels placed ahead of existing lining demolition. Spot bolts and mine straps should be used to anchor loose blocks in localized areas and to stabilize all temporary sidewalls and faces. Flashcrete should be applied as necessary, to control localized raveling in the temporary sidewalls. Within the predominant TT1 zone, sporadic TT2 zones are expected. To address this expected condition, the indicated excavation line for TT1 is the same as is required for TT2, which utilizes shotcrete.

Ground Class	Ground Description	Initial Support System
TT2	Typically slightly weathered gray gneiss and light gray to white pegmatite with a joint spacing from 2 to 6 feet. Shear/fault planes, joint/fracture weathering, and alteration products are typical for this rock class. Open, in-filled and slickensided fractures are present. Observed shear/fault planes may contain disintegrated rock between rock surfaces, with a thickness of alteration products generally less than 6 inches. The rock mass contains distinct sub-domains of lower quality rock characterized by clusters of very closely to closely spaced fractures and persistent, steep, in-filled fractures. There will be zones that exhibit raveling and moderate stand-up times.	Similar to TT1 ground, excavation will be sequenced in two headings. However, unsupported spans and round lengths will be limited to 10 feet. Ground support system recommended for TT2 consists of two layers of fiber reinforced shotcrete with pattern dowels placed after and through the first layer. The center pillar will also be reinforced by dowels before the demolition of the existing lining. Spot bolts, mine straps, flashcrete or combinations of any shall be used as means of stabilizing loose blocks, localized raveling of the excavation surface including temporary excavation surfaces such as sidewalls and heading faces.
TT3	Typically moderately weathered Light gray pegmatite and dark gray gneiss with a joint/fracture spacing of less than 2 feet, or multiple and random joint/fracture sets with smooth or slickensided surfaces, irrespective of joint/fracture spacing, or multiple zones of brecciated and heavily fractured rock with clay or disintegrated between rock surfaces, or one or more shear/fault planes with a filling thickness greater than 6 inches where stand-up time over the limits of each phase of the excavation sequence is limited.	Since stand-up time will be short in TT3 ground, cement or resin grouted spiles above springline are to be installed from previous rounds of excavations before excavating TT3 ground. After spiles are in place, unsupported spans and round length will be limited to a maximum of 5 feet. The face is divided into three major headings as shown on the Contract Drawings. If on occasion the excavation face or sidewall is determined to be unstable, then a bench or face berm shall be left in place to be removed in an Excavation Sequence IV as indicated in Drawings T8 and T14. For baseline purposes, 50% of the length of tunnel classified as TT-3 will be considered to require a bench or berm. Ground support system recommended for TT3 consists of two layers of fiber reinforced shotcrete with pattern dowels placed through rolled steel channel ribs after the first layer shotcrete. The channel sections must be secured by the dowels. A second layer of shotcrete is also required to provide sufficient arch support in this ground. Spiles are

Ground Class	Ground Description	Initial Support System
		required to be placed after every other array of dowels and steel channels before advancing headings. In TT3 ground, stabilizing the temporary excavation surfaces (sides and face, if required) between headings is equally important as supporting the final excavation surface. Therefore, liberal application of flashcrete in combination with spot bolts and straps is recommended on the temporary excavation surfaces.
TT2S	The TT2S classification is for the condition expected in the western part of the drive where a zone of the weaker TT3 conditions transects the axis of the tunnel at an oblique angle. The TT3 conditions are expected to be first exposed on the north rib and progressively increase as the tunnel is driven from the west.	As in TT2, the excavation will be driven in two headings: Heading I will be supported in the manner of TT3 and Heading II will be supported in the manner of TT2. Once the poorer TT3 conditions are exposed in the northern half of the total span, the ground support system will change to TT3.
TTP	Support Class TTP is defined for conditions at the portals where the rock cover is low and where the tunneling operations will turn under and begin mined excavation.	Initial support for Ground Class TTP consists of steel sets with shotcrete lagging and cement-grouted spiles placed from the face before turning-under to provide standup time for removal of the lining and enlargement to the full width. The recommended excavation sequence for TTP is two full-height headings and a 4 to 5 foot round length coinciding with the indicated spacing of the steel sets. Spot bolts and flashcrete are required to support the face once excavation is beyond temporary soil nails or dowels that are placed to establish the initial portal cut.

