ATTACHMENT E – TUNNEL DESIGN MEMORANDUM

SR-12 REALIGNMENT/RIO VISTA PRELIMINARY BRIDGE STUDY

TUNNEL OPTION

DESIGN MEMORANDUM

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ABBREVIATIONS

AASHTO	American Association of State Highway Transportation Officials
ADT	Average Daily Traffic
ANSI	American National Standards Institute
APS	Advance Planning Study
CALTRANS	California Department of Transportation
CD	Candela (a measure of luminous intensity)
DHV	Design Hourly Volume
FEE	The Functional Evaluation Earthquake
FHWA	Federal Highway Administration
GPM	Gallons Per Minute
HPS	High Pressure Sodium
IESNA	Illuminating Engineering Society of North America
KV	Kilovolt
KW	Kilowatt
LPS	Low Pressure Sodium
M	Moment magnitude
MH	Metal Halide
MW	Megawatt
NFPA	National Fire Protection Association
OGS	Original Ground Surface
PIARC	World Road Association
SR	State Route
SEE	Safety Evaluation Earthquake
V	Volt

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EXECUTIVE SUMMARY

Several options are being investigated for a permanent replacement of the existing Sacramento River Bridge on State Route (SR) 12 between Rio Vista and Brannan Island. The purpose of this study is to evaluate a tunnel option on an alignment parallel to and north of the existing SR12 Bridge.

The proposed tunnel is a twin-bore with one-direction of traffic in each bore. There are two 12-foot wide travel lanes in each direction, plus shoulders. The resulting clearance envelope measures 28.5 feet in width and 16.5 feet in height. The tunnel size used as a basis for this study has a 35-foot internal diameter to be excavated by an approximately 40 foot diameter Tunnel Boring Machine (TBM). Walkway space along the sidewalls and space above the roadway for lights, ventilation fans and signs is available due to the curvature of the circular tunnel section.

This design memorandum summarizes the results of the tunnel study including anticipated geologic conditions, design criteria, constructability evaluation, discussion of various tunnel system components required to satisfy operations and fire/life safety requirements. The basis for the cost and schedule estimates are also described. Drawing sheets for the tunnel plan, profile and cross section are included in Appendix A. The estimate of likely construction cost is provided in Appendix B. This study was performed prior to any geotechnical borings being completed along the proposed alignment. The current understanding of geologic site conditions is based in part on the information from the existing bridge dating back to the 1950s. Table summarizes pertinent findings of this study.

Table ES-1 Summary of Findings

Bored Twin Tunnel Alignment Length	5740 feet
Ventilation Assumed for Estimate	Longitudinal Ventilation with Jet Fans
Number of Cross Passages	8
Construction Duration	53-59 months
ESTIMATED COSTS	
Contractor Overhead-related Direct Costs	$41.6 Million
Mobilization	$48.7 Million
Bored Tunnels	$229.2 Million
Cross Passages	$26.8 Million
Portal Excavation and Structures	$97.5 Million
Tunnel Civil	$20.3 Million
Electrical, Mechanical Systems	$26.5 Million
Brannan Island Containment Cell	$45.4 Million
Subtotal Base Cost	$ 536.0 million
Contingency (50%)	$268.0 million
Likely Cost with Contingency	$803.9 million

The facility will require utility hook-ups for power, water and communications. These utility hook-ups are not included in the estimated costs.

Operating costs are dependent on assumptions about the supervision and maintenance of the tunnel, and the extent to which existing facilities can be used and shared. It is assumed that maintenance can be managed by a facility co-located at the existing Caltrans facility at the Antioch Bridge Toll Plaza, about 11.3 miles from the project; however, some limited systems and services are proposed for the tunnel so

operations could be based at the tunnel if and when required. Fire and life safety systems allowed for in the current estimate are based on the National Fire Protection Association (NFPA) 502 Standards and a number of other design guidelines and standards summarized in the design criteria section of this memo. Ultimately, the local fire department and other agencies will influence what is provided.

1 INTRODUCTION

This design memorandum has been prepared by Hatch Mott MacDonald (HMM) under an agreement with Lim and Nascimento Engineering Corporation (now AECOM), effective September 15, 2007, to evaluate a tunnel option for a preliminary bridge study for replacement of the Sacramento River Bridge on State Route (SR) 12 between Rio Vista and Brannan Island. The existing lift bridge was built in the 1950s and has reached the end of its useful life. The project location is shown in Figure 1-1.

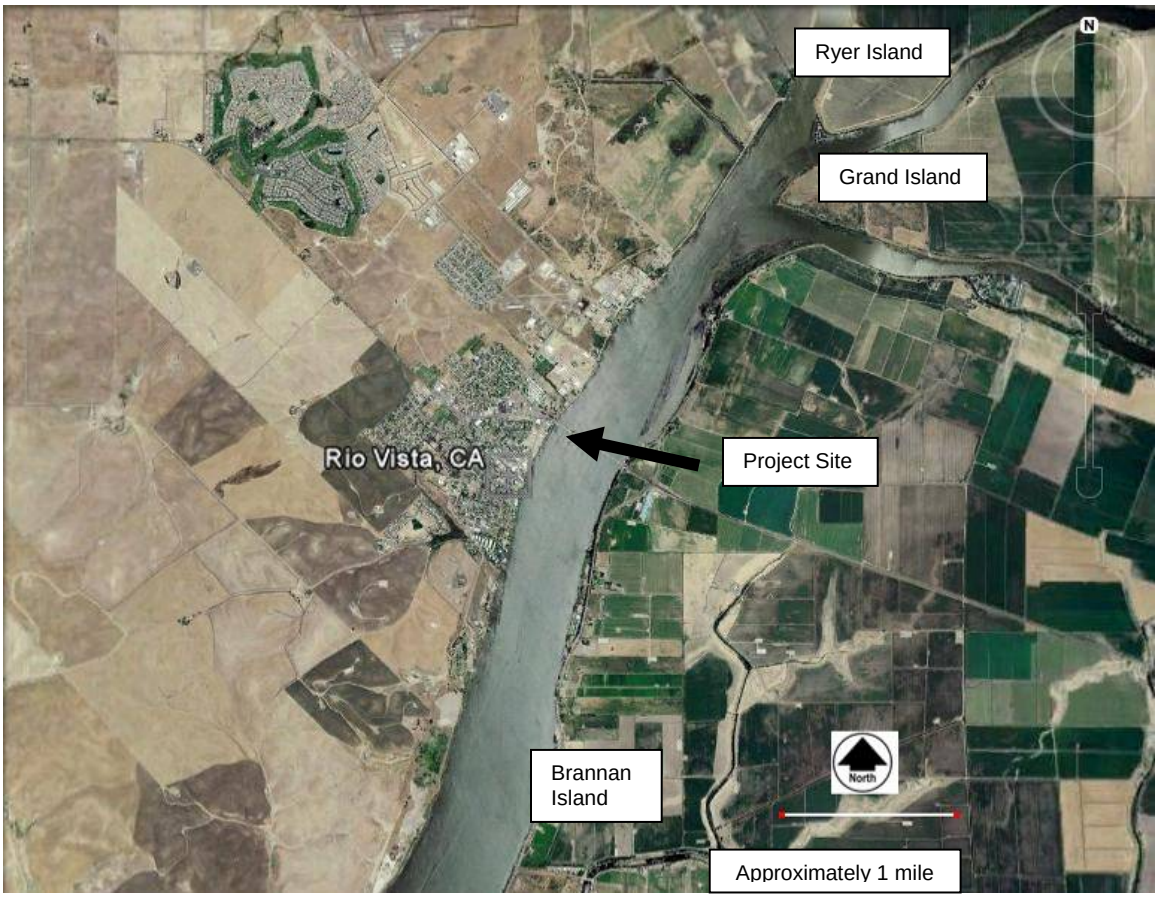


Figure 1-1 Project Location

1.1 Tunnel Description

The tunnel option will realign the highway for a length of approximately two miles parallel to and north of the existing bridge. This alternative includes retained cuts at the portals, and the possible need for a containment cell around the Brannan Island portal for flood protection. The underground portion will consist of twin bores linked with 8 cross passages for emergency egress. The alignment is shown in the Drawing Sheets in Appendix A. The project can be built parallel to SR 12 with minimal disruption or detour except during construction of the tie-ins themselves. The tunnel option will be designed to current Highway Design Manual new construction standards with the possible exception of shoulder width. The currently proposed tunnel option includes two 12-foot lanes each way and shoulder widths of 2 and 2.5 feet. Removal of the permanent bridges once traffic is routed onto the new realignment is not included in this study.

1.2 Scope of Study and Report

Development of the tunnel concept included the following considerations:

- Staging tunnel boring operations from the Rio Vista side to avoid the need for a containment berm on the working portal excavation so that spoil can be used to create the containment berm on the Brannan Island side.
- Using large diameter pressurized face tunnel boring machine (TBM) like the one shown in Figure 1-2 to excavate and line the tunnels with gasketed pre-cast concrete segments.
- TBMs launched and received in large sloping portal cuts that extend up to 65 feet below grade on land adjacent to the river crossing. Portal cuts partially backfilled with cut and cover segments of tunnel to reduce the depth of permanent structures at portals.
- On-site disposal of spoil on Brannan Island including use of spoil to create containment berm.
- Staging, scheduling and cost estimating developed considering environmental concerns associated with construction, disposal of excavated material, potential working season restrictions.
- An allowance for mechanical, electrical and transportation systems are included in the estimate to address operations, traffic management and fire/life safety requirements.

Figure 1-2 TBM for the Fourth Tube of the River Elbe Crossing, Germany (47 ft Dia)

2 BACKGROUND INFORMATION

2.1 Information Supplied

The following information supplied to HMM has been used in this study:

- Lane, shoulder and walkway configuration for tunnel cross-section, prepared by LAN/AECOM
- Alignment and profile option, prepared by LAN/AECOM
- Preliminary Geotechnical Memorandum, February, 2008, prepared by Taber Consultants.
- SR12 Realignment / Rio Vista Bridge Preliminary Hydraulics, October 23, 2009, prepared by WRECO.
- Caltrans as-built drawings and log of test borings for existing bridge

2.2 Geology And Geotechnical Conditions

The following is a brief summary of site geologic conditions. For more information, refer to the geotechnical report from Taber Consultants. For project elements located west of the Sacramento River and west of downtown Rio Vista, soils may be generally characterized as compact-very stiff gavel, sand, silt and clay. Locally along channels and flat areas, some soft-stiff clay and/or loose sand/gravel may be present to shallow depth.

At/near the west approach to the existing bridge in Rio Vista, there is as much as 30-40±ft of peaty soils overlying more competent “mineral” soils (sand/silt/clay). The thickness of the peat soils is expected to thin to the west and south with increasing distance from the axis of a buried tributary channel.

In the river, a characteristic profile (based on exploration by Caltrans for the existing bridge) consists of mud and loose sand to elev.-55±ft (30±ft below low channel grade) underlain by compact-very stiff sand and clay to elev.-90±, in turn underlain by very dense sand and very hard clay (to maximum depth of Caltrans exploration = elev.-110±). Mud and loose sand above elev.-55 are interpreted as very recent alluvium/bedload; they are potentially subject to scour and are not considered suitable or reliable for supporting any structure foundation loads.

East of the Sacramento River, a typical soils profile is expected to consist of 15- 25±ft of weak, compressible peaty soils overlying another 5-10±ft of soft clay grading downward to compact-dense sand and/or very stiff-hard clay. Peat soils are very weak and highly compressible, although a shallow “crust” (say, 2-3±ft thick) is common at the surface owing to oxidation and desiccation of the organic soil. Soft clay immediately below the peat is expected to be at least moderately compressible and to have limited shear strength. Peaty soils and soft clays have been noted to extend as far as 35-40± below existing grade at the time of investigation; some areas may have deeper compressible soil profiles.

2.3 Design Criteria and Requirements

2.3.1 Applicable Standards and Guidelines

The following design standards and guidelines are applicable:

- Caltrans Design Standard for Fire Protection and Ventilation of Vehicular Tunnels and Elevated Bridges, issued by Division of Engineering Services-Structures Design Services & Earthquake Engineering, Office of Electrical, Mechanical, Water & Wastewater Engineering, May 16, 2005
- Caltrans Design Information Bulletin 82 Pedestrian Accessibility Guidelines for Highway Projects September 7, 2001
- NFPA 502 *Standard for Road Tunnels, Bridges, and Other Limited Access Highways* 2004 Edition
- ANSI/IESNA RP-22-05 American National Practice for Tunnel Lighting
- IESNA *Lighting Handbook*
- AASHTO publication *An Information Guide for Roadway Lighting*
- FHWA publication *Tunnel Lighting Design and Procedures*
- Title 23 of the California Code of Regulations pertaining to flood protection

2.3.2 Seismic Design Criteria

The nearest major, capable/active faults (per CDMG OFR 92-01 and 92-03) are indicated to be the Antioch fault located 12±miles southwesterly and the coast Range- Sierra Nevada Block Boundary seismic source zone located about 8-miles southwesterly. The Midland fault is also shown on published mapping (USGS OFR 82-737) to cross beneath SR-12 1.6±miles east of the Sacramento River crossing. The Midland fault is a suspected potentially active fault.

While the project area is considered susceptible to significant ground shaking from events on nearby faults, it is not in an Alquist-Priolo Special Study Zone and the potential for fault-rupture is considered remote. Secondary seismic effects typically associated with loose/weak sands/fills are liquefaction, rapid densification, lateral spreading and ground lurching.

There are no historical records of damage resulting from earthquakes in Rio Vista. However, historic ground failure associated with the 1906 San Francisco Earthquake has been recorded to have occurred at locations west and southeast of the current location of the Rio Vista river crossings. Approximately 19 miles west of the existing river crossing, ground settlement of up to 11±ft was recorded/observed along the Southern Pacific Rail Road tracks. Ground settlement and lateral spreading of up to 3±ft was experienced 20± miles southeast at the Santa Fe Rail Road Bridge across the Middle River between Point Richmond and Stockton.

According to Taber Consultants, the existing bridge site is located approximately 7.6±miles (12.2±km) west of the Coast Ranges-Sierran Block Boundary Zone (CSB) fault; the style of this fault is listed as reverse including thrust (per Caltrans "California Seismic Hazard Map 1996" and accompanying technical report). A "peak bedrock acceleration" of 0.33 g can be assigned to this site, associated with a controlling event of 7.0 magnitude on this fault. Based on available boring data, the future bridge sites can likely be assigned a Soils Profile Type E or F, depending on future bridge location (per Table B.1, Caltrans "Seismic Design Criteria" (SDC) version 1.4).

Caltrans structure design practice requires certain increases in SDC response curves due to fault type and fault proximity. The near-field condition applies to this project and the 20% increase required for reverse

including thrust fault style. Based on the above information, structure design is recommended to be based on the following SDC parameters:

- Soil Type E or F
- Magnitude 7.0±0.25
- peak bedrock acceleration of 0.4 g

Other than the distortion and local instability of embankment/levee fills/slopes and potential for liquefaction in loose sands, the risk of secondary seismic effects appears low and is not considered to have a significant influence on cost or construction duration for the purpose of this study. Further study would be required to more closely define the above values or other site-seismicity characteristics.

3 MECHANICAL, ELECTRICAL AND TRANSPORTATION SYSTEMS

3.1 Civil-Roadway

The tunnel clearance envelope dimensions assumed for this study are shown in Appendix A. Traffic lanes are each 12-feet wide. The minimum vertical clearance over traffic lanes is 16.5 feet. The left shoulder and walkway provides longitudinal access to cross passages which are proposed to be located on approximately 650 foot centers.

3.2 Tunnel Waterproofing

For the bored tunnels, waterproofing will be provided by gaskets in the precast segmental lining as shown in Figure 3-1. Cross passageways will also be sealed with a membrane. Secondary grouting will be used to control leaks.

Figure 3-1 Gaskets in Precast Concrete Segments

3.3 Tunnel Drainage and Discharge

Tunnel drainage is provided to deal with two main sources of water:

- Highway run-off arising from "tracked-in" moisture, spillage and cleanup of spillage in the tunnel, washing down tunnel walls, and fire-fighting or testing of the fire-fighting facilities.

- Groundwater leakage inflows.

The tunnels will be a low point in the highway so there will be stormwater flow into the tunnels along the roadway. Grades of up to 6% and the 2% fall toward the curbs will provide sufficient surface drainage toward the central low points such that drain inlets and a highway drainage system inside the tunnels can collect the flows and either pump them out to a portal or to the river for discharge. The drainage systems will have to be designed with discharge points that will not freeze during the winter**.**

A recommended range of acceptable leakage, including cut-and-cover segments at the portals, is 10 to 100 gallons per minute (GPM) based on a typical allowable leakage criteria of 0.012 gallons per square foot of lining per day and an allowance for leakage from the portals. There is a possibility that seismic shaking could damage the seal on joints in the lining and allow leakage in excess of the acceptable leakage rate into the tunnel. The low-point pumping systems need sumps and a back-up power supply. It is recommended that the sump volume be accommodated within the precast segmental tunnel lining if possible to avoid the need for a tunnel enlargement. Initial inflows may pick up some alkalinity from the cementiteous grout, but this should soon stabilize to acceptable levels as the grout ages.

It is assumed that with minimal treatment, possibly just oil/water separators, all water inflows can be discharged to local water courses. However, it is recommended that the highway runoff portion can be retrofitted with additional treatment or a different discharge arrangement if requirements change in the future. Depending on the soap used for tunnel-washing or foam used for fire fighting operations, the drain water may or may not be routed to a holding tank prior to discharge. At present, no holding tank is included in the estimate.

3.4 Tunnel Finishes

The choice of tunnel finishes has a direct effect on lighting design and on maintenance requirements. Many modern tunnels adopt a system of light colored walls to improve lighting efficiency, with a dark colored ceiling. This minimizes the surface area requiring treatment and seems to help drivers feel comfortable and maintain lane position. The main options for surface finishes are:

- Paint or stain is applied directly to the permanent structural lining. This is the lowest cost option, and also requires no additional space within the structural cross section. However, the surface can deteriorate if water penetrates the tunnel lining or if the tunnel walls require frequent washing. Repainting may be necessary at intervals of 10 years or less if it is desired to maintain a good appearance. Painting has been used in the past for Caltrans tunnels including the Collier Tunnel on Route 199 and the Caldecott Bores 1 and 2 on SR 24. An example of a painted tunnel finish is shown in Figure 3-2.

- Tiles are applied to a grout bed directly on the permanent structural lining. A very small (about one inch) additional space is required within the structural cross section. Tiles can be cleaned readily, and stand up to repeated washing, though they may stain in areas of continuous water inflow. There may be concern about tiles in the tunnel crown over traffic lanes – tiles may become detached and fall. The effects of freezing conditions would have to be evaluated. The Caldecott Third Bore is an example of a tile finished as is the tunnel shown in Figure 3-3.

- Panel systems can comprise either vitreous enameled steel (durable but expensive) or plastic coated metals, supported on a stainless steel framework. Panel systems can be cleaned easily, and individual panels replaced if they become damaged. Any water inflows occur behind the panels so the finish appearance is not diminished. Significant additional space (4-inches or more) within the structural cross section is required to accommodate the panel support system, but this is often in the sidewall area where extra space is available due to the curvature of the arch. The panels are susceptible to impact damage. Panels are used above the roadway in the Caldecott Third Bore, and are specified for Caltrans Devil's Slide Tunnel on Highway 1. A tunnel with a panel finish is shown in Figure 3-4.

It is currently assumed that a panel system on the walls with an untreated ceiling that will go dark over time would be adopted. Lighting would be directed toward the roadway and reflective finish and away from the untreated ceiling. The possibility of either of the three options should be evaluated in detail in a future project phase.

Figure 3-2 Fresh Painted Tunnel, Slovakia on Left, Aged Paint in Tunnel (SR 199) on Right

Figure 3-3 The Tile Finish in the Baltimore Inner Harbor Tunnel, USA (above)

Figure 3-4 Panel Finish In Pen Y Clip Tunnel, Wales, UK (right)

3.5 Fire/Life Safety

NFPA 502, Standard for Road Tunnels, Bridges and Other Limited Access Highways, governs the Fire/life Safety requirements of the tunnels. The current addition of the Standard is dated 2008. Lighting is governed by ANSI/IESNA RP-22-05 American National Practice for Tunnel Lighting, the current edition is dated 2005. Extracts from NFPA 502 (2004) and ANSI/IESNA RP-22-05 summarized in Table 3-1 list the main design principles. The items listed in NFPA 502 should be considered in the design and may be required as part of maintenance and operation agreements between Local Agencies and Caltrans. These agreements go hand in hand with an Emergency Response Plan which is outlined in NFPA 502.

