LOS ANGELES COUNTY METROPOLITAN TRANSPORTATION AUTHORITY

WESTSIDE PURPLE LINE EXTENSION PROJECT, SECTION 3
ADVANCED PRELIMINARY ENGINEERING

Contract No. PS-4350-2000

Building, Utility and Adjacent Structure Protection – Tunnels (Final)

Task No. 58.03.110.03B

Prepared for:

Metro

Prepared by:

wsp

777 South Figueroa Street, Suite 1100
Los Angeles, CA 90017

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EXECUTIVE SUMMARY

The Los Angeles County Metropolitan Transportation Authority (Metro) is preparing the Advanced Preliminary Engineering (APE) for Section 3 of the Westside Purple Line Extension (WPLE) Project. As part of the design, structures along the proposed tunnel alignment have been identified that are within the zone of influence of tunneling. These structures have been evaluated to establish the potential effects of settlement from tunneling on the structures and the results summarized in this report.

The subway tunnels for Section 3 of the Metro WPLE will extend along a corridor in Los Angeles from the proposed Section 2 Century City Constellation Station to the Tail Track Exit Shaft west of the proposed Westwood / Veterans Administration (VA) Hospital Station in west Los Angeles. The excavated diameter of the tunnels within Section 3 is about 23.5 feet. The tunnels will typically be lined with precast concrete segmental linings, except in Santa Monica Fault Zone, where a special lining is proposed. Within Section 3, there will be two stations – one at Westwood / UCLA and the other at Westwood / VA Hospital. Since the tunnels will be driven prior to the excavations for the stations, impacts to existing adjacent buildings and other infrastructure due to tunneling through the station area are addressed in this report. However, impacts to buildings due to excavations for the station and associated crossover structures are addressed in a separate report.

Allowable Settlement Criteria

The following criteria were used for this preliminary assessment of movements to structures along the tunnel alignment:

1. Total settlement of any part of a structure to be less than ½ inch.
2. Differential settlement – settlement of one point of a structure relative to another, to be less than L/600, where "L" is the distance between the two points.

Structures subject to settlements less than these levels can be expected to have insignificant impacts due to tunneling. A more detailed analysis in final design is required to confirm settlement levels based on the Final Design and construction methods and to further identify buildings and utilities where mitigation measures may be required.

Buildings along the Alignment

Within the WPLE Section 3 corridor, a total of 205 separate buildings were identified within limits extending 120 feet laterally from each tunnel excavation. The tunnels pass directly beneath private and public properties In Section 3. Data was collected for these buildings to identify structure type, foundation layouts, basement structures, and whether existing below grade construction could interfere with tunnel construction, including basement levels, tiebacks or foundation piers and piles.

Confirmation of existing building information including below grade construction will also need to be conducted at the time of final design.

Major Utilities along the Alignment

Within the WPLE Section 3 corridor, an inventory of major utilities within 120 feet of the lateral excavation limits for each tunnel was performed and recorded in a database. For purpose of this report, a Major utility is defined as meeting the following utility type and size:

- All size gas and oil lines
- Water lines of 12-inches or greater in size
- Power, telecom cable and fiber optics cables with 12 ducts or larger
- Storm drains of 21-inches or greater in size
- Sanitary sewer of 10 inches or greater in size

About 145 major utilities, were identified along the proposed tunnel alignment. Confirmation of all the major utilities along and crossing the alignment will also need to be conducted at the time of final design.

Assessment of Building and Major Utility Settlement along the Section 3 Tunnel Alignment

The primary safeguard for the protection of buildings is the selection of an appropriate tunneling method – one that minimizes ground loss and the ground movements that could affect buildings. State-of-the-art pressurized, closed-face, soft ground Tunnel Boring Machines (TBMs) with earth pressure balance or slurry shield technology provide immediate support of the ground as it is being excavated through monitoring and control of TBM operations. As a result, excavated volumes can be controlled and the risk of ground loss that causes settlement can be reduced. With these types of TBMs operating in the ground conditions found at the tunnel horizon, it is anticipated that ground loss will be limited.