5.2.2 Baseline Conditions and Distribution of Support Classes

For baseline purposes, Table 2 describes the anticipated conditions and support classes along the length of the eastbound tunnel between the assumed turn under points at each portal.

Table 2 Anticipated Conditions and Baseline Limits by Ground Class

Station Limits	Condition	Assigned Ground Class
142+30 - 142+50	West Portal turn-under point. Thin rock cover and portal face that is skewed to the tunnel axis are expected. Close joint spacing and zones of extremely weathered rock are expected. Further, significant quantities of decomposed wood lagging and cribbing and corroded steel rod and rail placed as forepoles during original tunnel construction may be expected over the existing tunnel.	TTP
142+50 - 142+80	Rock cover is expected to thicken sufficient for use of dowels and fiber reinforced shotcrete for the support of the arch.	TT2
142+80 - 143+40	A zone of weaker, intensely fractured ground is expected to be first exposed on the north rib as the existing lining is removed in the drive from the west portal. This zone will intersect with the axis of the tunnel at an oblique angle. As the lining is removed and the tunnel is advanced towards the east more of the face and roof will be composed of the intensely fractured rock mass. As this fractured material is encountered, fiber reinforced shotcrete and pattern dowels placed through steel channels (as used in TT3) bearing on the remaining portion of wall and extending over the width of Heading I is prescribed to support the fractured material.	TT2S
143+40 - 144+00	The fractured material is expected to extend over half the total width of the tunnel. At this point the shotcrete, steel channel and dowel pattern shall be extended over the entire arch and sidewall for support.	TT3
144+00 - 144+20	The fracturing of the rock is expected to decrease to the point where the steel channel is no longer required to support the arch. Dowels and fiber reinforced shotcrete will be required	TT2
144+20 - 145+30	Fracturing and joint spacing of the rock mass is expected to continue to improve to allow for the use of dowels and wire mesh for the support of the arch.	TT1
145+30 - 145+50	A zone of more fractured material is expected to be exposed along the south rib and roof. Fiber reinforced shotcrete and dowels will be needed for support.	TT2
145+50 - 148+40	The fractures in the rock mass are expected to be reduced to where the use of shotcrete is no longer necessary; returning to wire mesh and pattern dowels.	TT1

Station Limits	Condition	Assigned Ground Class
148+40 - 148+50	Some additional fracturing near the portal is expected, which will require the use of fiber shotcrete in addition to the dowels for support.	TT2
148+50 - 148+65	At the portal turn-under point at 148+65, steel sets, shotcrete and cement grouted spiles placed above the excavation line across the arch are to be used for ground support.	TTP

5.2.3 Anticipated Contamination

During the Environmental Site Assessment conducted for this Project *[Reference Section 1.3) of this GBR]* an assessment was made of three forms of possible contamination:

(a) Groundwater: Groundwater discharging from the two tunnel under-drains into the box culvert immediately east of the Twin Tunnels was sampled and tested. The tests indicated that this water contained concentrations of metals, including arsenic, iron, lead, manganese and selenium that slightly exceed surface water-quality standards. No evidence was identified that these detections were the result of mine activities and they were considered likely the result of natural processes. For baseline purposes, it is to be assumed that groundwater will not require treatment for metal contamination.

(b) Rock Contamination: One outcrop (above the west portal of the eastbound tunnel), and three rock-core samples (from the horizontal boring drilled on the south side of the eastbound tunnel) were collected for chemical analysis. The results of all analysis did not indicate that the materials were contaminated in concentrations of metals that exceed State or Federal environmental action limits. For baseline purposes, it is to be assumed rock from the tunnel excavation and from excavations of the outcrops will not require handling or disposal in accordance with regulations for materials contaminated with concentrations of metals that exceed State or Federal environmental action limits.

(c) Toxic Gas: No information on the possible presence of toxic gas was obtained during the Environmental Assessment. For baseline purposes, it shall be considered that toxic gases are not present in the rock formations at the Project location.