Table 3-1 – Fire/Life Safety Requirements

	Code Reference	Requirement	Comments
1	NFPA 502, 7.2 (2)	Where the tunnel length is 300 feet or greater, standpipe systems shall be installed.	This means a water supply must be developed
2	NFPA 502, 7.4.1.3	Automatic fire detection to identify fire location	Within 50 ft of fire
3	NFPA 502, 7.4.1	At least two systems to detect, identify, or locate a fire in a tunnel, including one manual means, shall be provided.	Fire alarm pull boxes and another form of sensor such as heat or smoke could constitute the two systems
4	NFPA 502, 7.4.1.1.1	Fire alarm boxes	Spaced at 300 ft, and at means of egress from the tunnel
5	NFPA 502, 7.4.1.2.1	CCTV	To be considered in the design. If used to satisfy 7.4.1, requires 24-hour observation
6	NFPA 502, 7.5.1	Wherever necessary for dependable and reliable communications, a separate radio network capable of two-way radio communication for fire department personnel to the fire department communication center shall be provided	The site may be suitable for a wireless communication link
7	NFPA 502, 7.6	Traffic Control	To be considered in the design.
8	NFPA 502, 7.6.1	Provide a means for stopping approaching traffic after activation of fire alarm in the tunnel.	Approaches shall be closed in such a manner that responding emergency vehicles are not impeded in transit to the fire site.
9	NFPA 502, 7.9	Portable fire extinguishers	Spacing 300 ft
10	NFPA 502, 7.12	Tunnel drainage system	Required so that spills of hazardous or flammable liquids cannot propagate along the length of the tunnel, however, no tunnel length or drain inlet spacing criteria are established
11	NFPA 502, 9	Standpipe and water supply	At portal and within the tunnel. Class 1
12	NFPA 502, 9.3	Fire Dept connections	As required
13	NFPA 502, 9.4.2	Hose connections	Spacing 150 ft

	Code Reference	Requirement	Comments
14	NFPA 502, 10	Ventilation during fire emergencies	Analysis would be carried out to determine fan size and spacing
15	NFPA 502, 10.2.2	The desired goal shall be to provide an evacuation path for motorists and to facilitate fire-fighting operations	
16	NFPA 502, 10.2.3	In tunnels with bi-directional traffic, where motorists can be on both sides of the fire site, smoke stratification shall not be disturbed, longitudinal air velocity shall be kept to low magnitudes smoke extraction shall be considered	Twin tunnel configuration avoids the need for bi-directional traffic. Longitudinal ventilation with jet fans proposed
17	NFPA 502, 11	Electrical systems	Main and standby power supply systems required.
18	NFPA 502, 12	Emergency response plan	To be developed with emergency response teams
19	NFPA 502, 12.5	Central Supervising Station (CSS)	Where a CSS (off-site) is used, an alternate that can function efficiently during an emergency is also required.
20	NFPA 502, 13	Control of hazardous materials	Rules and regulations to be addressed
21	RP-22-05	Tunnel Lighting	Lighting is required for tunnels greater than 410 ft

3.6 Ventilation

3.6.1 Ventilation Objectives

The objectives of a permanent highway tunnel ventilation system are to:

- Dilute vehicle exhaust emissions such as carbon monoxide (CO), nitrogen oxides (NO_x) and other dangerous and poisonous gases, and reduce to acceptable levels during all operating conditions.
- Provide for the control of smoke in the event of a fire in order to assist evacuation procedures and fire fighting.
- Provide ventilation to emergency egress routes.
- Provide auxiliary ventilation to prevent dead air space.
- Maintain acceptable air quality in the regions surrounding the portals and any ventilation shafts.
- Provide automatic and manual gas monitoring equipment.

3.6.2 Ventilation Types

The different types of ventilation system that can be used are longitudinal, transverse and semi-transverse. They can be combined, or used in conjunction with air replacement, or mixed in different parts of one tunnel.

The type of ventilation system selected depends on tunnel length, number of lanes, traffic flow, traffic mix and method of tunnel construction. The method of discharge of polluted air from the tunnel (either through the portal or through an exhaust stack) may be determined in part by the environmental requirements of the areas surrounding the portal.

- Longitudinal ventilation, in its simplest form, consists of air entering at one portal, passing through the length of the tunnel and exiting at the other portal. Some air movement is generated by the piston action of the vehicles moving through the tunnel, and assisted or inhibited by winds blowing onto the portals. Mechanical assistance is provided by jet fans mounted in the crown of tunnel such that they blow air in the direction of the desired longitudinal flow.

- Transverse ventilation is independent of any longitudinal flow and depends on flow across the tunnel from a supply duct to an accompanying exhaust duct. Supply and exhaust connections to the road space are fed from fan systems housed outside the tunnel. The main disadvantage of the transverse system is the high cost of construction and operation, to provide portal ventilation buildings and ventilation ducts running the length of the tunnel.

- Semi-transverse ventilation is a version of transverse ventilation, including only one duct, supply or exhaust. The most common type uses a supply duct. The advantage of a semi-transverse system is that it is less expensive than a fully-transverse system but retains the ability to provide fresh air at the points where it is most required. In case of a fire, the flow can be reversed to extract smoke from the traffic space, and this can be an attractive alternative from the operating point of view involving a "Single button" response. However, it may be difficult to verify that this will provide enough air velocity to prevent smoke layering in all conditions.

3.6.3 Design Considerations

The design of the tunnel ventilation system should be carried out to the appropriate standards, namely:

- NFPA 502 (2008) – *Standard for Road Tunnels, Bridges, and Other Limited Access Highways*.

- PIARC (1995) – *Road Tunnels: Emissions, Ventilation, Environment* – with subsequent amendments.

The tunnel should be designed to ensure the safety of tunnel users in the event of a tunnel fire.

3.6.4 Ventilation Recommendations

For uni-directional tunnels, Caltrans has adopted longitudinal ventilation sized to meet the fire hazard represented by vehicles using the tunnel, with restrictions on hazardous loads if the structure size will not accommodate ventilation equipment to meet that hazard. These can only be finally resolved by calculations specific for the proposed tunnel, and discussions with Caltrans, the state Fire Marshall and the local fire jurisdiction(s).

Longitudinal ventilation designed for fire smoke control is assumed as the basis for this study. Sufficient clearance for the fans is required in the arch above the clearance envelope. A five-foot diameter clear space should be allowed for each fan based on a maximum fan housing diameter of 4 feet-4 inches.

A ventilation analysis is proposed for the next phase of tunnel project development to consider the following design issues:

- For a tunnel carrying hazardous loads, there may be resistance to adopting longitudinal ventilation regardless of the results of ventilation analysis. This may depend on escape or fire-fighting scenarios prescribed by Caltrans or by the fire authorities.

- The greater exhaust emissions from vehicles climbing the steep grades up to 6% will increase the amount of ventilation required to control air quality in the tunnel.

- On steep grades to blow the smoke from a significant fire downhill towards to the lowpoint may well be problematic. The Memorial Tunnel Fire Ventilation Test Program was conducted on a 3.2% grade, and we understand the latest European recommendations are suggesting gradients be limited to 3%, but tunnels are still being planned with gradients well in excess of this.

3.7 Tunnel Lighting and Power Distribution

3.7.1 Lighting System

Tunnel lighting design will be based on ANSI/IESNA RP-22-05 American National Practice for Tunnel Lighting. The IES *Lighting Handbook*, the AASHTO publication *An Information Guide for Roadway Lighting*, and the FHWA publication *Tunnel Lighting Design and Procedures* also provide useful information for tunnel lighting design.

The lighting scheme for tunnels incorporates increased lighting intensity within a threshold zone at the portals and a transition zone to the typical lighting for the remainder of the tunnel. The threshold zone intensity is designed to allow the drivers' eyes to adjust to the darker tunnel. The light intensity required depends on the orientation of the portal, the portal surroundings, including the portal structure and light transition canopy if used (see Figure 3-5) and the intensity of sunlight as governed by time of day and weather conditions. The light intensity can be under automatic control by photocells. During daylight hours, the required lighting level in the threshold zone will be in the range 200 to 300 cd/m², reducing to 10 cd/m² in the interior zone. The minimum lighting level at night should be 2.5 cd/m², in accordance with IESNA RP-22 *Practice for Tunnel Lighting*.

Figure 3-5 Light Transition Canopy

Location and alignment of the light fixtures will be designed to provide the most efficient lighting for the roadway traffic lanes. The location of all elements of the lighting system will be coordinated with the locations of the tunnel fans and other tunnel equipment. Maintenance access will be a key consideration during final design of electrical and mechanical systems, and mounting of the light fixtures and support for the conduit and cable providing power to the light system should be determined taking this into account. The lighting system will be provided with reliable power for a fire emergency in accordance with NFPA 502 (2004), 11.4 (1), and lighting for personnel egress and to highlight special features will be designed as specified in NFPA 502 (2004), 11.6.

3.7.2 Light Sources

The following light sources will be considered for tunnel lighting: fluorescent, low pressure sodium (LPS), high pressure sodium (HPS) metal halide (MH), and Light Emitting Diode (LED).

Tunnel lighting luminaires will be ruggedly constructed to withstand the harsh tunnel environment. The luminaires will be constructed to withstand vibration, air turbulence caused by traffic movement and tunnel ventilation systems, exhaust fumes, dirt and often damp corrosive conditions. The luminaire design will take into account the possibility of washing by high-pressure spray and mechanical brushes. LPS luminaires appear to be used on the Caltrans Tunnels near Yosemite on SR 41 and SR 120; however, HPS luminaires were installed recently in the Caldecott Bores 1 and 2 and are reportedly specified for Devil's Slide, so these should also be considered. For the basis of estimating, HPS luminaires are assumed.

3.7.3 Power System

Codes and Criteria: NFPA 502 (2004), 11.4 requires a secondary source for electrical power. NFPA 502 (2004), 11.5 requires the primary source of electrical service to be the local electrical utility, and permits the secondary source to be a separate service, provided it can be demonstrated that a single event within the utility system cannot affect both the primary and secondary source. Permanent power supply is not included in the estimate.

4 TUNNEL CONCEPT

4.1 Tunnel Cross Section

4.1.1 Single Bore Versus Twin Bore

Whether to have a single bore or a twin bore tunnel configuration is often influenced by fire and life-safety concerns although these concerns can be engineered into either configuration. In this instance, given the desire for 2 traffic lanes in each direction, concessions may need to be made on vertical clearance and shoulder width to bring the single bore option down to a practical size. A single bore sized to accommodate 2 lanes in each direction is currently being designed by the Washington State DOT for their Alaska Way Viaduct Replacement Project in downtown Seattle (Figure 4-1). The bore size in Seattle will be approaching 60 feet in diameter, making this the world's largest. The worlds largest completed tunnel bores currently stand at around 47 to 50 feet, and there are several of these. Also there is talk of a 60 foot diameter bore in Russia, though the order for the TBM has not yet been placed.

If a twin bore configuration is adopted, the planned Tunnel at the Port of Miami, Florida or the SR 75/282 project in Coronado California can be used as examples of the bore configuration. The Coronado tunnel concept is based on one lane each way with full shoulders, and having a bore size of about 37 feet diameter. The Port of Miami tunnel shown in Figure 4-2 has two lanes in each direction, but substandard shoulders and consequently the design speed is 35 miles per hour. The excavated diameter of the Miami Port tunnels is about 40 feet.

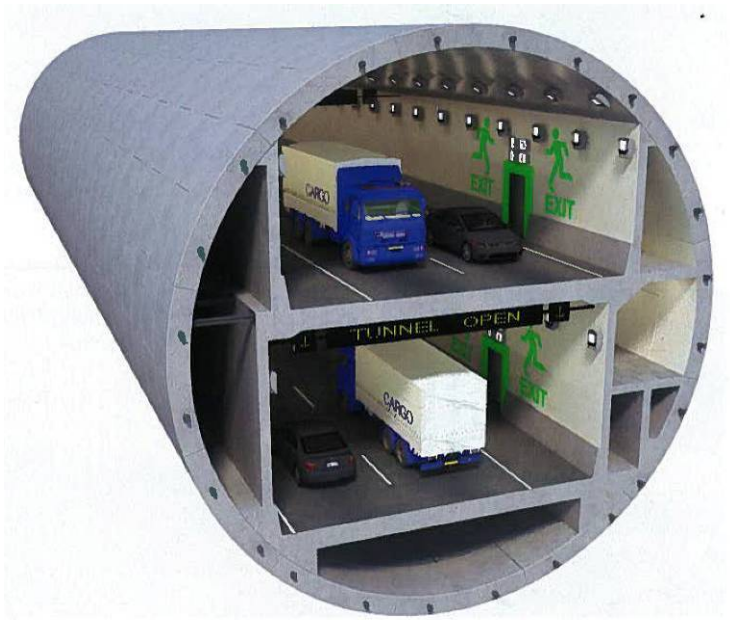


Figure 4-1 Planned Alaska Way Viaduct Replacement Single Bore Cross Section

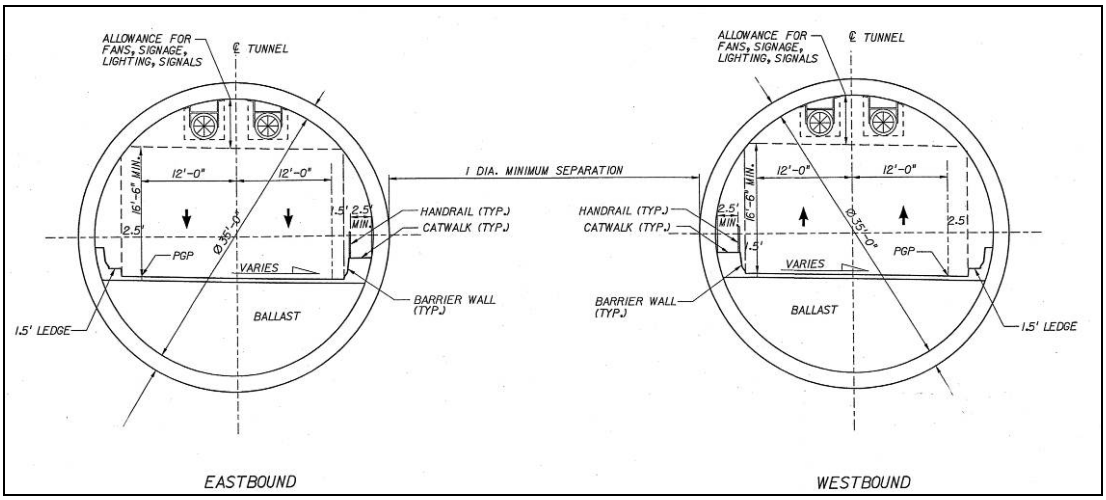


Figure 4-2 Cross-Section for Proposed Port of Miami Tunnel

4.1.2 Pillar Width for Twin Bores

The twin bore TBMs can be launched from an excavation where the separation between bores is a half a diameter or less but should diverge to at least one diameter of separation or more for the majority of the alignment consistent with good practice to limit the overlap of zones of soil influenced by TBM excavation.

4.1.3 Recommended Cross Section

A twin bore configuration is recommended to minimize the depth of portal excavations, though a single bore configuration may have advantages and could be considered in the next phase of tunnel study. Based on the cross-section shown in Appendix A, an approximately 40 foot diameter TBM is necessary to construct each of the proposed bores. The TBM will construct a precast concrete segmental lining that can serve as both the initial and final lining for the tunnel. This size has been used as a basis for estimating and is assumed to be sufficient to allow space for ventilation fans, illumination, traffic signs. The tunnel size should be optimized during final design.

4.2 Tunnel Alignment

This section identifies some basic alignment considerations for the twin bore configuration.

4.2.1 Cover Before Commencing Bored Tunneling

A half of a diameter of soil cover is typically justified through design evaluations as the minimum cover before turning under to commence tunneling. Given the bore sizes being contemplated, the resulting portal cuts take up a significant area. The portal cuts can be completed as cut and cover tunnels using a twin cell box configuration. Portal drawings for the Coronado project are provided in an Appendix C for example of what twin bore portals could look like. Architectural treatments would be applied to the

portals, particularly the one in Rio Vista. Figure 4-3 shows an example of a similar portal proposed for Coronado California.

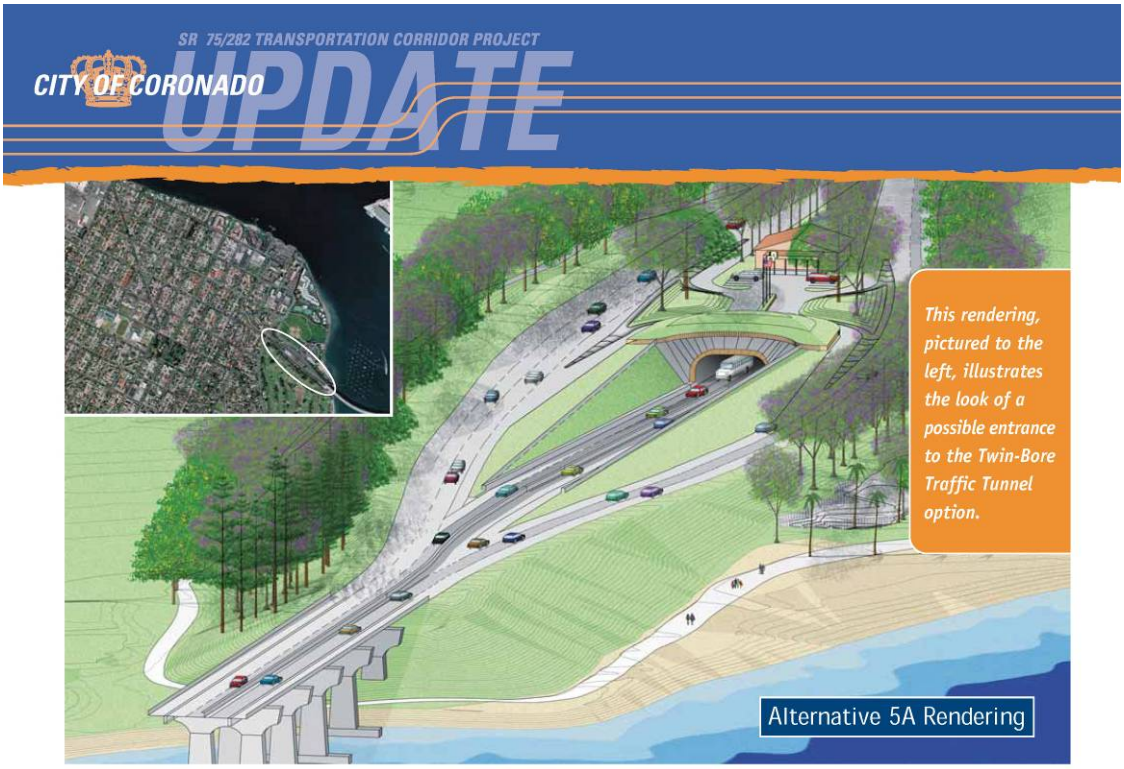


Figure 4-3 Architectural Rendering of Proposed Coronado Tunnel Portal

4.2.2 Cover to Limit Risk of Scour and Prevent Flotation

This section addresses profile constraints related to flotation and scour. Based on the report received from WRECO dated October 23, 2009 that addressed river hydraulics and scour, it appears that the risk of scour is not a constraint on the tunnel profile.

Based on the site conditions described in the Preliminary Geotechnical Memorandum by Taber dated February, 2006, and a review of as-built geotechnical information from the existing bridge dated 1952, it appears that the top of stiff to hard cohesive soil layers is at -84 to -89 feet using the same datum as the 1952 log of test borings. Locating the crown of the tunnel lining at or below the top of this layer would minimize risk of finding design issues later when liquefaction and lateral spreading analyses are performed. However, the tunnel would not necessarily need to be this deep to limit the risk of flotation. Preliminary analysis shows no risk of flotation under static load conditions. This should be reconfirmed using the results of site specific geotechnical information when available.

4.2.3 Emergency Egress

Emergency egress will need to be included in the tunnel options. For twin bore tunnels, the egress is via cross-passage to the opposite bore. NFPA 502 establishes recommendations on the location and spacing of cross passages. A total of 8 cross passages are assumed in this study as a basis of estimate.

4.2.4 Radius of Curvature

Large diameter TBMs have limits on their ability to negotiate tight curves in alignment. A minimum radius of curvature of 2,000 feet is comfortable with 1,000 feet being achievable. It is presumed that highway geometric design requirements, particularly with respect to sight distance will require curve radii of 1000 feet or greater.

4.2.5 Flood Protection Issues

Title 23 of the California Code of Regulations is written to govern waters of the Central Valley and is likely to have an influence on the proposed alignment. The Reclamation Board is the resource agency of the State of California established under the statutes of Title 23. The Reclamation Board's primary interest is in protecting lands subject to overflow and in complying with obligations to the U.S. Army Corps of Engineers related to maintaining flood protection.

The Brannan Island levee is under the jurisdiction of the Reclamation Board. Brannan Island is considered a Delta Lowland, having ground surface elevation below minus 5 feet. Construction of the SR 12 Tunnel option is likely to be considered an encroachment according to Title 23. Development of the tunnel option by Caltrans or the local counties is likely to require a permit from the Reclamation Board An endorsement from the "Local Maintaining Agency" which in this instance is Reclamation District (RD)2067 is also likely.

Title 23 does not contain requirements that directly apply to tunnels of the size contemplated, but there are rules governing smaller utility tunnels that would likely be imposed on the project. Some of the most relevant clauses are summarized in Table 4-1.