Additional protection measures have been designated as mandatory at two locations, due to proximity of the tunnels to the structures and utilities, at the request of stakeholders. The locations (addressed separately) are as follows:

- Tunnel Crossing beneath Utilities within Sepulveda Boulevard
- Tunnel Crossing beneath 10250 Santa Monica Boulevard (Westfield Mall)

Further analysis and additional documentation are required at a third site where the tunnels pass beneath I-405 Freeway/Wilshire Boulevard Interchange. This crossing is documented in the Final Project Study Report and associated Preliminary Foundation Report (Metro, 2017a). A final PS&E must be prepared by the Design-Build Contractor that will be submitted to Caltrans, the owner of the interchange. As a result of the analyses and the review by Caltrans, additional protection requirements may be required for the crossing.

1.0 INTRODUCTION

The Los Angeles County Metropolitan Transportation Authority (Metro) is preparing the Advanced Preliminary Engineering (APE) for Section 3 of the Westside Purple Line Extension (WPLE) Project. This is one of the three sections being constructed. The Section 3 subway system extends along a corridor in Los Angeles from the proposed Century City Constellation Station to the Tail Track Exit Shaft west of the proposed Westwood/Veterans Administration (VA) Hospital Station in Westwood. Within this corridor, the project team has evaluated potential impacts to adjacent structures and major utilities from tunneling and related shaft and cross passage excavations.

1.1 Building and Utility Protection Program

Tunneling can produce settlements that impact adjacent structures. In general, for structures and utilities within the zone of influence of tunneling (defined as the extent of ground disturbance trough at the ground surface, due to tunneling), the selection and proper use of an appropriate tunneling, paired with careful monitoring, are sufficient to control ground movements. Although at some locations additional protection for structures and utilities may be required in the form of ground modification or underpinning. For contract purposes, the Limit of Observation is defined as zone within 120 feet of the excavation limits of each tunnel, where tunneling has influence on ground settlement.

The selection of an appropriate method of protection is determined on a case by case basis. Therefore, an evaluation of the effects of settlement on each building and major utility along the alignment must be carried out. For buildings or major utilities identified as requiring additional protection, beyond the use of appropriate tunneling techniques, measures are to be developed during final design. This report provides preliminary recommendations.

During construction, it will be necessary to verify that settlements do not exceed predictions and that buildings and major utilities do not undergo movements that could cause damage. Therefore, during tunneling, a construction monitoring program and preconstruction survey will be required that:

1. The instrumentation and monitoring data confirms tunneling is being carried out in accordance with the technical requirements.
2. Provides a record of the structural condition for each building or major utility along the alignment before and after tunneling to demonstrate that no damage has occurred or where it has, to identify necessary repairs.

Instrumentation will include multipoint borehole extensometers, inclinometers and surface settlement markers installed along the alignment, and monitoring points along major utilities. Monitoring will be performed before, during and after the tunnel boring machine (TBM) passes. Building monitoring also requires settlement points, tilt meters, crack monitors, liquid level sensors and visual inspection of buildings and utilities.

1.2 Allowable Criteria for Building and Major Utility Settlement

The following criteria were used for this preliminary assessment of movements to structures along the tunnel alignment:

- Total settlement of any part of a structure to be less than ½ inch.

- Differential settlement – settlement of one point of a structure relative to another, to be less than L/600, where "L" is the distance between the two points.

These are based on the building evaluation criteria presented in the Metro Rail Design Criteria (MRDC), Section 5/Structural/Geotechnical Subsection 5.6.5 C, Rev 10: 10/26/16. They are generic criteria that do not specifically evaluate allowable settlement or distortion based on factors such as building construction, age, and materials use, however MRDC requires analysis consider these factors.

These criteria have found acceptance on previous Los Angeles Metro Projects [Redline and Metro Gold Line Eastside Extension (MGLEE)] as well as other tunneling projects (West Side CSO Tunnel, Portland, Oregon; East Side CSO Tunnel, Portland, Oregon; ECIS, Los Angeles, California). Structures subject to settlements less than these levels can be expected to have insignificant impacts due to tunneling. A more detailed analysis in final design is required to confirm settlement levels based on the Final Design and construction methods and to further identify buildings and utilities where mitigation measures may be required.

The primary safeguard for the protection of buildings and major utilities is the selection of an appropriate tunneling method, one that minimizes ground loss and ground movements that could affect buildings. For the Section 3 tunnels, state-of-the-art pressurized, closed-face, soft ground TBMs (earth pressure balance or slurry shield) are required. They can provide immediate support of the ground as it is being excavated. With closed face TBMs operating in the ground conditions found at the tunnel horizon, it is anticipated that ground loss from tunneling can be limited.