5.3 Overbreak

In determining the volumes of rock to be excavated in tunnel lengths within each of the different Ground Classes, the Contract Drawings define an Excavation Line outside the Design Line which allows clearance for the different elements of the required initial ground support to be installed outside the Final Lining. It is acknowledged that the Contractor must nominally increase the size of the planned excavation to assure that this clearance for the initial ground support for the tunnel arch and sidewall excavations is universally achieved, and a Contractual Overbreak Line has been indicated on Contract Drawing Tunnel CP2 Sheet T3 to recognize this fact. However, under the terms of the Contract which include agreements between Owner and Contractor defined in the Risk Register, all overbreak volumes outside the Excavation Line will be measured, including for the tunnel invert excavation, and compensation for any additional excavation, and additional shotcrete and concrete will be made based on the terms of the Risk Register Agreement included by reference in Section 109 of the Specifications, which recognizes the fact that a proportion of the overbreak will be the responsibility of the Owner due to the precondition of blast damage to the rock during excavation for the original tunnel construction. Smoothwall blasting techniques as required in the Specifications are to be employed and adjusted as needed to suit changes in ground conditions so as to minimize overbreak volumes and preserve the integrity existing strength of the natural rock arch.

6 Instrumentation

Contract plans require the installation of several forms of instrumentation to monitor the effects of the Eastbound tunnel excavation on the Westbound tunnel and to confirm the adequacy of initial ground support measures placed for the Eastbound tunnel widening.

Instrumentation to be installed in the Westbound tunnel under Package 1B consists of optical survey targets on the tunnel lining, multipoint borehole extensometers in the pillar between the tunnels, and crackmeters on selected cracks, all to be remotely monitored with a datalogger. Details of the proposed system are described in Draft Geotechnical Instrumentation Plan - West Bound Tunnel, CDOT I-70 Twin Tunnel Widening Project, Yeh and Associates, September 7, 2012. In addition to these instruments, three geophones (or seismographs) are required to be installed in the westbound tunnel by the Contractor to monitor blasting vibrations.

Instrumentation for the Eastbound tunnel consists of optical survey targets to be installed at the approximate locations indicated in the plans as the headings are advanced. These optical targets will be read regularly using a manual or automated total station and will serve as the principal method by which ground deformations will be measured to confirm stable conditions are achieved and maintained and the adequacy of the levels of initial support installed. Continued convergence or increased rates of convergence shall be viewed as signs for caution and that additional support measures are required immediately.

7 Groundwater

Groundwater inflows were reported during the construction of the original tunnels but no groundwater flows were observed in any of the geotechnical borings at the time of drilling. No flowing water was observed in the south tunnel at the time of exploration. During the winter exploration, ice formations were observed in two locations approximately one foot above the top of the barricade of the north wall of the north tunnel, near the west portal. The ice was apparently formed by water seeping out of tunnel liner joints, and formed 6-inch to 12-inch thick ice blocks. Water leaching out of rock into the space between the rock mass and the interior of the concrete liner void at the west end of the tunnel was frozen. Two informal water samples which were obtained from penetrations through the crown of the concrete liner gave a measured pH of 8 or slightly higher.

The tunnel rock mass is a fundamentally dry, fractured, free-draining material, with no apparent springs or permanent water sources. Ground water flows appear to be ephemeral, related to topography and precipitation events. Mapping initially performed in the pilot tunnel of the north (current westbound tunnel) indicated that approximately 100 feet east from the west portal, water seepage from the roof was estimated at 1 to 2 gallons per minute. Further east into the tunnel water was estimated coming out of the base of the north wall at 1 gallon per minute. These values would have been dependent on the amount of local precipitation transiting the rock mass at the time of the observations and probably do not represent the maximum flow. A probable maximum flow through the rock mass inside the tunnel is difficult to estimate but 20-30 gallons per minute seems a reasonable value.

A maximum cumulative inflow into the Eastbound tunnel of 80 gallons per minute shall be assumed for baseline purposes.

8 Impacts on Westbound Tunnel

Provided that the Contractor is following ***all provisions of the Contract*** in blasting, excavating and supporting the widened Eastbound Tunnel, any resulting damage to the adjacent Westbound Tunnel will be presumed to be due to a pre-existing condition and will be the responsibility of the Owner.

Any need to reduce blasting vibrations in the Westbound tunnel lining below contractually allowed limits due to an actual or perceived risk of damage to the Westbound tunnel lining, and which results in a reduction in the rate of Eastbound tunnel excavation-advance from that contractually allowed, will be compensated under the terms of the Agreement established in the Risk Register.

-------------- End of Geotechnical Baseline Report -----------