Table 4-1 Clauses of Title 23 Pertinent to the Tunnel Option

Clause	Requirement	Commentary
Clause 112 and Table 8.1	Work is not allowed during flood season without a variance. The flood season is defined as November 1 through April 15	Although this clause does not specifically address tunnels under water ways, it has historically applied to tunnels. Unfortunately from past experience, variances are typically not granted in advance of the flood season making construction planning very difficult
Clause 123, f)	Pipelines, conduits and utility lines may be installed under a levee or stream channel by tunneling, jacking, or boring if the following conditions are met: 1) the pipeline conduit or utility line is at least thirty feet under the levee;	
Clause 123, f)	3) if the installation is to be more than fifty feet below the levee and the entire floodway and streambed, the board may waive the requirement for a permit provided a letter of intent is filed with the board prior to commencement of the project;	Proposed alignment is more than 50 ft beneath the Brannan Island levee so its possible that the permit could be waived

Clause	Requirement	Commentary
Clause 123, f)	4) The portal and outlet of a tunnel, jacking or boring must be a minimum distance of ten feet beyond the projected levee slope without an approved stability and seepage analysis.	Typical annulus grouting during tunneling will cut off seepage. Additional grouting could be provided to reduce seepage
Clause 123, f)	5) Installation may occur during the flood season and when the water surface elevation in the floodway is expected to be above the elevation of the landside levee toe if adequate containment cells are constructed at the portal and outlet;	
Clause 123, f)	6)The installation of a pipeline conduit, or utility line under levees in the Sacramento-San Joaquin Delta lowlands requires adequate containment cells at portal and outlet when the installation is less than fifty feet below the streambed and levee toes	Containment cell may not be required, but Rec Board could require anyway if waiver on prohibition of work during flood season is lifted
Clause 123, f)	8) pipelines and conduits open to the waterway and below a levee must have a positive closure device which is accessible at all times unless it is demonstrated to be unnecessary.	Not applicable to a highway tunnel

4.2.6 Portal Considerations on Brannan Island

There is recent precedent for tunnels under the Sacramento River and levee system using the same tunneling methods proposed for the SR 12 tunnel option. HMM designed two river crossings for the Sacramento Regional County Sanitation District (SRCSD) that were completed in 2006 by Affholder Construction. Provision of containment cell flood protection around the tunnel portals was required to addressed flooding risk even though the project was not in Delta lowland. Having the containment cell flood protection may have been a factor when the Reclamation Board waived the restriction on work during the flood season on that project.

It is understood that ground surface level on Brannan Island in the vicinity of the portal is about 10 feet below sea level, and that a berm up to the height of the Reclamation District 2067 levee along the Sacramento River may be required. This could be constructed as a reinforced concrete structure or an earth fill structure. Either way, it will be a significant structure in terms of its cost. Spoil from tunnel excavation may be used to create a portion of this berm to minimize spoil hauling.

The need for a containment cell at the Brannan Island portal for flood protection may not be explicitly required by applicable regulations, but project experience form LNWI suggests one should be included for budgeting purposes; therefore, it is included in the estimate.

4.3 Appurtenant Facilities

An operations and maintenance building is recommended to be located on site at a location to be identified. Alternatively, this space could be created underground as a niche in the portal cut or in the tunnel, near the portal. Underground construction would be more costly.

The fire fighting water must be supplied from a well or the river or a local water supply. If supplied from the river, a decision must be made whether or not to include facility for this in the project, or to let the local fire company draw water if and when needed. As a basis of estimate, it has been assumed that a fixed facility will be required. Two options for fixed facility are:

- a high capacity river intake designed to be supplied year-round by the river even during low flow, or
- a lower capacity fixed pump station or mobile pumping station that fills a tank on site. The lower capacity pump station could possibly be designed to fill the tank during high river flow periods.

Permitting issues may influence the preferred configuration.

5 CONSTRUCTION CONSIDERATIONS

5.1 Main Tunnel Excavation Methods

For the twin-bored tunnels, a closed face tunnel boring machine will be used to install a single-pass 35-foot internal-diameter lining system consisting of gasketed, pre-cast concrete segmental rings concurrently with TBM advance to stabilize the ground and limit groundwater inflow into the tunnel excavation. For the purpose of this report, these rings are referred to as a Precast Concrete Tunnel Lining (PCTL). The twin tunnels could either be constructed concurrently using two TBMs or consecutively using one TBM. There will be segments of cut and cover structure that are constructed in the low-cover areas of the portal cuts.

This will be one of the first applications of a round TBM-bore for a highway in North America, but this does not mean that this type of project is unprecedented. Two other similar projects are nearing construction in the US, the Alaska Way Viaduct Replacement Project in Seattle, Washington and the Miami Port Tunnel in Florida. Table 5-1 summarizes these and other TBM-bored highway tunnel projects from around the world.

A one-pass tunnel lining system has been assumed as the basis for sizing the tunnel. A one-pass lining system uses the initial gasketed lining installed during tunneling as the final permanent lining. An alternative to a one-pass lining system is a two-pass lining system. In a two-pass lining system, a secondary lining is installed inside of the initial lining. Secondary linings can be used to correct alignment deviations and support interior waterproof membranes but they add significantly to the cost of the work because of the increased tunnel size necessary to accommodate the thickness of the lining, because they are constructed after tunneling, which adds significantly to the schedule, and because the lining itself is a significant structure that must be designed to support its own weight as well as resist external hydrostatic and seismic loads.

Waterproofing, fire protection, structural capacity and constructability can all be addressed in a one-pass lining design using proven methods. Similar one-pass systems have been or will be installed for highway and transit tunnel projects in soft ground as summarized in Table 5-1.

The road deck can be constructed by the TBM or trailing equipment concurrently with tunneling using either precast concrete elements as shown in Figure 5-1 or compacted fill. The cost differential is assumed to be insignificant at this stage.

Table 5-1 Partial Listing of Worldwide TBM-Bored Highway Tunnel Projects

Project	1 or 2 Pass Lining	Lining thickness (in)	TBM Diameter (ft)	# Bores	# of Road Decks in Bore	# of Lanes in Each Bore	Tunnel Alignment Length (mi)	TBM Manufacturer	Completion Schedule Status
A86 West Project, East Tunnel, Paris France	1	18	38.1	single	2	6	6.2	Herrenknecht	To be completed in 2007
A86 West Project, West Tunnel, Paris France	1	unknown	39.9	single	1	2	4.7	unknown	unknown
Shanghai Changjiang Under River Tunnel Project, Chongming, China	1	26	50.5	twin	1	3	4.5	Herrenknecht	To be completed in 2010
Nanjing, China	?	unknown	47.6	twin	1	3	2.3	Herrenknecht	Completed
Islisberg, Switz.	2	unknown	38.7	twin	1	unknown	2.9	Herrenknecht	Completed
Second Heinenoord Crossing, Netherlands	1	28	27.2	twin	1	2	0.6	unknown	Completed
SMART, Kuala Lumpur	1	20	43.3	single	2	4	3.4	Herrenknecht	Completed
Fourth Elbe, Autobahn A7, Hamburg, Germany	1	28	46.6	single	1	2	1.6	Herrenknecht	Completed 2002
Hubertustunel, Den Haag	?	unknown	34.4	unknown	unknown	unknown	1.9	unknown	Unknown
Westershelde, Netherlands	1	18	36	twin	1	2	4.1	unknown	Completed 2002
Madrid M30 Northern Bypass	?	unknown		twin	1	unknown	1.3	unknown	Design completed
Madrid M30 Southern Bypass	?	24	44.1	twin	1	3	2.2	Herrenknecht, Mitsubishi	Under construction
Miami Port Tunnel	1	24	41	twin	1	2	0.6	unknown	Planned
Lefortovo Highway Tunnel, Moscow, Russia	?	unknown	46.6	unknown	unknown	unknown	1.4	Herrenknecht	Completed 2003
Hanshin Freeway, Kyoto, Japan	?	unknown	35.5	unknown	unknown	unknown	unknown	Hitachi-Zosen	Completed
North Island Access Tunnel, Coronado, CA	1	18	36.5	twin	1	1	1	unknown	Planned

Notes:
Unknown because project is in early phase of project development or information is currently unavailable

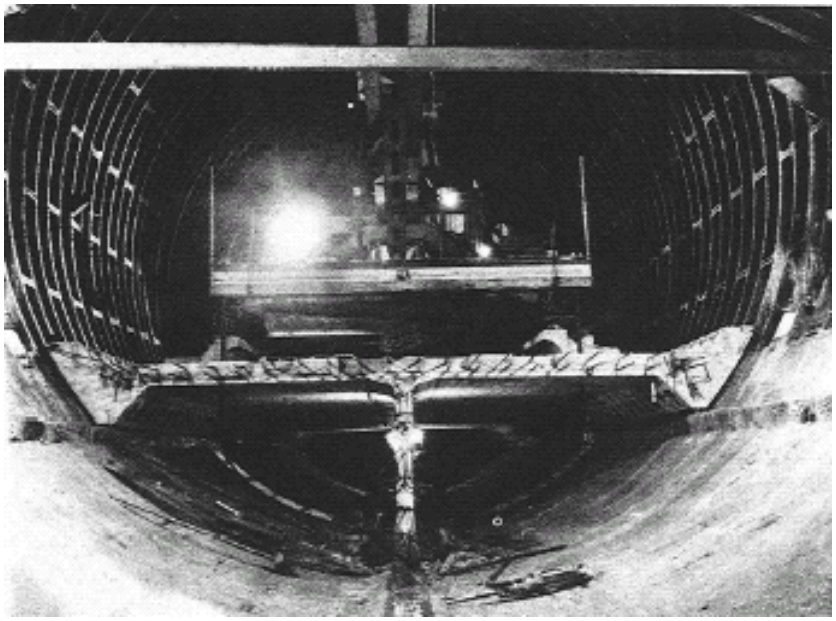


Figure 5-1 Precast Road Deck Installation

5.2 Cross Passages

Criteria governing the clear space inside cross passages has not been developed. For purposes of current evaluations, an excavated diameter of 13-feet and an inside diameter of about 10-feet has been assumed. Cross passages will be created by labor intensive hand-tunneling methods that requires pre-excavation ground improvement. Construction of these cross-passages requires the following elements:

- Temporary Support of Running Tunnels (See Figure 5-2);
- Pre-excavation Ground Improvement (See Drawing BC-701, Appendix D);
- Breakout through Running Tunnel Segmental Lining ;
- Excavation and Temporary Support of Cross-Passages (See Drawing BC-503, Appendix D); and
- Installation of Permanent Lining and Facilities (See Drawing BC-501, Appendix D).

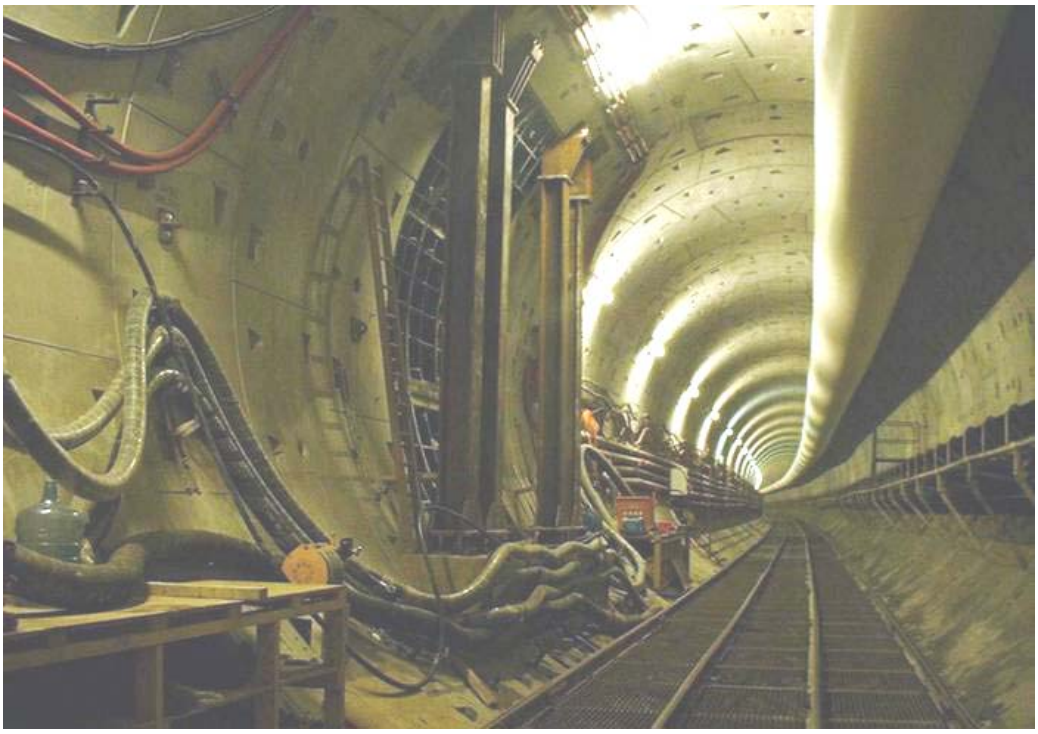


Figure 5-2 Temporary Support of Precast Segment Lining at Cross-Passage Break-out

A cross-passage should not be located directly beneath the Brannan Island levee because cross-passage areas are at risk of higher tunneling induced surface settlement, thus it is possible for additional cross passages due to less than optimal spacing. Given the anticipated ground conditions consisting of a mix of firm to squeezing clays and raveling to flowing silty sand and sand, pre-excavation groundwater depressurization and/or grouting will be used prior to cross passage excavation. The approach is to construct temporary support using steel ribs and liner plate. A preliminary assessment of anticipated temporary loads indicates that the ribs can be W4 x 13 sections spaced at approximately four feet, with standard 3/8-inch liner plate. Other methods, including the use of grouted spiles, should be considered during design.

Figure 5-3 SMART Tunnel constructed with Precast Concrete Tunnel Lining for Highway and Storm Drainage in Kuala Lumpur, Malaysia

5.3 PCTL Design Considerations

PCTL segments are designed on the principal of providing a flexible tunnel lining that deforms under initially non-uniform earth pressures. Outward deformations mobilize passive resistance of the ground mass and inward deformations mobilize active pressures. This action serves to redistribute the ground stresses until a relatively uniform radial stress develops in the deformed lining. The deformations in a segmental lining primarily occur through rotations that are concentrated at the flexible radial joints. If the lining were stiff, bending moments in the lining would be generated during this deformation. In contrast, if the lining is too flexible, it will undergo large deformations during the erection process under self-weight and uneven annulus grout pressure before the annulus grout hardens and the lining is stabilized.

The scope of structural design for the tunnel lining includes seismic analyses in addition to the typical design steps. These lining design steps include the following:

- Lining type selection,
- Geometric design,
- Structural design,
- Concrete design,

- Design of accessory devices (such as gaskets and dowels), and
- Development of the lining installation procedure.

This study evaluated the lining thickness on a preliminary basis, including consideration of TBM jacking loads that typically control lining thickness and concrete strength. This preliminary evaluation indicated that a lining thickness of 18-inches could be used with a minimum concrete compressive strength of 5,000 psi. Higher strength concrete is commonly used for precast concrete to minimize form-stripping time and to increase the lining durability due to the relationship between strength, density and permeability. There will likely be two mats of reinforcing, one on each face.

5.4 Construction Issues

5.4.1 Construction Sequence and Schedule

The following site constraints have been assumed for this evaluation of the preferred construction sequence:

- Access will be from the east and west via SR12 and from the south via SR160.
- Permanent spoil disposal sites are available throughout the delta lowlands. Beneficial re-use of the tunnel spoil for levee improvement should be investigated.
- It is likely that all spoil suitable for structural fill in levee construction can be reused for the east portal containment berm on Brannan Island if required.

The minimum construction cost is anticipated to result from the use of a single TBM to bore both tunnels of the twin bore configuration, though this should be confirmed by further study. The resulting schedule duration is 53 months assuming continuous tunnel excavation through the flood season which may require a variance form the Reclamation Board. Compressing the schedule via the use of two TBMs tunneling concurrently would increase the severity of the construction traffic impact on local highways.

5.4.2 Construction Water and Groundwater Disposal

The proposed pressurized face tunneling method for construction of the twin-bore tunnels does not require dewatering and will limit the amount of water contained in the excavated spoil. Similarly, the support of excavation walls for the portal excavations would be designed as groundwater cut-offs to limit the amount of inflow to portal excavations. The resulting groundwater volumes requiring treatment before discharge will be estimated based on tolerable leakage and rainfall that could collect within the portal excavations.

5.4.3 Spoil Generation Volumes

A spoil disposal of 770,000 cubic yards of material (bulked spoil volume) is assumed for the portal, twin tunnel and cross passage excavations based on the bank excavation quantities summarized in Table 5-2. An average bulking factor of 1.15 was used for estimating haulage and spoil disposal volumes. These volumes do not allow for over-excavation of unsuitable peaty foundation material that may be encountered in the portal areas.

Table 5-2 Excavation and Fill Quantities

Item	Comment	Bank Cubic Yards
West Portal	Soil Excavation	65,000
Twin Tunnels	Soil Excavation	534,000
Cross Passage	Soil Excavation	2,000
East Portal	Soil Excavation	65,000
Brannan Island Containment Cell	Up to	1,500,000
	Approximate Net Shortage to be imported for Containment Cell	800,000

6 MAINTENANCE AND OPERATIONS

6.1 Tunnel Operations and Maintenance Center

A tunnel operations facility reasonably adjacent to the tunnel itself would be used during maintenance operations, and would be the location of the Command Post for emergency situations. Routine 24-hour supervision of the emergency monitoring and reporting systems could be established at an existing Tunnel Operations Center or at the existing Antioch Bridge Caltrans Facility. There are no standards for the location of 24-hour remote monitoring. Either the local or the remote facility could constitute the Central Supervising Station described in NFPA 502 (2004), 12.5. NFPA 502 (2004), 12.5.6 requires some duplication of equipment at another site in case the Central Supervising Station is out of service. NFPA 502 (2004), 12.5.4 also requires recording of radio and television communications and closed-circuit television transmissions during an emergency.

At either location, staff would have the capability to monitor the fire alarm and detection system, and control the traffic signs and signaling system. Staff would also have the capability and training to communicate with participating agencies in case of an emergency. The Tunnel Operations Center would provide support for emergency response agencies and provide an incident command post during emergencies.

6.2 Emergency Response

The general requirements for emergency response are set out in NFPA 502 (2004), Chapter 12. The Standard gives guidance as to the typical incidents that should be considered during the development of the emergency response plan and the participating agencies that might be needed to coordinate and assist. NFPA 502 (2004), 12.5 gives some specific requirements applicable to the central supervising station for the operation and supervision of the facility, and for the establishment of a command post when the emergency procedure plan is invoked. Exercises and drills should be conducted at least twice a year, and records, both written and recordings kept during emergencies, exercises and drills.

Successful implementation of tunnel systems requires coordination between the operations and maintenance group and the local emergency response agencies. Development of an incident response team or a standard procedure for handling tunnel emergencies is critical to operation of the tunnel. In an incident, a command center would be established at the Tunnel Operation Center. From the command center, local agencies would be able to monitor status of the incident and be able to communicate with the responding personnel. An incident response procedure will allow the local agencies to respond to an emergency as a team, resolve the incident and allow traffic flow to resume safely and effectively.

7 COST ESTIMATES

7.1 Cost Estimating Methods and Assumptions

The scope of work for the estimate was based on the project as described in this report and as shown on Drawing Sheets in Appendix A and similar examples in Appendix C and D. Engineering assumptions and historical data for similar soft ground bored highway tunnel projects in the planning and construction stages such as Alaska Way Viaduct Replacement, Miami Port tunnel and SR75 Coronado Tunnel were used. The estimates assume current 2010 pricing and should be escalated to the planned mid-point of construction.

The indirect costs of underground construction can be a higher percentage of the direct cost of underground work than for typical highway work. As such, indirect costs are estimated separately and included in the cost estimate.

7.2 Construction Costs

The estimate described in this study includes:

- A twin bored tunnel alignment length of 5,740 feet. With portal cut and cover segments, the total tunnel length would be 6,110 feet.
- 8 Cross Passages
- Cross section shown in Appendix A
- Spoil disposal of approximately 770,000 cubic yards of material.
- MET systems outlined in Section 3, including fans, lights, traffic control (power supply to the site is excluded)
- a near site operations building and upgrades to a remote 24-hour Caltrans facility. The existing Caltrans facility at the Antioch bridge has been identified as a possible site. This is to satisfy NFPA 502 guidelines for a central supervising station.

Estimated costs are summarized in Table 7-1. A cost breakdown is provided in Appendix B.

Table 7-1 Structures Construction Costs

Item	Cost
Contractor Overhead-related Direct Costs	$41.6 Million
Mobilization	$48.7 Million
Bored Tunnels	$229.2 Million
Cross Passages	$26.8 Million
Portal Excavations	$97.5 Million
Tunnel Civil	$20.3 Million
Electrical, Mechanical Systems	$26.5 Million
Brannan Island Containment Cell	$45.4 Million

Item	Cost
Subtotal Base Cost	$536.0 Million
Contingency (50%)	$268.0 Million
Total Including Contingency	$803.9 Million

Significant elements of the project are excluded from this cost. The following are excluded elements of work that need to be added in to obtain a structure cost that includes complete tunnel operation and maintenance systems:

- approach roadway beyond portal cuts
- conveyance treatment and discharge of tunnel drainage beyond the tunnel portals
- permanent power supply to the site including main transformer
- permanent water supply for fire water
- communications link from tunnel to remote central supervising station
- removal of existing bridge
- traffic control and detour during construction
- Soft costs of temporary construction easement, right of way acquisition, environmental, design and construction management services, agency costs, testing and start-up.

7.3 Recommendations for Further Study

The costs developed for this study are based on a brief desktop study of ground conditions and a minimal amount of engineering to define major cost elements of the project. As such, the estimates are very preliminary in nature and are consistent with order-of magnitude estimates. Additional investigations and studies can be performed to develop the basis for a revised estimate with better accuracy. A partial listing of some of these activities is provided below.

- Geotechnical site investigation including over-water drilling
- Development of site specific seismic design criteria and site response analyses
- Liquefaction and lateral spreading analyses to all optimization of tunnel profile and length
- Evaluate a single bore cross section
- For twin bore option, evaluate one TBM versus two TBMs in terms of cost and schedule benefits
- For the twin bore option, evaluate a staged construction where one bore is completed and put into service, allowing for addition of a second bore at a later date

- Discussions with permitting agencies to gain understanding of permitting constraints and impacts to cost and schedule.

Appendix A

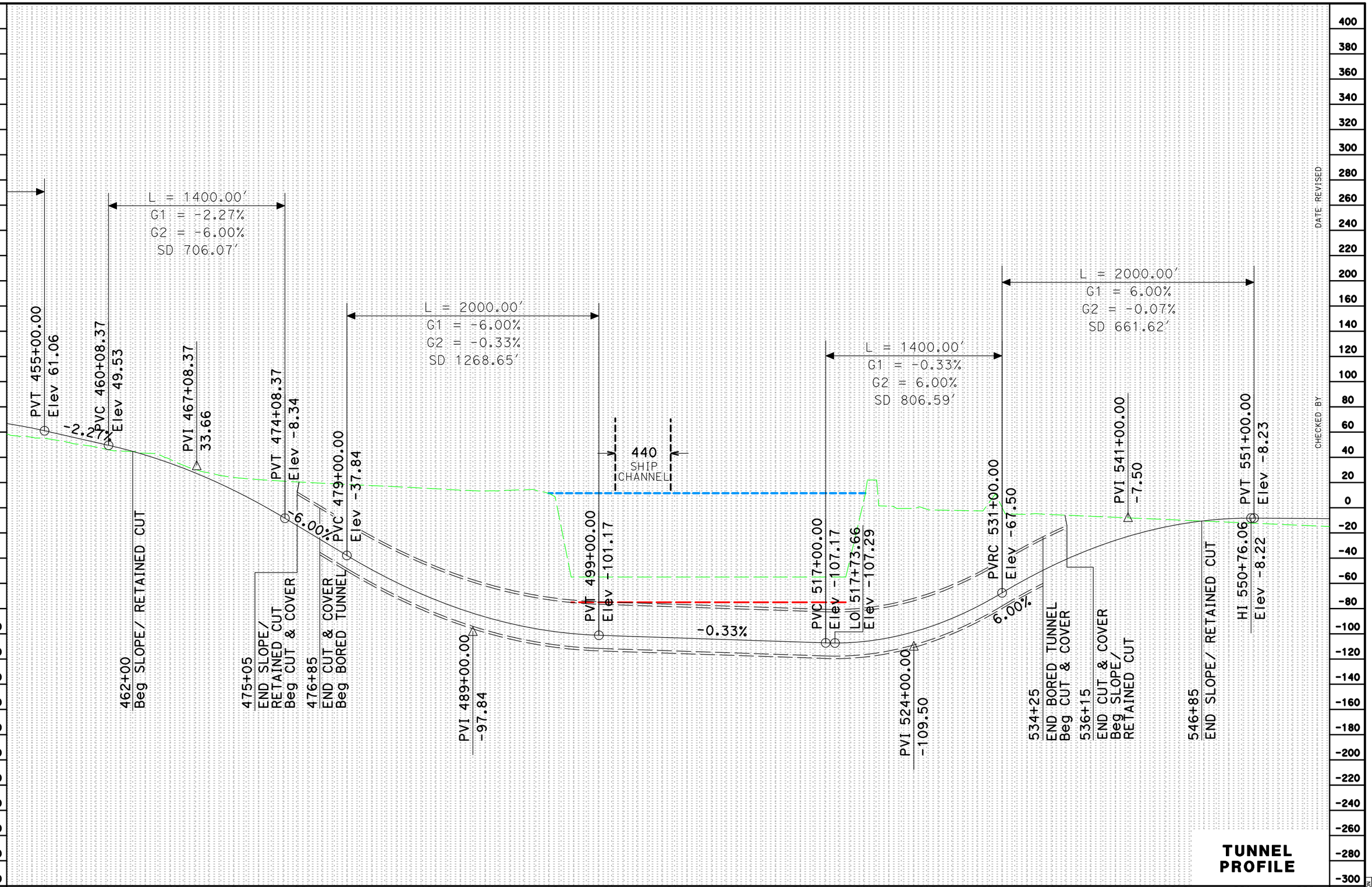
Drawing Sheets Provided by AECOM

TUNNEL PLAN

DESIGN OVERSIGHT	CALCULATED/ DESIGNED BY	DATE	REVISED BY
	CHECKED BY		DATE REVISED

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

LAST REVISION 00-0-00



CONSULTANT FUNCTIONAL SUPERVISOR

CALCULATED-DESIGNED BY

CHECKED BY

REVISED BY

DATE REVISED

LAST REVISION

RELATIVE BORDER SCALE
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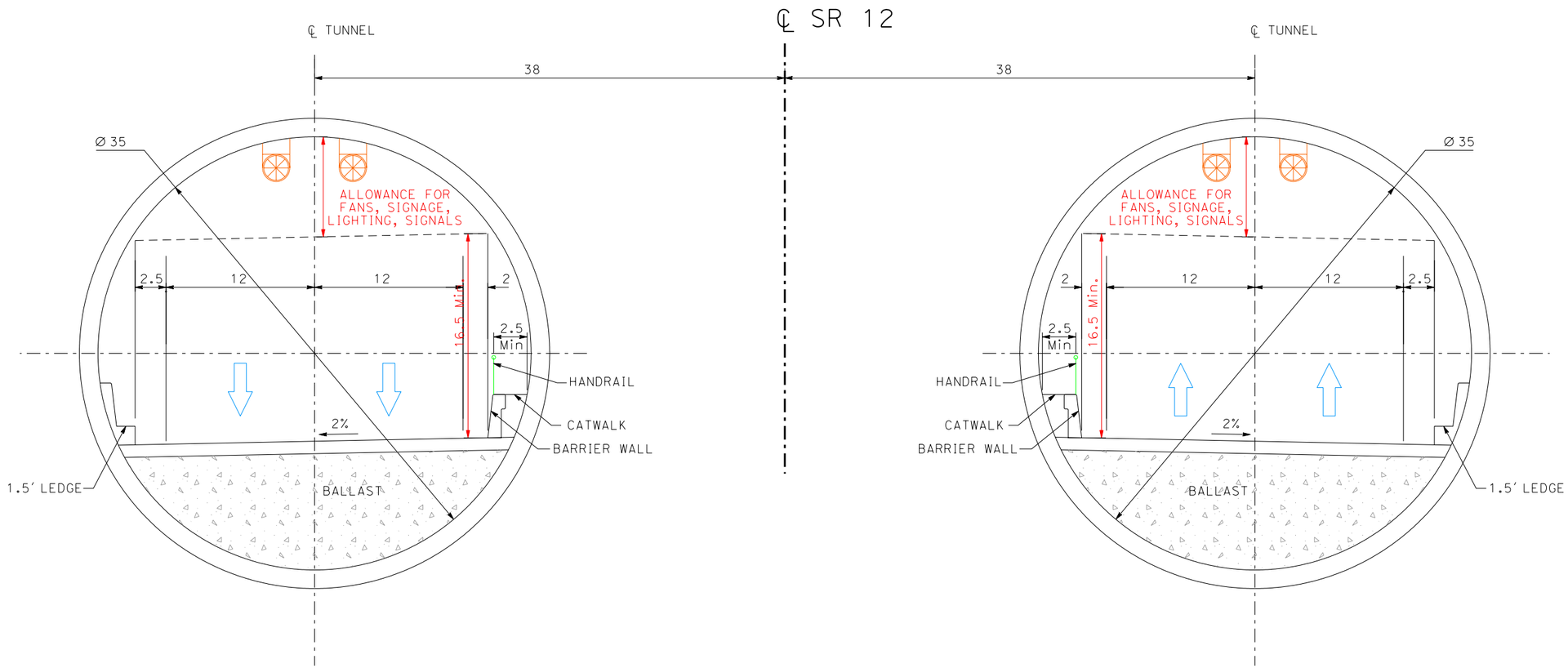


TYPICAL SECTION FOR PROPOSED SR 12 TUNNEL

SCALE 1" = 10'

Appendix B

Estimate of Likely Construction Cost

Hatch Mott MacDonald

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

MISCELLANEOUS GENERAL PLAN ESTIMATE ☐ **OR PLANNING ESTIMATE** ☐

STRUCTURE	BRIDGE NO.	RECD. BY	ESTIMATING GROUP IN
TYPE	DIST. CO.	RTE 12	OUT

TNL AND APPROACH LENGTH 8485 FT x WIDTH 57 FT = AREA 483645 FT SQ.

DESIGN SECTION _____ QUANTITIES BY RPAB DATE 1/7/10 ESTIMATE NO. _____

PROJECT INCL.: Tnl, portals, systems QUANTITES CHCKD. BY DY DATE 1/7/10 PRICED BY. RPAB

AND $ _____ ROADWORK CHARGE UNIT AND EA _____ COST INDEX _____

	CONTRACT ITEMS	UNIT	QUANTITY	PRICE	AMOUNT
1	CONTRACTOR OVERHEAD-RELATED DIRECT COSTS	LS	1	41,599,058	41,599,058
2	TBM SUPPLY	LS	1	30,800,000	30,800,000
3	BORED TUNNEL	LF	11,480	17,283	198,406,765
4	CROSS PASSAGES	EACH	8	3,346,127	26,769,014
5	PORTALS	LS	1	97,491,388	97,491,388
6	TUNNEL CIVIL	LS	1	20,260,805	20,260,805
7	FIRE AND LIFE SAFETY SYSTEMS	LS	1	26,535,012	26,535,012
8	CONTAINMENT BERM	LS	1	45,376,696	45,376,696
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					

ROUTING

1. DESIGN SECTION _____
2. DESIGN A SUPERVISOR
3. DESIGN B SUPERVISOR
4. PLANNING

_____

_____

_____

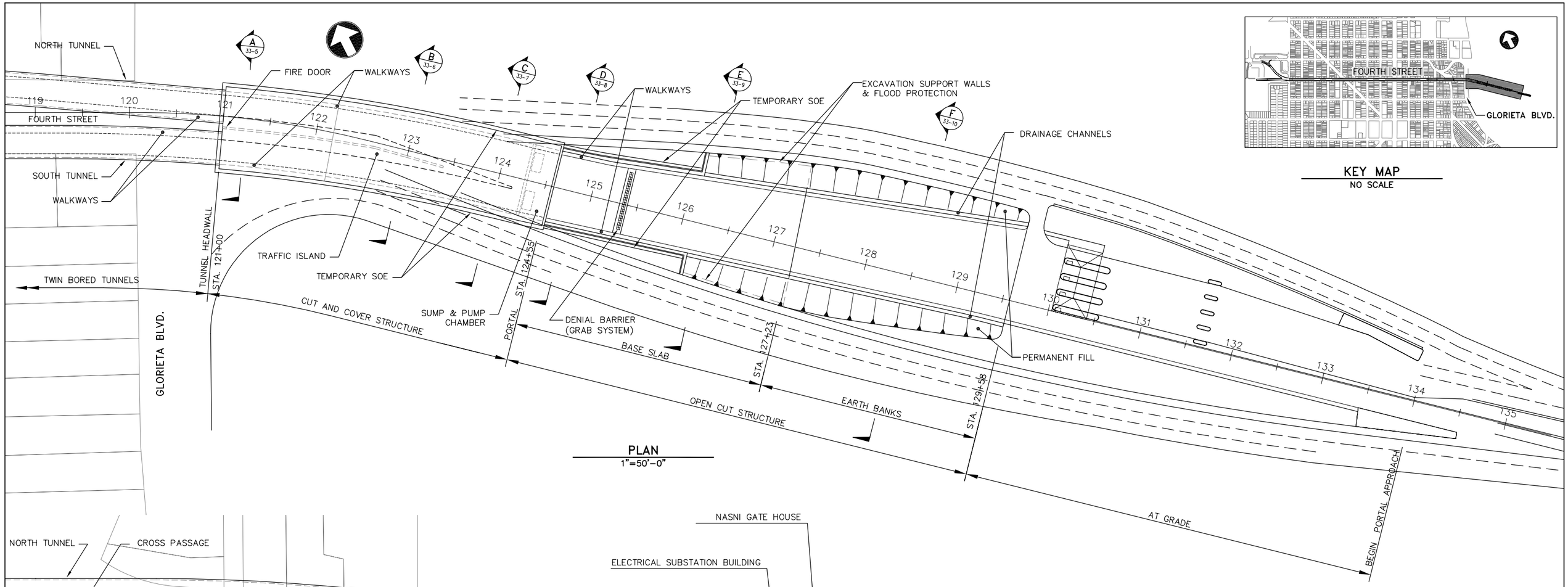
SUBTOTAL		487,238,738
ADDITIONAL MOBILI	(10.0%)	48,723,874
SUBTOTAL STRUCTURE ITEMS		535,962,612
CONTINGENCIES	(50.0%)	267,981,306
TUNNEL TOTAL	($ 70,030 /FT)	803,943,917
BRIDGE REMOVAL (CONTINGS INCL)		0
WORK BY RAILROAD OR UTILITY FORCES		0
GRAND TOTAL		803,943,917
FOR BUDGET PURPOSES - USE		803,940,000

COMMENTS: Tunnel cost (2010 $) incl. tunnel portals, twin tunnels and cross-passages. tunnel MET systems, operation and mantenance facilities, 25% owner's contingency, but excludes cost of design, right-of-way, construction management, and owner oversight

Appendix C

State Route 75/282 Transportation Corridor Study

Coronado Tunnel Portal Drawing Examples



PLAN
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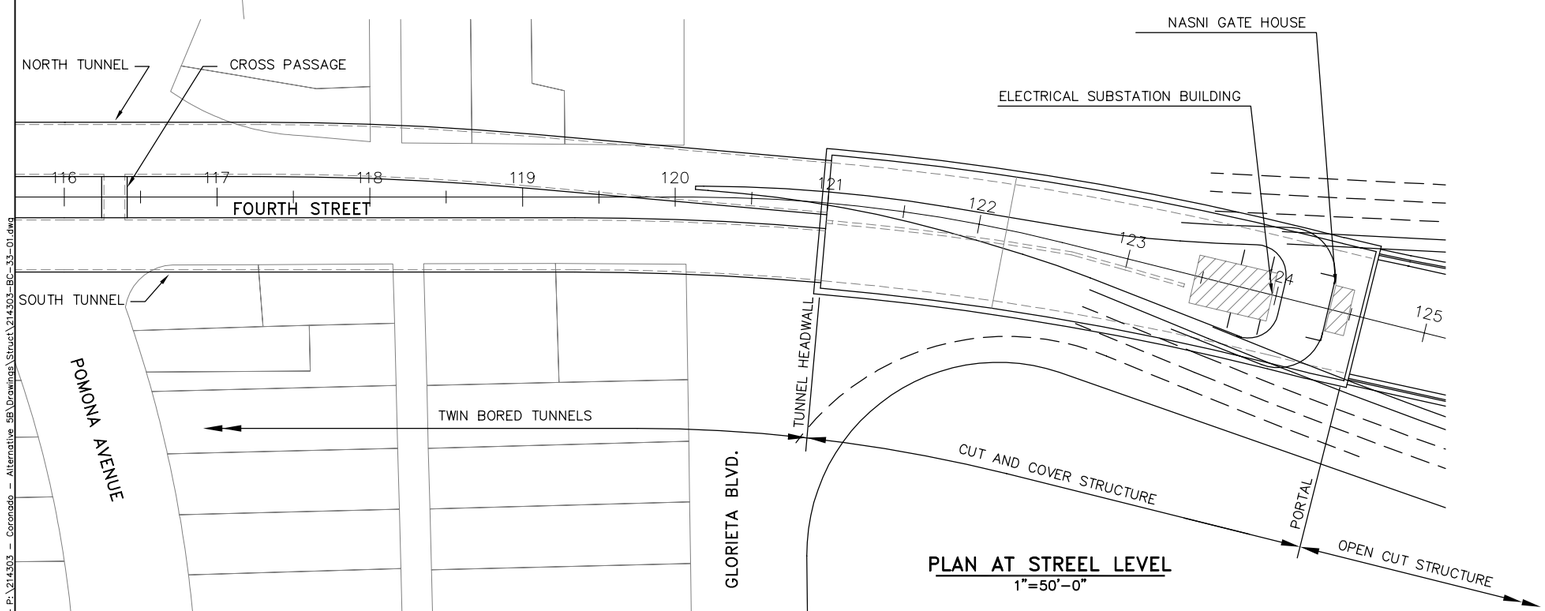
KEY MAP
NO SCALE



PLAN AT STREEL LEVEL
1"=50'-0"

PRELIMINARY DRAFT

REV	DATE	Description
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Hatch Mott MacDonald

Approved: Date:

The City of CORONADO

Approved: Date:

STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
LAYOUT PLAN

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH			
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
DRAWING FILE NAME. 214303–BC–33–1			1	17	

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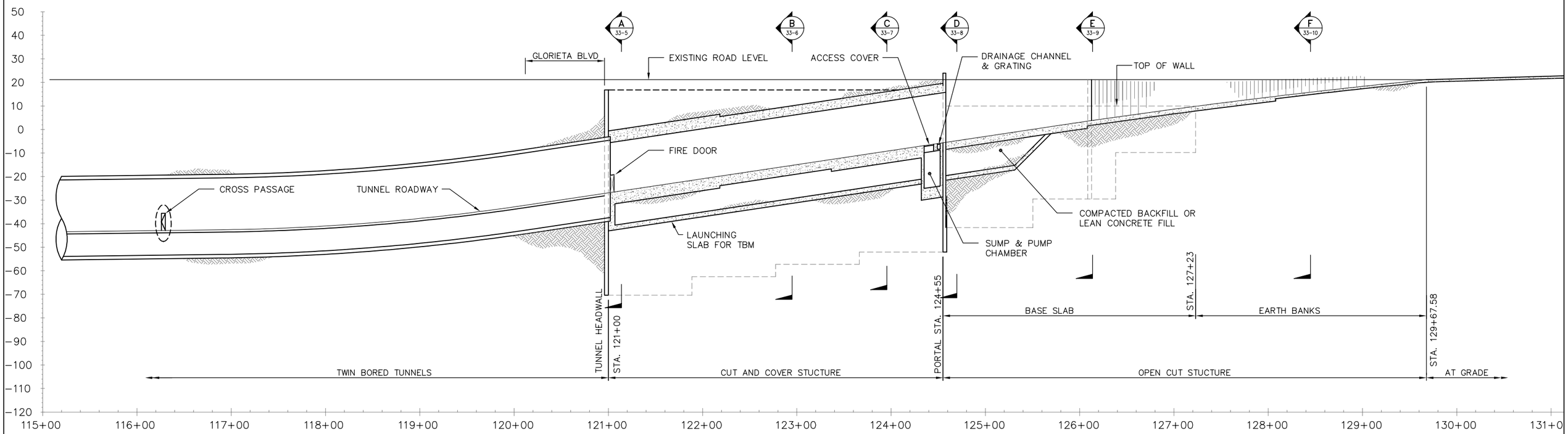

PROFILE

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STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B – TWIN BORED TUNNELS
PROFILE

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
DRAWING FILE NAME. 214303-BC-33-2			2	17	

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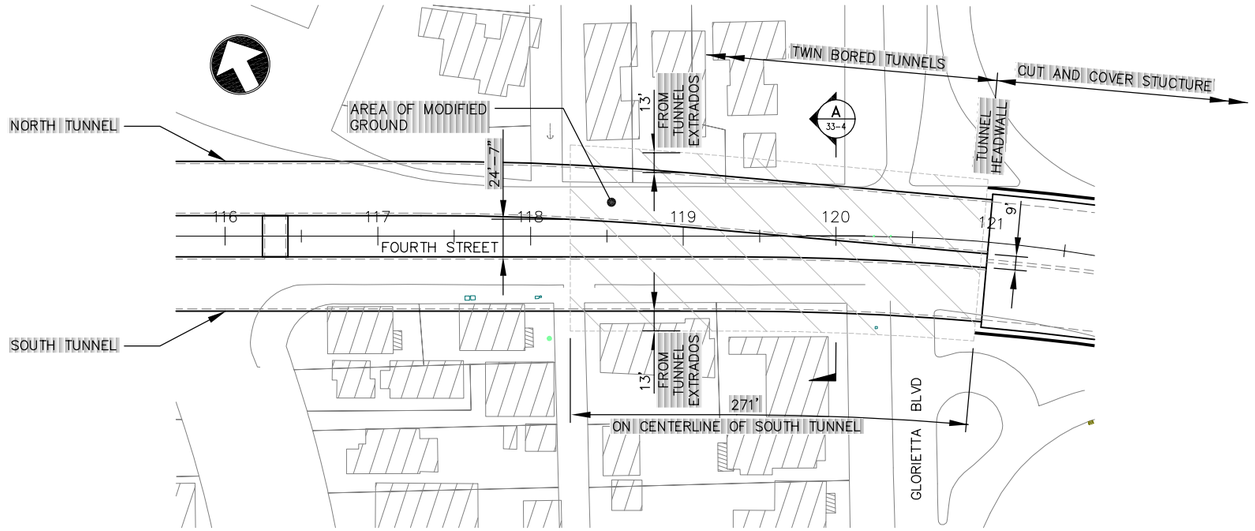

PLAN
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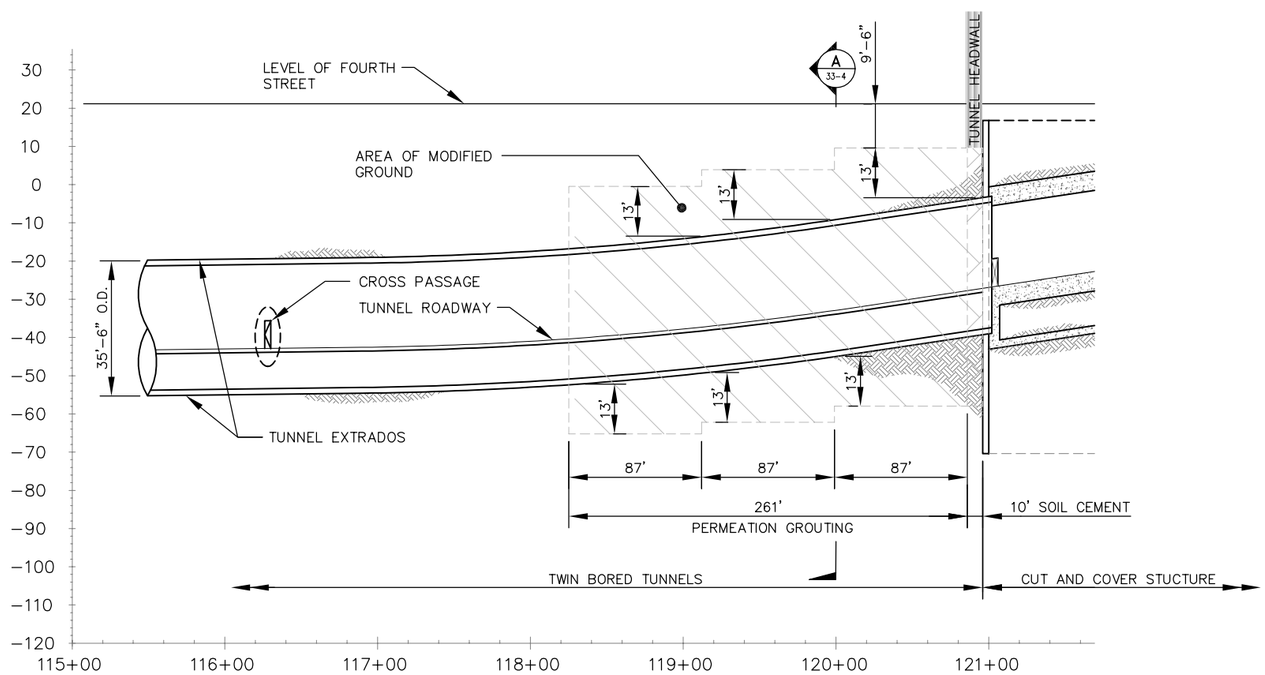

TUNNEL PROFILE
HORIZ: 1:50 VERT: 1:20

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TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B – TWIN BORED TUNNELS
MODIFIED GROUND LAYOUT

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
DATE:12/05/06	DATE:12/05/06	DATE:12/05/06			
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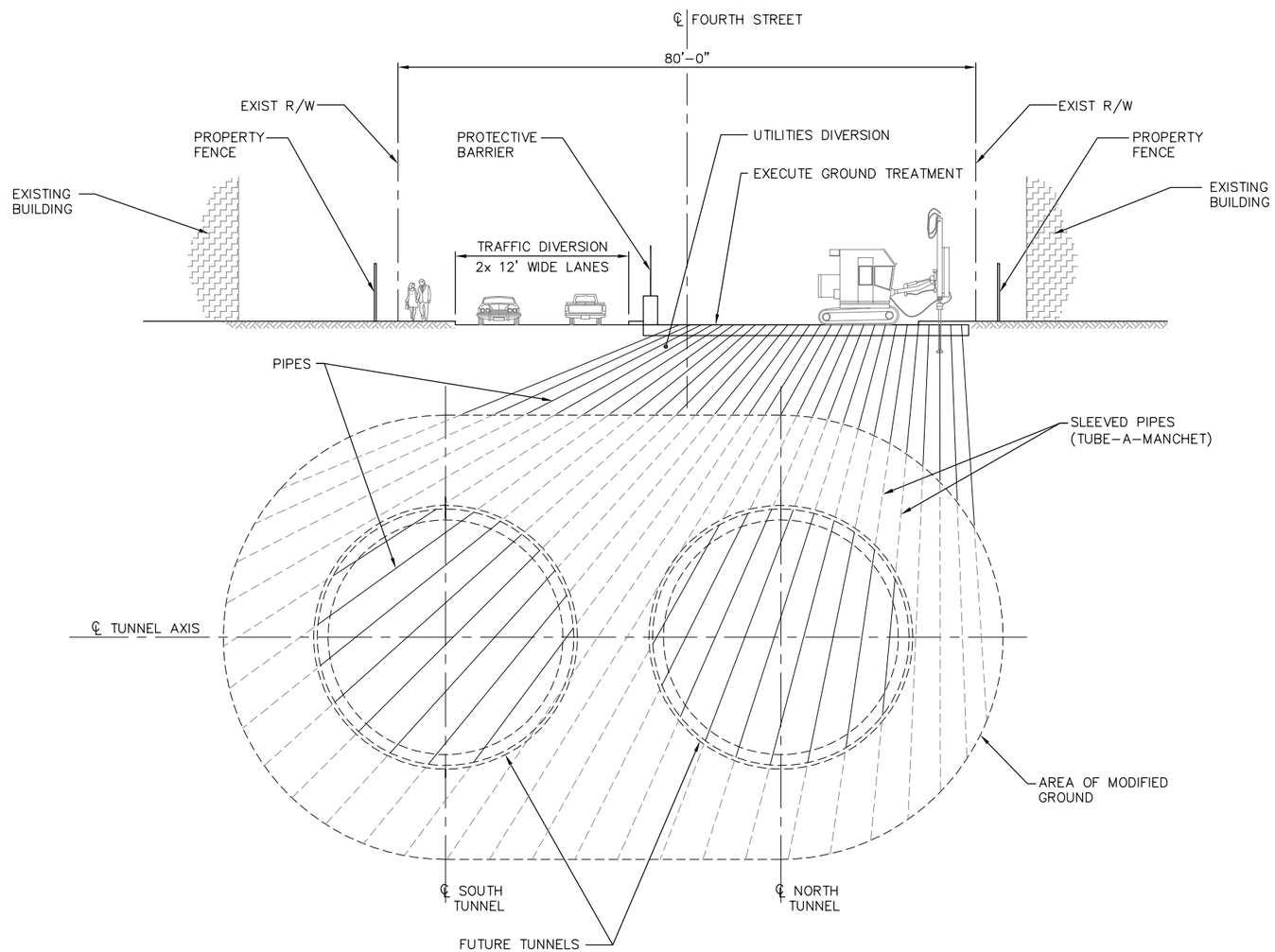

SECTION
1"=10'-0"

A
33-4
33-3

PRELIMINARY
DRAFT

REV	DATE	Description

PRELIMINARY NOT FOR
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STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SECTION A

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
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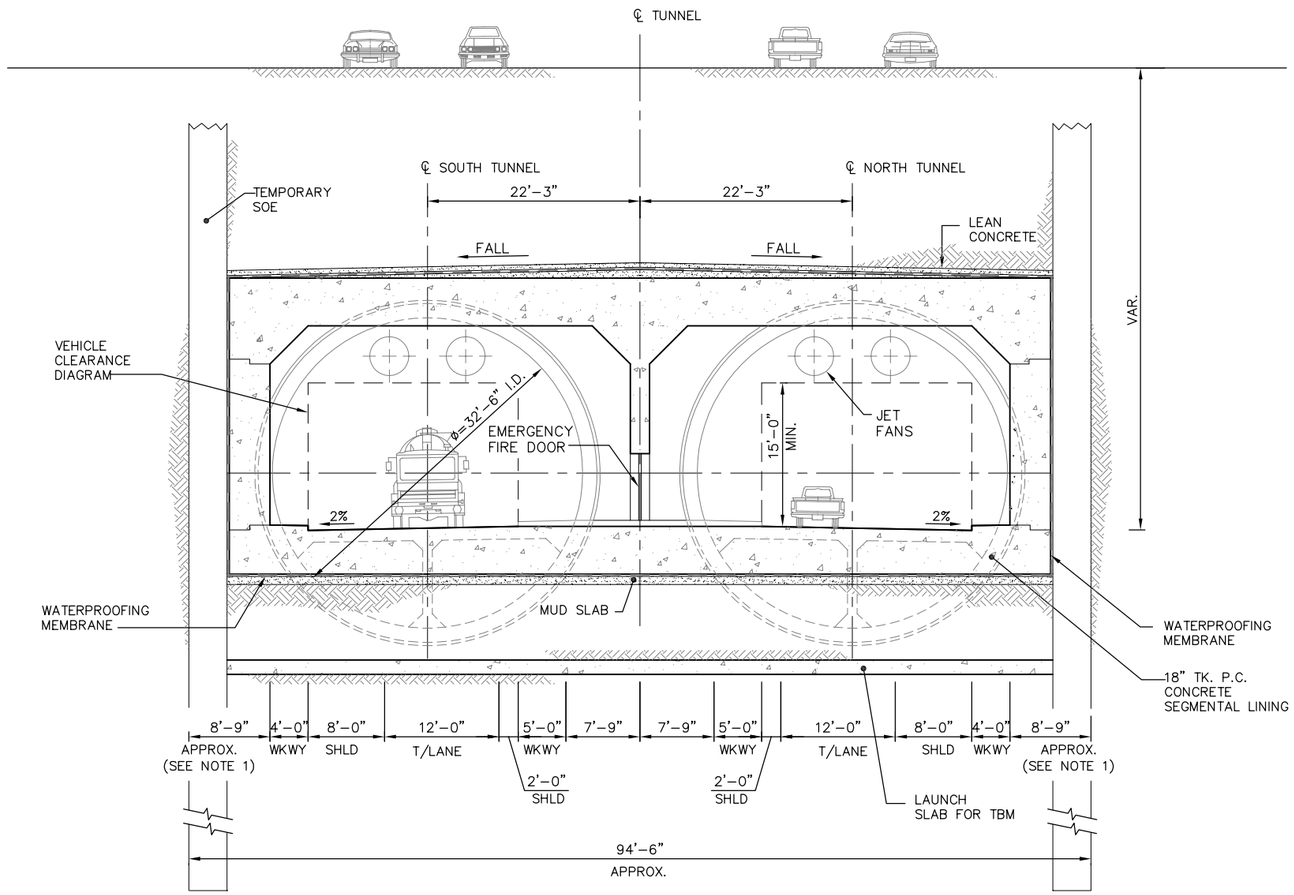

SECTION
1/8"=1'-0"

A
33-5
33-1
33-2

NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY SOE

PRELIMINARY DRAFT

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TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
SECTION B

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH			
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
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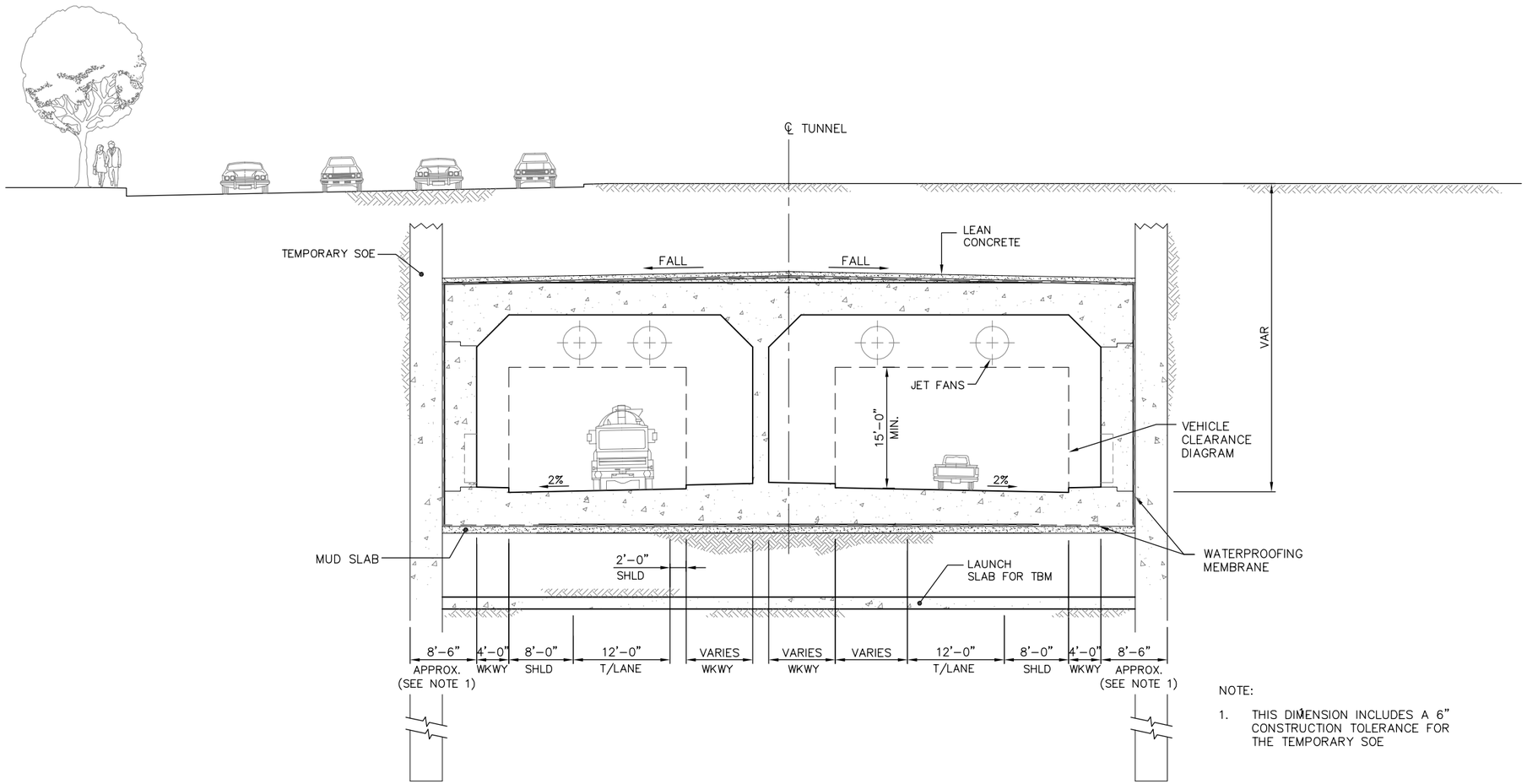

NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY SOE

SECTION B
1/8"=1'-0"
33-6
33-1
33-2

PRELIMINARY DRAFT

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STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
SECTION C

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH	6	17	
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			

DRAWING FILE NAME. 214303–BC–33–6

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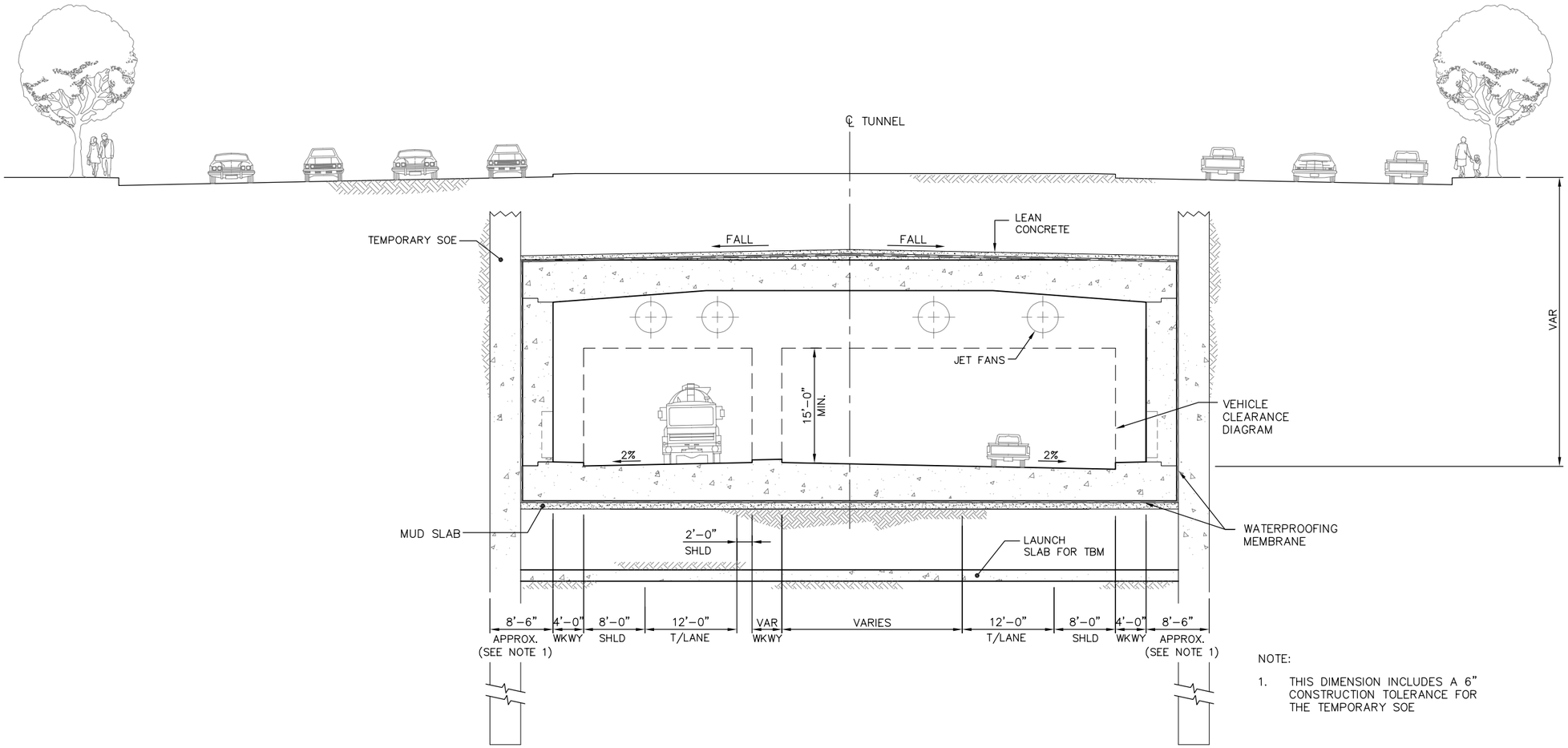

NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY SOE

SECTION C
1/8"=1'-0"
C 33-7
33-1
33-2

PRELIMINARY DRAFT

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TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SECTION D

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06	7	17	

DRAWING FILE NAME.
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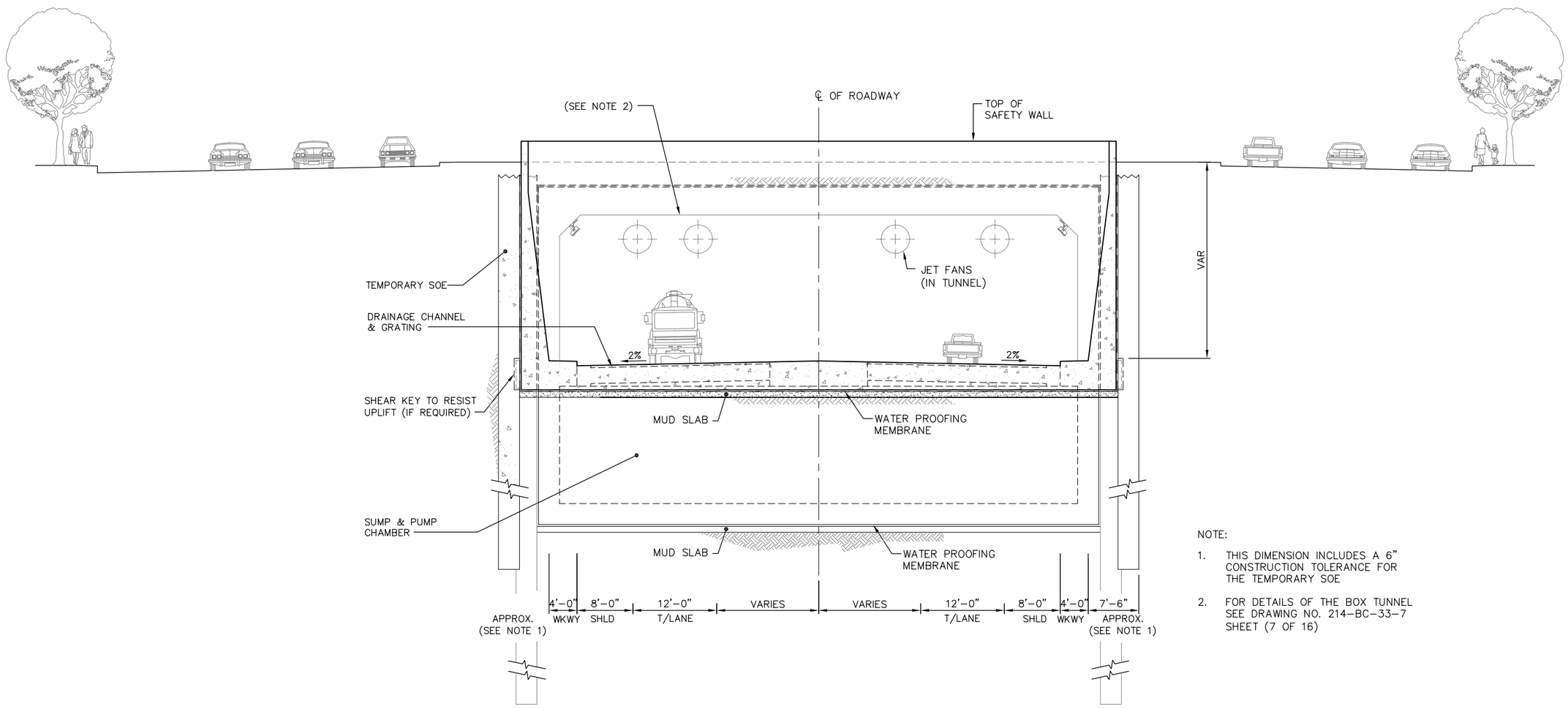

SECTION
1/8"=1'-0"

D
33-8
33-1
33-2

NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY SOE
2. FOR DETAILS OF THE BOX TUNNEL SEE DRAWING NO. 214-BC-33-7 SHEET (7 OF 16)

PRELIMINARY DRAFT

REV	DATE	Description
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STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SECTION E

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06	8	17	

DRAWING FILE NAME. 214303-BC-33-8

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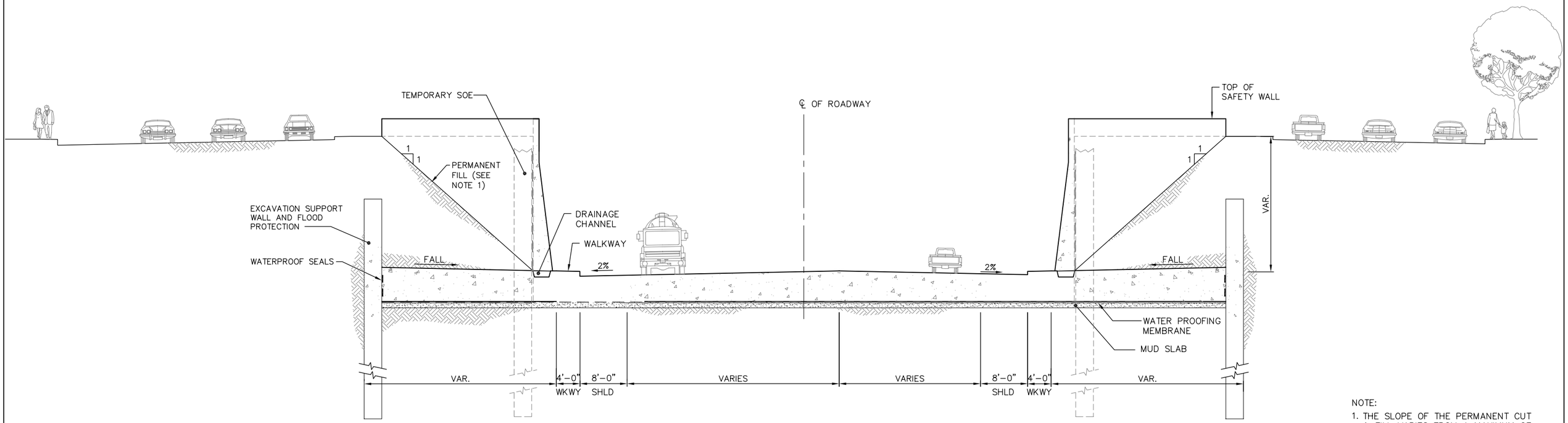

NOTE:

1. THE SLOPE OF THE PERMANENT CUT & FILL VARIES FROM A MAXIMUM OF 45° AT THE PORTAL

SECTION
1/8"=1'-0"

E
33-9
33-1
33-2

PRELIMINARY DRAFT

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TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B – TWIN BORED TUNNELS
SECTION F

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH	9	17	
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			

DRAWING FILE NAME.
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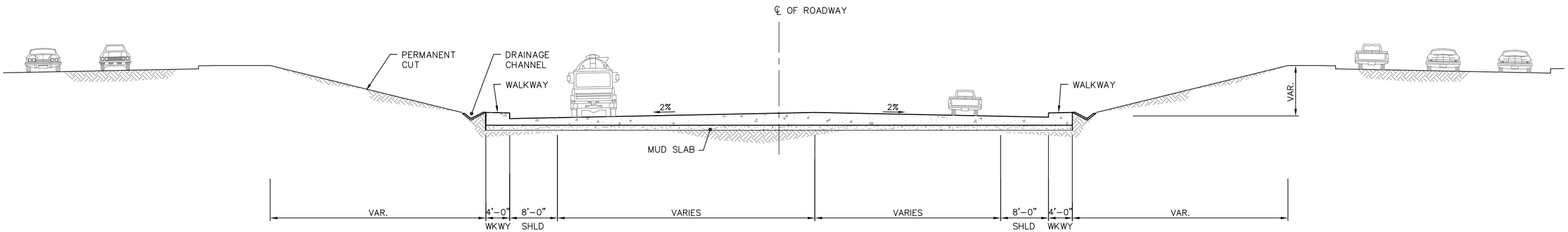

SECTION
1/8"=1'-0"

F
33-10
33-1
33-2

PRELIMINARY
DRAFT

REV	DATE	Description
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The City of CORONADO

Approved: _____ Date: ____

STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SECTION G

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH			
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
DRAWING FILE NAME. 214303-BC-33-10			10	17	

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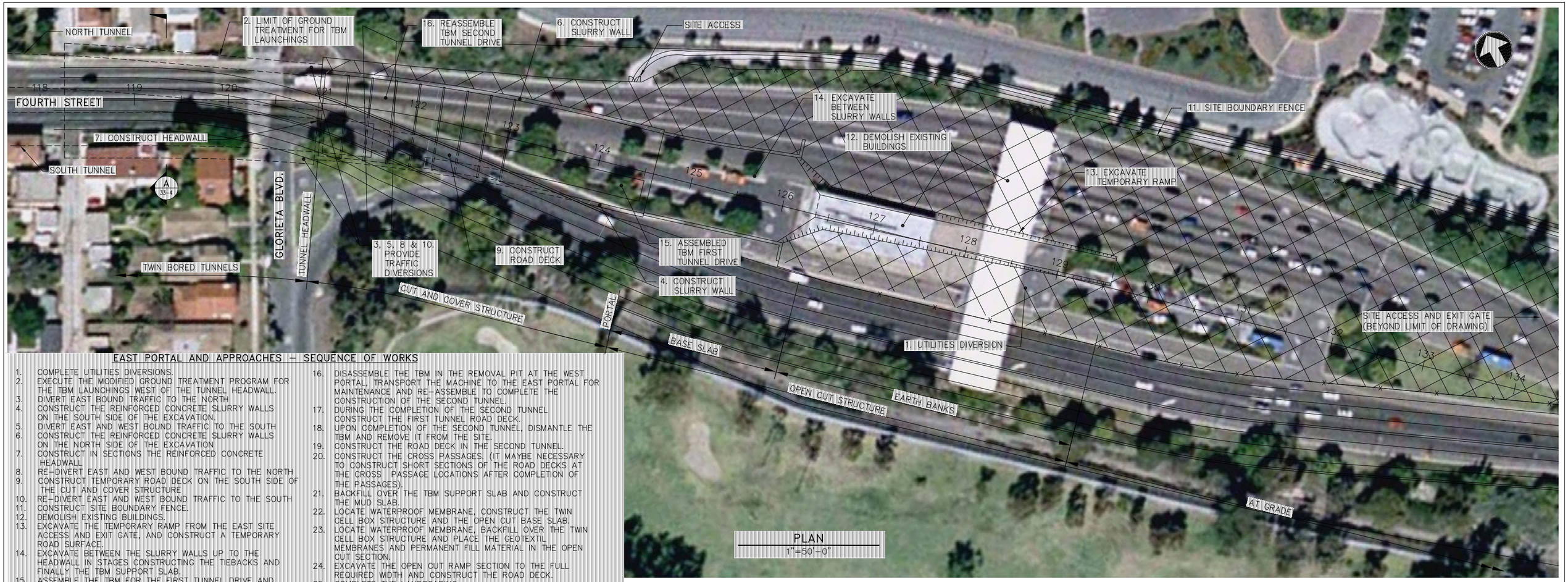
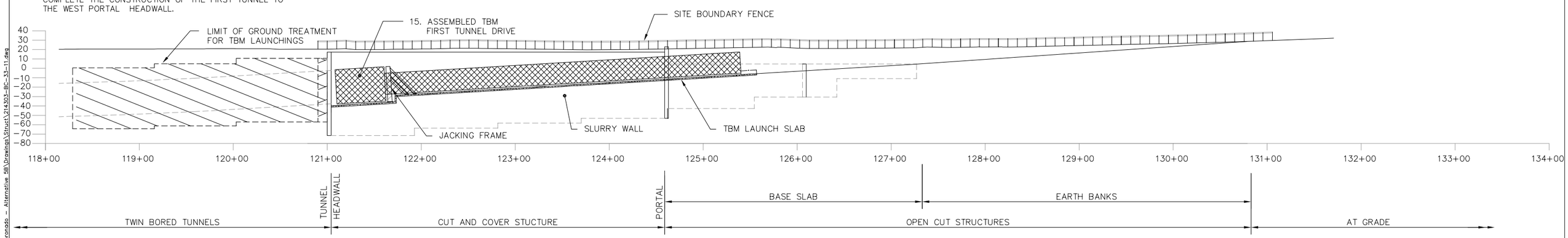


PLAN
1"=50'-0"

EAST PORTAL AND APPROACHES – SEQUENCE OF WORKS

1. COMPLETE UTILITIES DIVERSIONS.
2. EXECUTE THE MODIFIED GROUND TREATMENT PROGRAM FOR THE TBM LAUNCHINGS WEST OF THE TUNNEL HEADWALL.
3. DIVERT EAST BOUND TRAFFIC TO THE NORTH
4. CONSTRUCT THE REINFORCED CONCRETE SLURRY WALLS ON THE SOUTH SIDE OF THE EXCAVATION.
5. DIVERT EAST AND WEST BOUND TRAFFIC TO THE SOUTH
6. CONSTRUCT THE REINFORCED CONCRETE SLURRY WALLS ON THE NORTH SIDE OF THE EXCAVATION
7. CONSTRUCT IN SECTIONS THE REINFORCED CONCRETE HEADWALL
8. RE-DIVERT EAST AND WEST BOUND TRAFFIC TO THE NORTH
9. CONSTRUCT TEMPORARY ROAD DECK ON THE SOUTH SIDE OF THE CUT AND COVER STRUCTURE
10. RE-DIVERT EAST AND WEST BOUND TRAFFIC TO THE SOUTH
11. CONSTRUCT SITE BOUNDARY FENCE.
12. DEMOLISH EXISTING BUILDINGS.
13. EXCAVATE THE TEMPORARY RAMP FROM THE EAST SITE ACCESS AND EXIT GATE, AND CONSTRUCT A TEMPORARY ROAD SURFACE.
14. EXCAVATE BETWEEN THE SLURRY WALLS UP TO THE HEADWALL IN STAGES CONSTRUCTING THE TIEBACKS AND FINALLY THE TBM SUPPORT SLAB.
15. ASSEMBLE THE TBM FOR THE FIRST TUNNEL DRIVE AND COMPLETE THE CONSTRUCTION OF THE FIRST TUNNEL TO THE WEST PORTAL HEADWALL.
16. DISASSEMBLE THE TBM IN THE REMOVAL PIT AT THE WEST PORTAL, TRANSPORT THE MACHINE TO THE EAST PORTAL FOR MAINTENANCE AND RE-ASSEMBLE TO COMPLETE THE CONSTRUCTION OF THE SECOND TUNNEL.
17. DURING THE COMPLETION OF THE SECOND TUNNEL CONSTRUCT THE FIRST TUNNEL ROAD DECK.
18. UPON COMPLETION OF THE SECOND TUNNEL, DISMANTLE THE TBM AND REMOVE IT FROM THE SITE.
19. CONSTRUCT THE ROAD DECK IN THE SECOND TUNNEL.
20. CONSTRUCT THE CROSS PASSAGES. (IT MAYBE NECESSARY TO CONSTRUCT SHORT SECTIONS OF THE ROAD DECKS AT THE CROSS PASSAGE LOCATIONS AFTER COMPLETION OF THE PASSAGES).
21. BACKFILL OVER THE TBM SUPPORT SLAB AND CONSTRUCT THE MUD SLAB.
22. LOCATE WATERPROOF MEMBRANE, CONSTRUCT THE TWIN CELL BOX STRUCTURE AND THE OPEN CUT BASE SLAB.
23. LOCATE WATERPROOF MEMBRANE, BACKFILL OVER THE TWIN CELL BOX STRUCTURE AND PLACE THE GEOTEXTIL MEMBRANES AND PERMANENT FILL MATERIAL IN THE OPEN CUT SECTION.
24. EXCAVATE THE OPEN CUT RAMP SECTION TO THE FULL REQUIRED WIDTH AND CONSTRUCT THE ROAD DECK.
25. COMPLETE THE LANDSCAPING.



PROFILE
1"=50'-0"

GRAPHIC SCALE
50 0 25 50 100
(IN FEET)

PRELIMINARY DRAFT

REV	DATE	Description

PRELIMINARY NOT FOR CONSTRUCTION OR RECORDING

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Approved: Date:

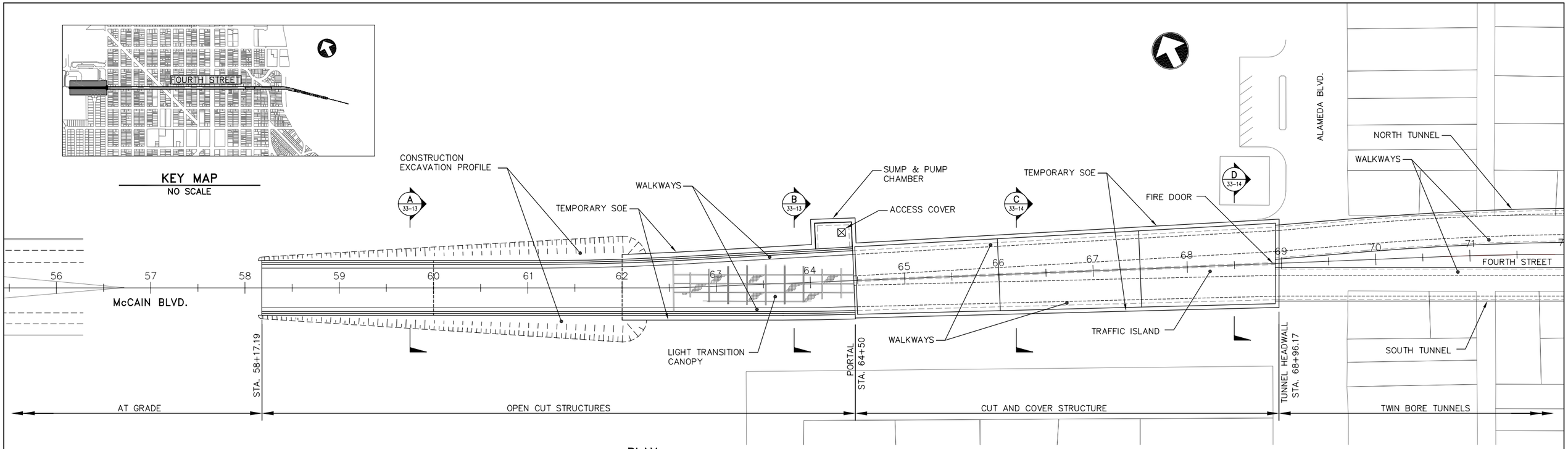
STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

EAST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SITE LAYOUT PLAN AND PROFILE

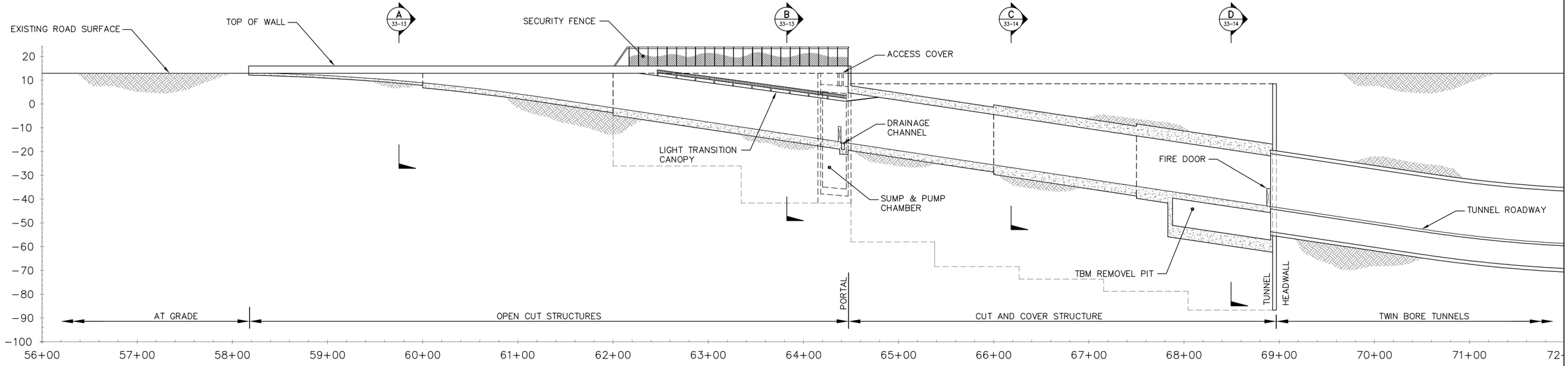
DR JE	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE:12/05/06	DATE:12/05/06	DATE:12/05/06			
DRAWING FILE NAME. 214303-BC-33-11			11	17	

Dec 05, 2006 - 1:20pm - esp32485 - P:\214303 - Coronado - Alternative 5B\Drawings\Struct\214303-BC-33-11.dwg

KEY MAP
NO SCALE



PLAN
1"=50'-0"



PROFILE
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PRELIMINARY DRAFT

REV	DATE	Description

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STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

WEST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
LAYOUT PLAN & PROFILE

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06	12	17	

DRAWING FILE NAME. 214303–BC–33–12

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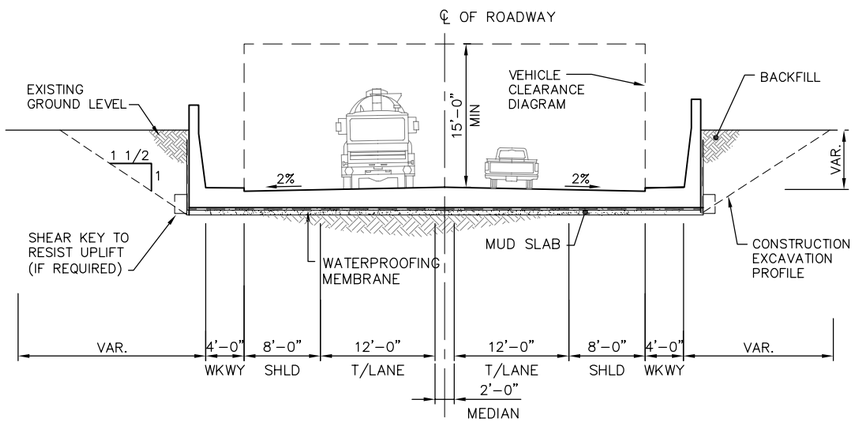
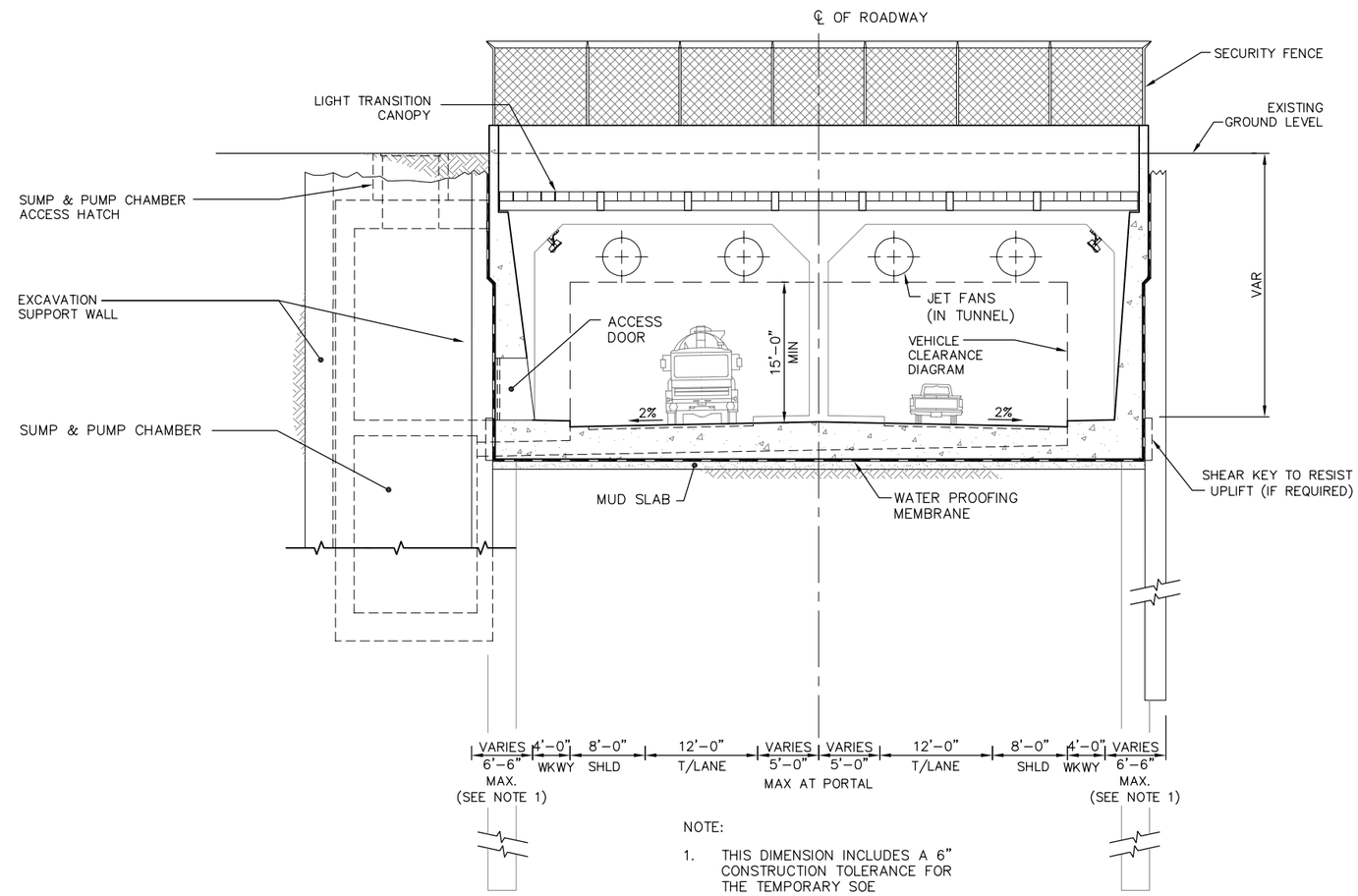


SECTION A (33-13 / 33-12)
1/8"=1'-0"



NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY SOE

SECTION B (33-13 / 33-12)
1/8"=1'-0"

PRELIMINARY DRAFT

REV	DATE	Description

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Hatch Mott MacDonald
Approved: Date:

The City of CORONADO
Approved: Date:

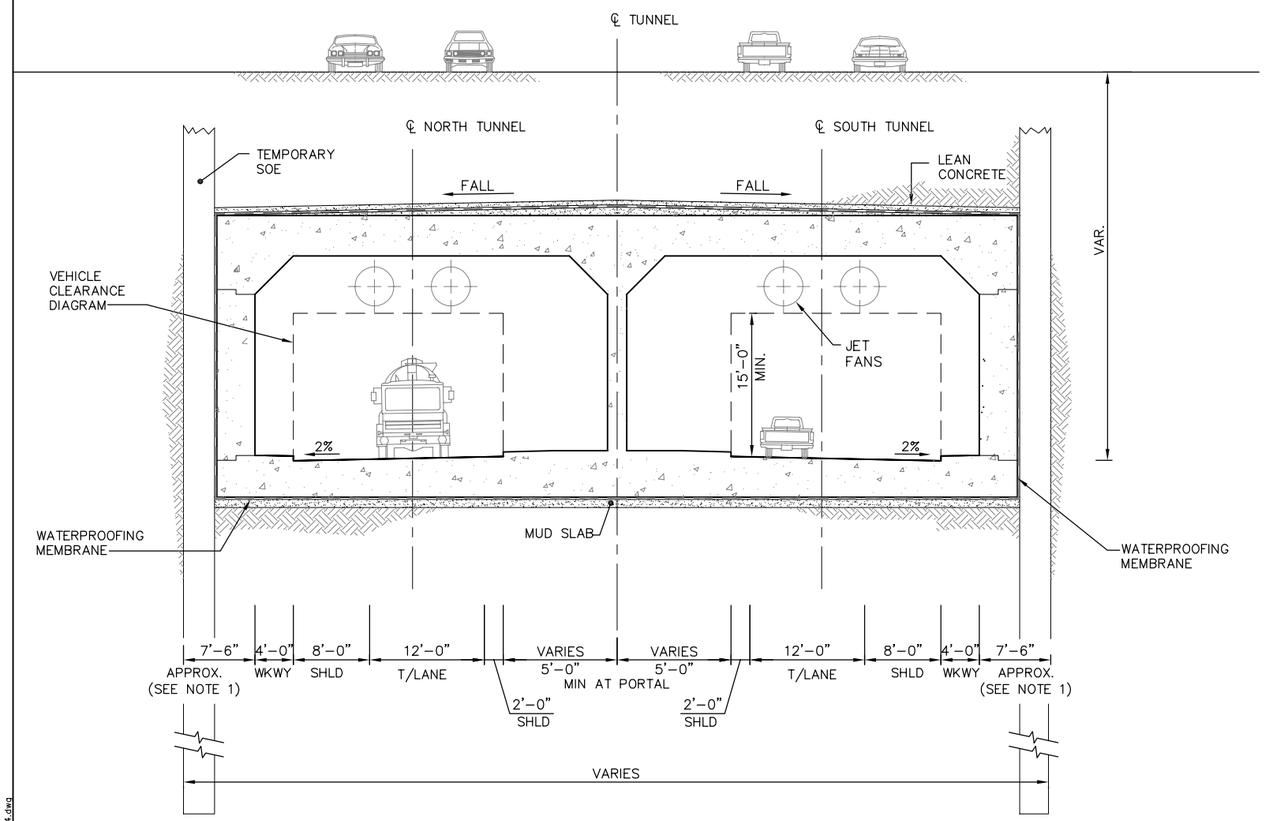
STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

WEST PORTALS AND APPROACHES ALTERNATIVE 5-TWIN BORED TUNNELS SECTIONS A & B

DR RS	DES ACH	CK ACH	SHEET NO	TOTAL SHEETS	REV #
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06	13	17	

DRAWING FILE NAME. 214303-BC-33-13

Dec 05, 2006 - 1:22pm - esp32485 - P:\214303 - Coronado - Alternative 5B\Drawings\Struct\214303-BC-33-13.dwg



SECTION C
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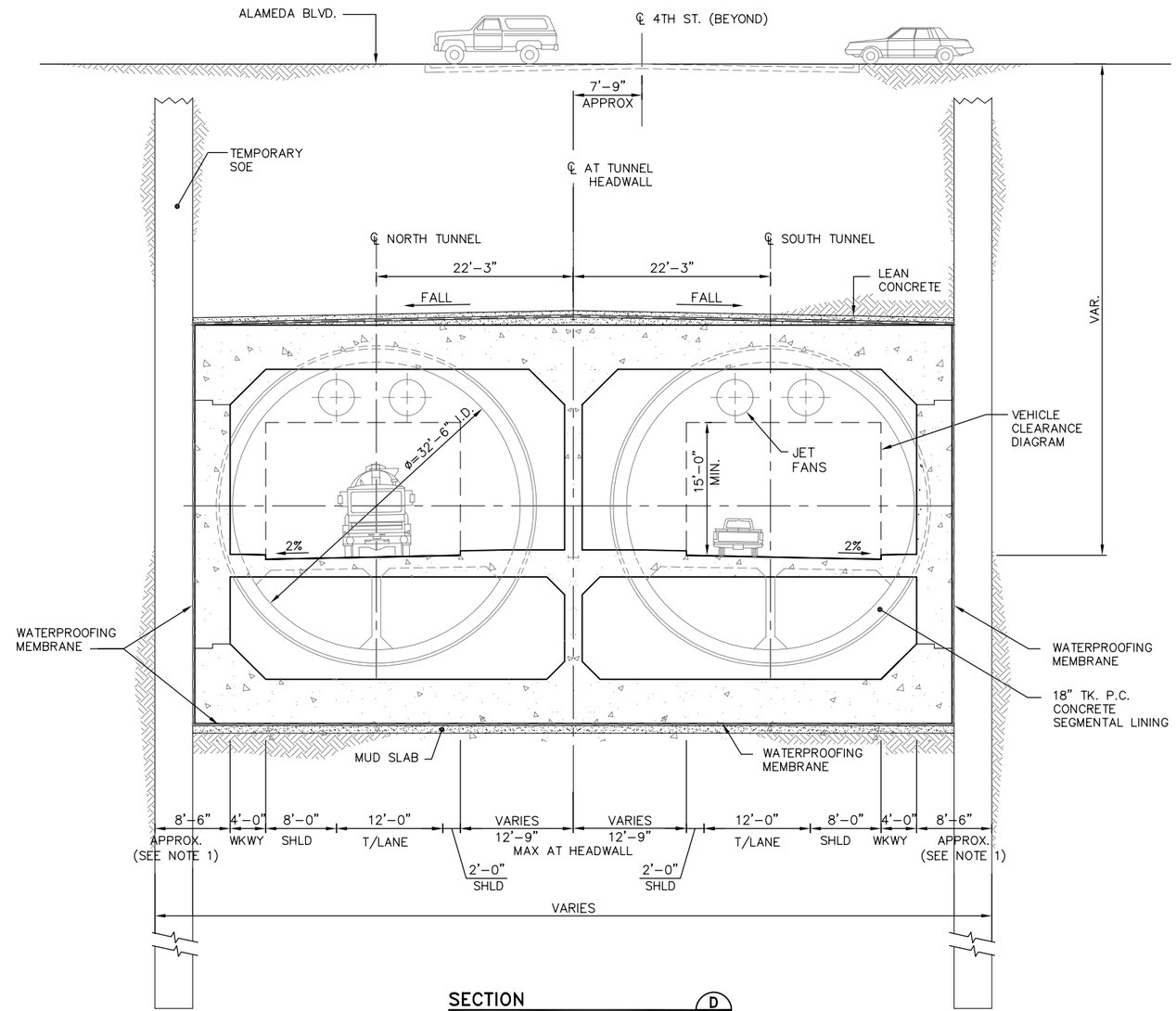
33-14
33-12



SECTION D
1/8"=1'-0"
33-14
33-12

NOTE:

1. THIS DIMENSION INCLUDES A 6" CONSTRUCTION TOLERANCE FOR THE TEMPORARY WALLS

PRELIMINARY DRAFT

REV	DATE	Description
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STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

WEST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
SECTIONS C AND D

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH	14	17	
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			

DRAWING FILE NAME. 214303-BC-33-14

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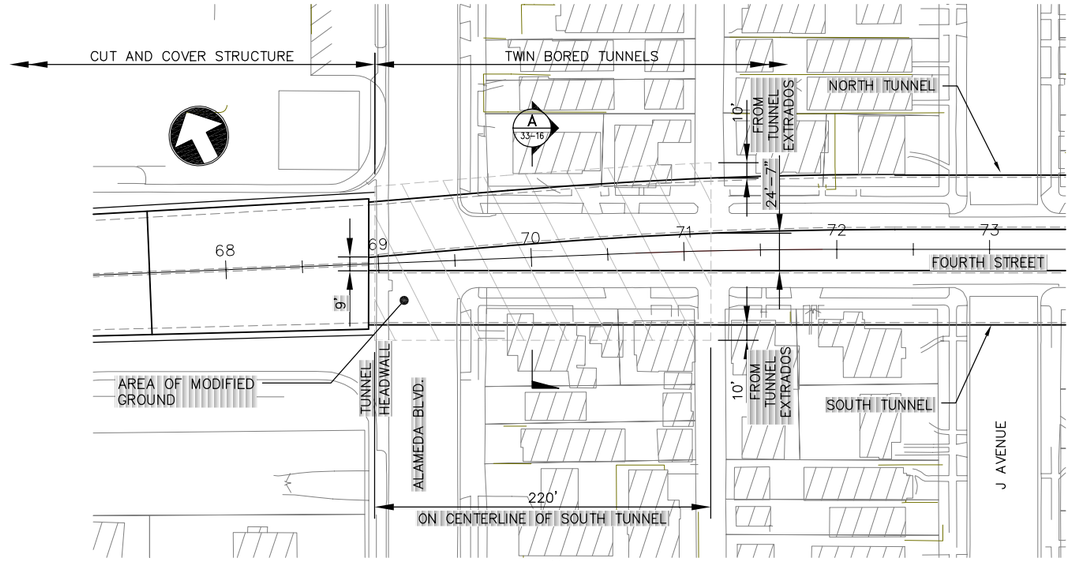

PLAN
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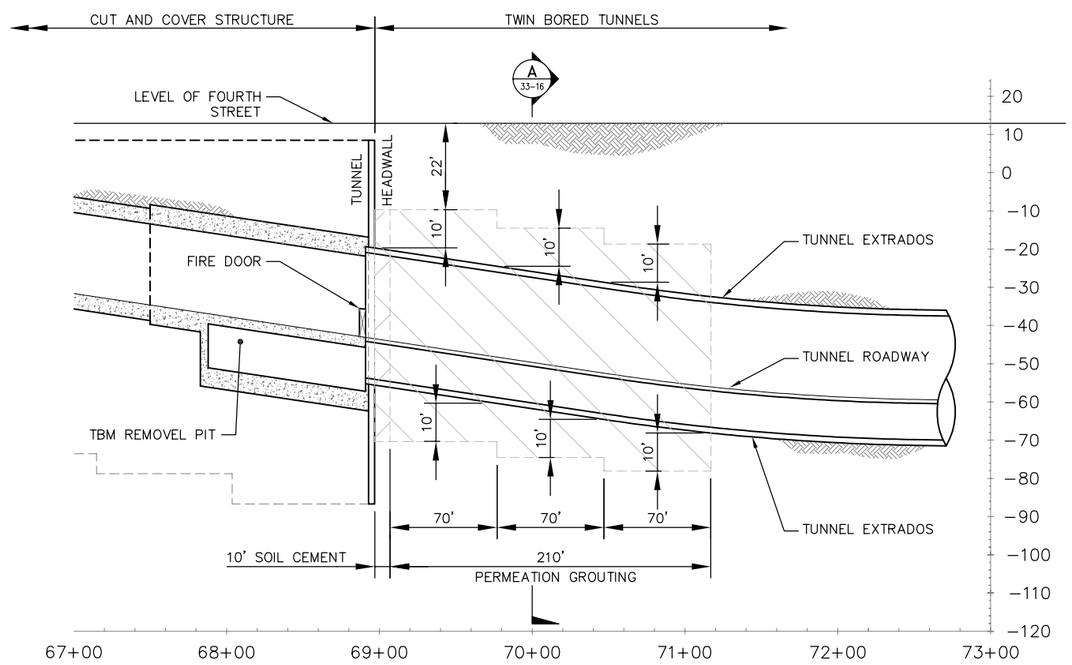

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The City of CORONADO

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STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

WEST PORTAL AND APPROACHES
ALTERNATIVE 5B–TWIN BORED TUNNELS
MODIFIED GROUND LAYOUT

DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH			
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
DRAWING FILE NAME. 214303–BC–33–15			15	17	

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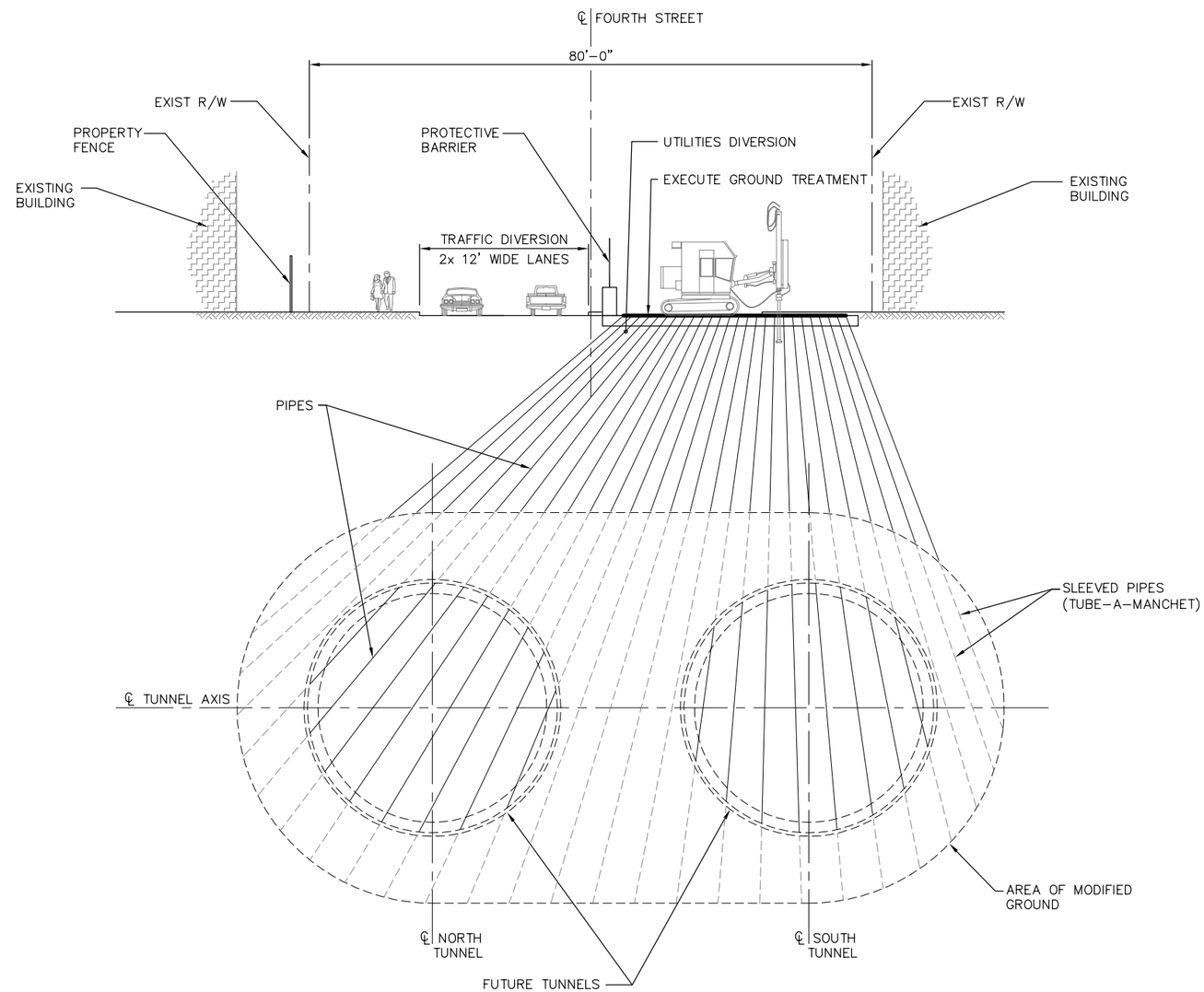

SECTION A (33-16 / 33-15)
1"=10'-0"

PRELIMINARY DRAFT

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STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

WEST PORTAL AND APPROACHES
ALTERNATIVE 5B-TWIN BORED TUNNELS
SECTION A

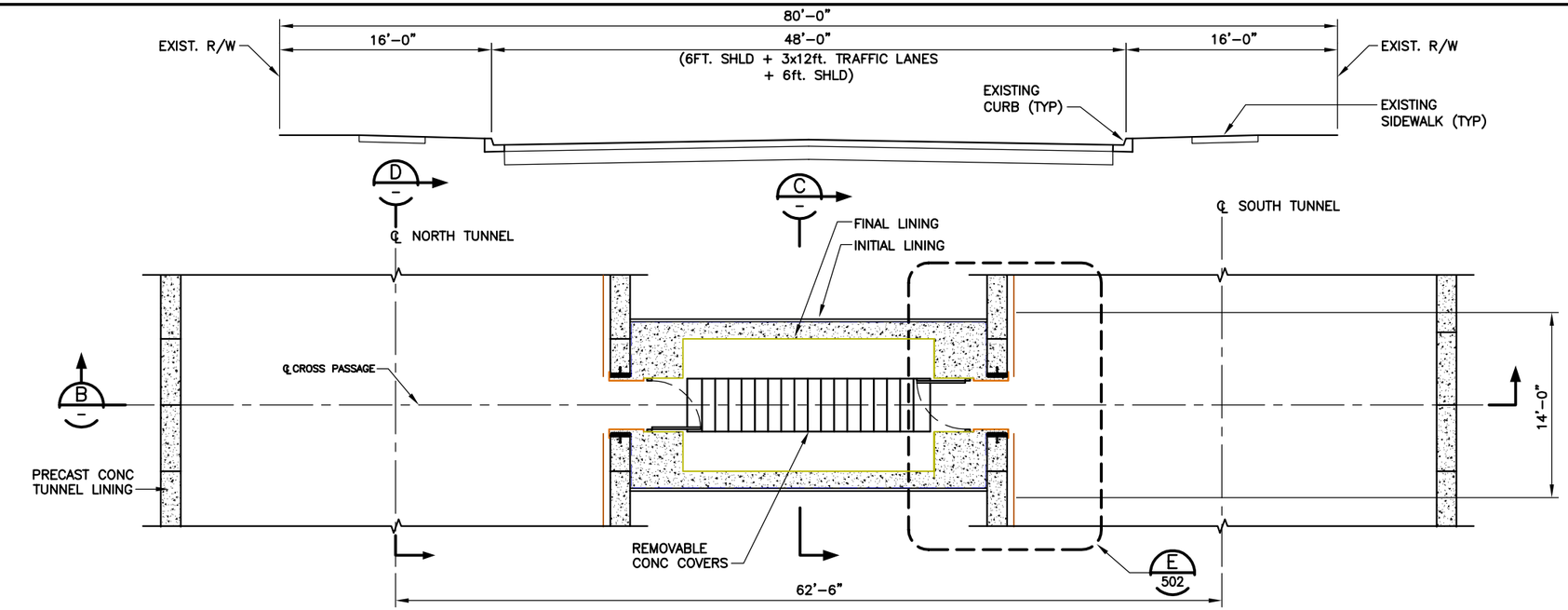
DR	DES	CK	SHEET NO	TOTAL SHEETS	REV #
RS	ACH	ACH			
DATE: 12/05/06	DATE: 12/05/06	DATE: 12/05/06			
DRAWING FILE NAME. 214303-BC-33-16			16	17	

Dec 05, 2006 - 1:24pm - esg32485 - P:\214303 - Coronado - Alternative 5B\Drawings\Struct\214303-BC-33-16.dwg

Appendix D

State Route 75/282 Transportation Corridor Study

Coronado Tunnel Cross Passage Drawing Examples

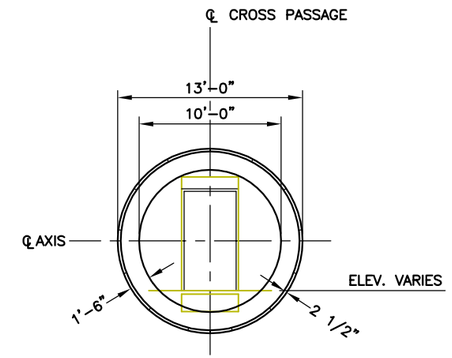


* INDICATES DIMENSION TAKEN AT TUNNEL AXIS.

PLAN A 501

NOTES:

1. SKEW ANGLE ON PASSAGE C DUE TO VARIANCE IN LOCATION OF RINGS OF S1 AND S2 RUNNING TUNNELS TO BE ±8' (FEET) MAX.
2. WHERE ELEVATION BETWEEN S1 AND S2 TUNNEL AXIS VARY, THE CROSS PASSAGE SLOPE IS TO BE ADJUSTED TO SUIT ACTUAL CONDITIONS.



SECTION C 501
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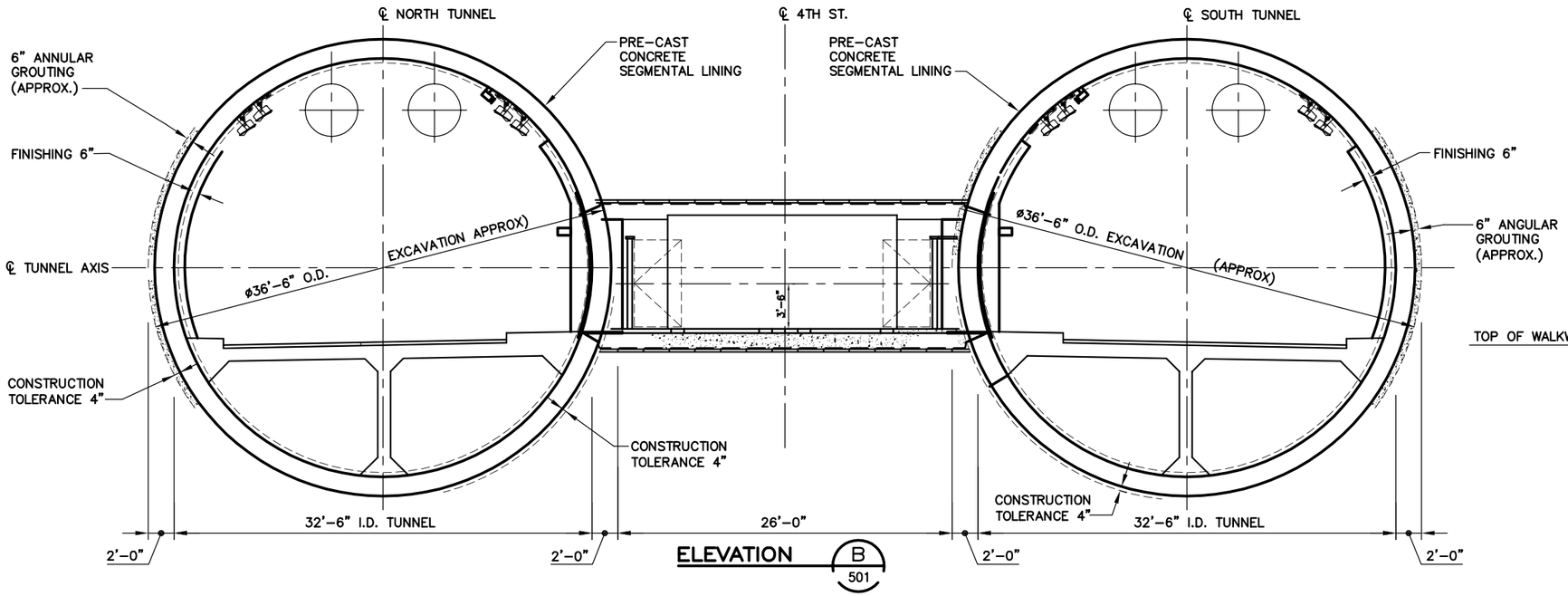
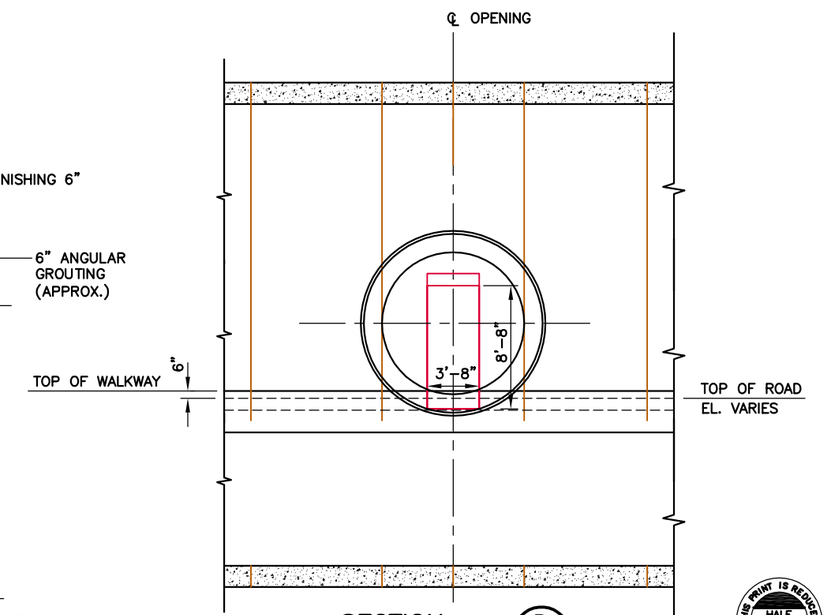


ELEVATION B 501



SECTION D 501
SCALE: NTS

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Hatch Mott MacDonald
Approved: Date:

The City of CORONADO
Approved: Date:

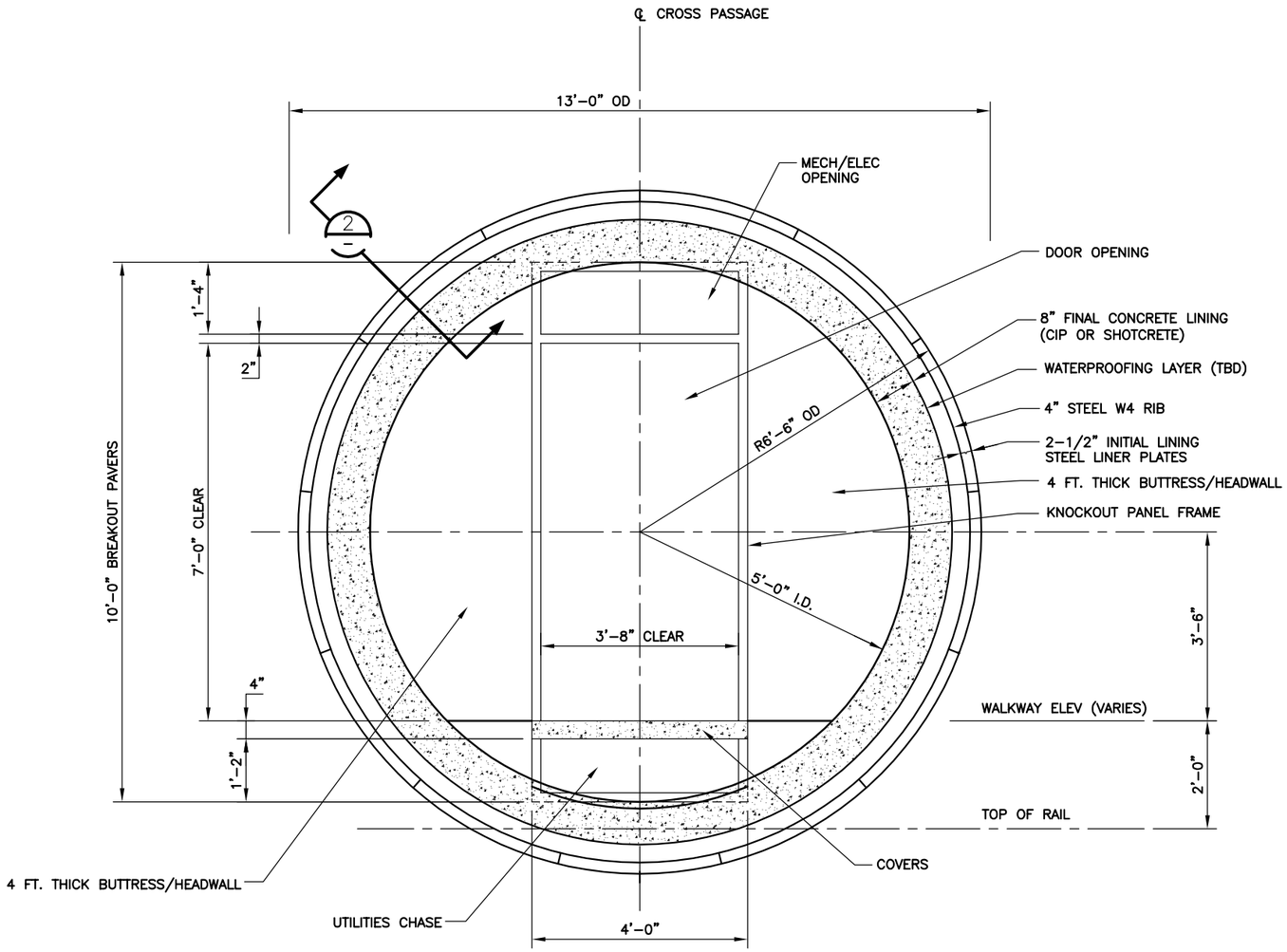
STATE ROUTE 75/282 TRANSPORTATION CORRIDOR PROJECT

CROSS PASSAGES
GENERAL ARRANGEMENT

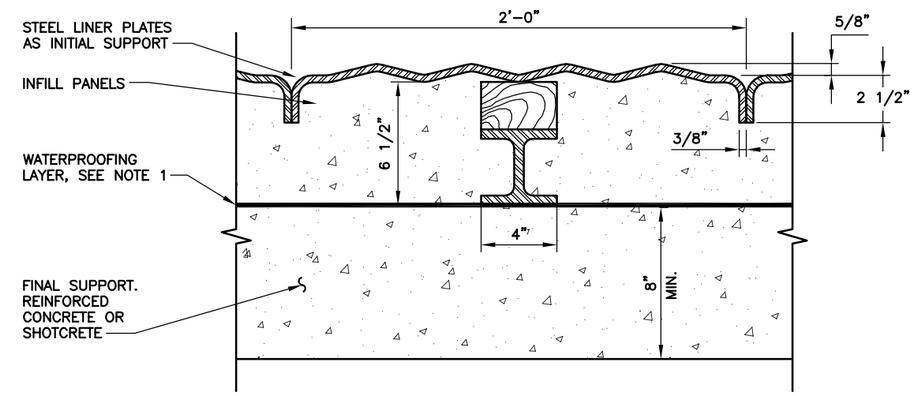
DR NLP	DES SR	CK DJY	SHEET NO	TOTAL SHEETS	REV #
DATE –	DATE –	DATE –	501		0

DRAWING FILE NAME. 214303-BC-501

May 15, 2006 – 2:13pm – eurl4256 – P:\PB\Coronado_214303\16.0 Drawings\cross passages 16.dwg\C6. from SYRT\214303-BC-501.dwg



TYPICAL SECTION (1 / 503) TYPICAL SUPPORT
SCALE: 3/4"=1'-0"



SECTION (2 / 503) TYPICAL SUPPORT
SCALE: 3"=1'-0"

NOTE:

WATER PROOFING SHALL BE SPRAY-ON TYPE FOR SHOTCRETE OPTION, AND EITHER SPRAY-ON OR SHEET MEMBRANE FOR C-I-P OPTON

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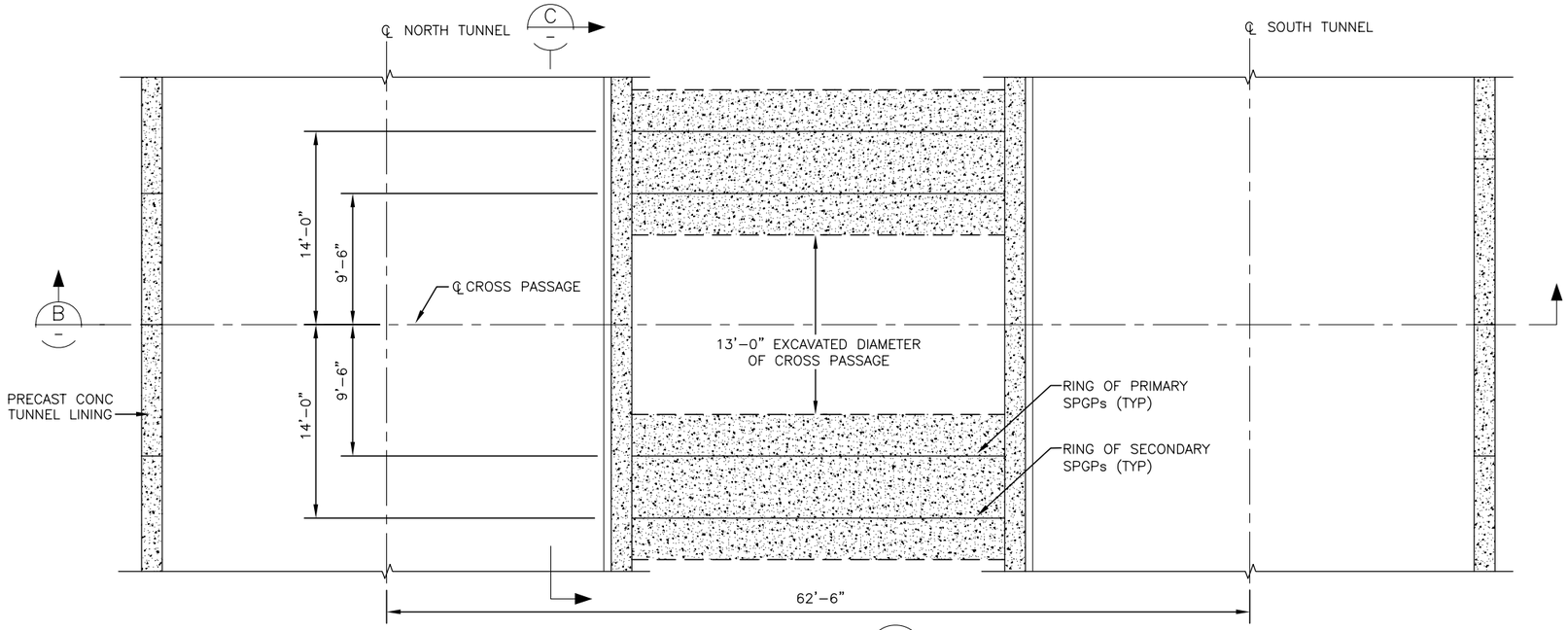
Approved: Date:

The City of CORONADO
Approved: Date:

STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT
CROSS PASSAGES
EXCAVATION AND SUPPORT OPTIONS

DR NP	DES SR	CK DJY	SHEET NO	TOTAL SHEETS	REV #
DATE -	DATE -	DATE -			
DRAWING FILE NAME. 214303-BC-503			503		0

Nov 15, 2006 - 2:13pm - ruid4256 - P:\PB\Coronado 214303\16.0 Drawings\cross passages 16jan05 from SVBT\214303-BC-503.dwg



* INDICATES DIMENSION TAKEN AT TUNNEL AXIS.

PLAN (A)
SCALE: 3/16"-1'-0"

NOTES:

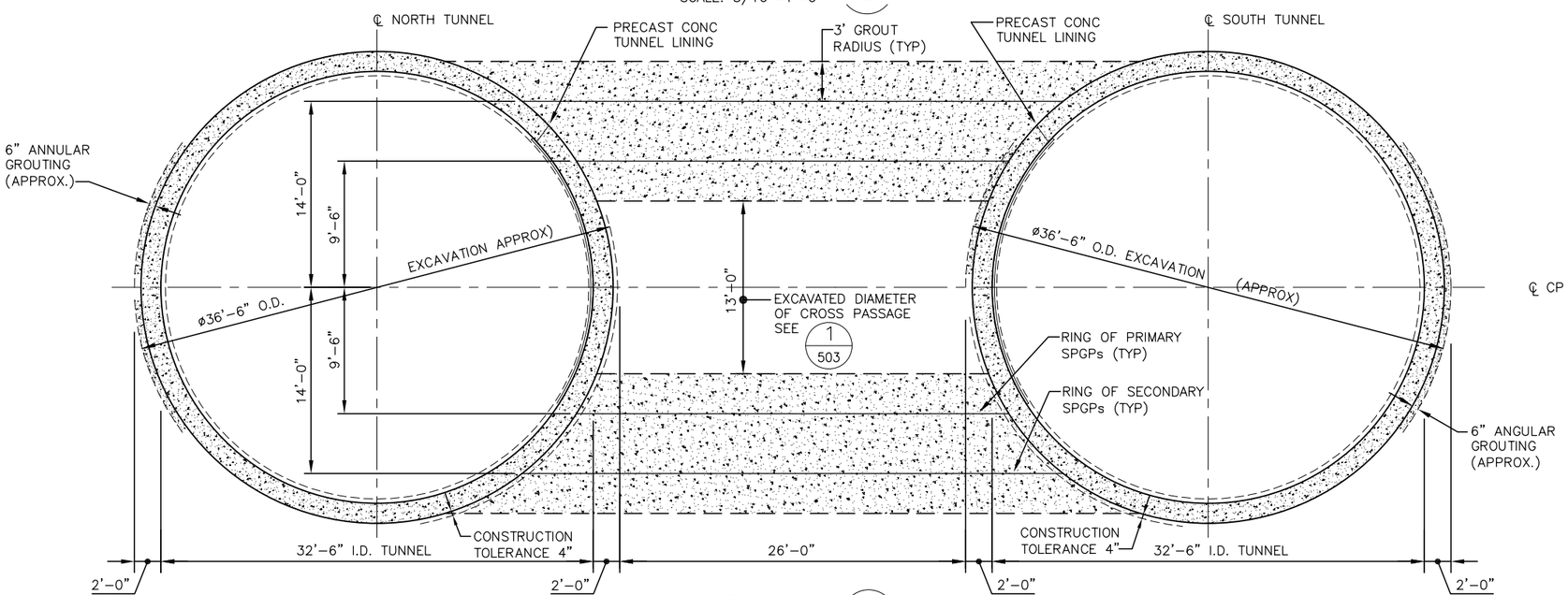
1. GROUT HOLES ARE HORIZONTAL AND DRILLED FROM ONE TUNNEL EITHER BEFORE OR AFTER SECOND TUNNEL.
2. SLEEVE PORT GROUT PIPE (SPGP) INSTALLATION SEE DWG 702.
3. SPGP LOCATION COORDINATED WITH SEGMENT DESIGN, INCLUDING PREMARKED GROUT HOLE COLLAR POSITIONS.
4. VOLUME OF GROUTED SOIL PER CROSS PASSAGE Vg=1,100 yd^3.

SEQUENCE:

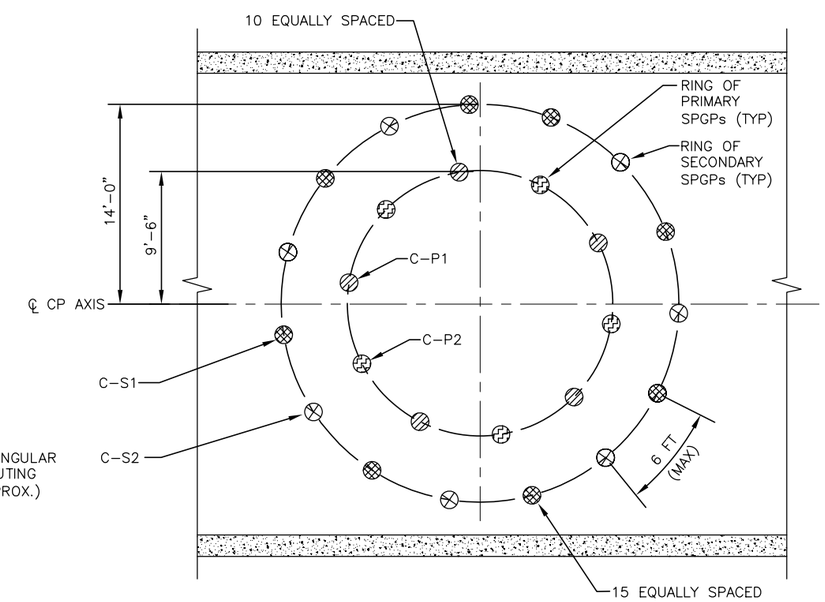
1. DRILL HOLES C-P1.
2. PERFORM PRIMARY GROUTING IN C-P1 HOLES, MONITOR GROUT TRAVEL THROUGH HOLE A3.
3. PERFORM SECONDARY GROUTING IN C-P1 HOLES.
4. DRILL HOLES C-P2.
5. PERFORM PRIMARY GROUTING IN C-P2 HOLES.
6. PERFORM SECONDARY GROUTING IN C-P2 HOLES.
7. DRILL HOLES C-S1
8. PERFORM PRIMARY GROUTING IN C-S1 HOLES.
9. PERFORM SECONDARY GROUTING IN C-S1 HOLES.
10. DRILL HOLES C-S2
11. PERFORM PRIMARY GROUTING IN C-S2 HOLES
12. PERFORM SECONDARY GROUTING IN C-S2 HOLES
13. AT END OF GROUTING, DRILL ADDITIONAL SAMPLING HOLE FROM ALTERNATE TUNNEL AND INSTALL PIEZOMETER AT MIDLENGTH.

LEGEND:

- C-P1
- C-P2
- C-S1
- C-S2



SECTION (B)
SCALE: 3/16"-1'-0"



ELEVATION (C)

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The City of CORONADO — Approved: Date:

STATE ROUTE 75/282
TRANSPORTATION CORRIDOR PROJECT

CROSS PASSAGES
PERMEATION GROUTING

DR NLP	DES SR	CK DJY	SHEET NO	TOTAL SHEETS	REV #
DATE 04/20/07	DATE 04/20/07	DATE 04/20/07	701		0

DRAWING FILE NAME. 214303-BC-701

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