In WPLE Sections 1 and 2 where the tunnel diameter and pillar widths were on the order of 21 feet, ground settlements were computed to be less than 0.5-inch when the ground loss volume was limited to 0.5 percent of tunnel volume. For Section 3, the ground loss is limited to 0.35 percent of tunnel volume and additional tunneling constraints have been specified.

1.3 Building and Utility Protection Program Approach

For WPLE Section 3, the building and utility protection program activities implemented during APE and the previous phases of work have consisted of:

1. Identifying buildings and major utilities within the zone of influence of tunneling.
2. Assembling records of the design and as-built condition of structures and major utilities potentially impacted.
3. Performing analyses of structures and utilities to evaluate required preliminary protection measures.

1.4 Purpose of the Building and Utility Protection Program Report - Tunnels

This report documents:

1. Criteria for assessing effects of tunneling on structures and utilities.
2. Existing buildings, structures and major utilities along the alignment.

3. Records obtained from property owners and other sources (geotechnical reports, information from the City of Los Angeles Department of Building and Safety, as well as utilities). Although such records are not included in this report, they are available for reference.
4. Results of preliminary settlement predictions and list of buildings and structures, and utilities identified as needing additional protection.
5. Preliminary assessment of building and utility protection measures that could be considered by final designers.
6. Recommended Building and Utility Monitoring Program.
7. Site-specific ground improvement program, where required.

1.5 Background

Although the following remarks were made over twenty years ago and significant advances have been made in the application of state-of-the-art tunneling technologies in the United States since, the remarks remain pertinent to all tunneling works. They were made at a Tunnel Review Board meeting for the Los Angeles Metro Rail System in 1994 by Dr. Ralph Peck, a world-renowned tunneling expert, when discussing issues related to tunneling through soft ground in urban areas.

> *"Tunneling is an art that inevitably causes changes in stress in the soil in which it is conducted with corresponding deformations and surface settlements. The introduction of modern tunneling machines has not changed this fundamental fact. Every soft ground tunnel project has caused settlement of the overlying street surfaces and adjacent buildings. Good practice aims to minimize these movements, but it cannot eliminate them.*
>
> *Tunneling is conducted in natural soils. The conditions to be encountered can be investigated by a variety of techniques, but the inherent variations of natural materials preclude the possibility of determining in advance the nature and location of all materials that may affect the tunneling operations. It is to be expected that there will be surprises. Some of the surprises may be the result of past construction activities, not necessarily of record.*
>
> *Good practice attempts to minimize the detrimental effects of tunneling by investigation of conditions, choice of appropriate tunneling methods and equipment, and good construction control. It also recognizes that underground construction is inherently costly, and that to attempt to eliminate the possible detrimental effects of every uncertainty would be prohibitively expensive. Therefore, every modern system is designed on the premise that minor disturbances or damage may occur at some locations, and that the cost of repairs is part of the project costs. Usually, these repairs constitute minor inconveniences for a short time."*

Tunneling advances in the United States have improved significantly since the 1990's with the use of closed and pressurized face tunnel boring machines and single pass pre-cast concrete gasketed tunnel linings. However, these advances do not entirely eliminate the risk of ground settlements. The issues presented by Dr. Peck remain. They must be acknowledged and taken into consideration during design and construction of tunneling projects in urban areas.

In summary, a tunneling method must be compatible with the subsurface conditions. To be effective, it must minimize ground movements that damage structures or utilities and include practical controls that will include the experience of the tunneling contractor and its labor force.

2.0 ALIGNMENT AND GEOLOGY

2.1 Project Alignment

Section 3 is an approximately 2.6 mile long section of subway that is an extension of the Metro Purple Line. It runs from the proposed Century City Constellation Station at Century City near the intersection of Constellation Boulevard and Avenue of the Stars and terminates at a shaft called the "Tail Track Exit Shaft" near the proposed Westwood / VA Hospital at Westwood (see Figure 2-1 for the complete WPLE alignment). The Section 3 alignment route is as follows:

- Tunnel Reach 6: From the Century City Constellation Station's western end, the tunnels run west on Constellation Boulevard and turn north beneath the Westfield Mall to Century Park West. The tunnels pass beneath private residences and city streets until the intersection of Manning Avenue and Wilshire Boulevard. The tunnels turn west on Wilshire Boulevard and continue beneath Wilshire Boulevard to the western end of Westwood / UCLA Station near Gayley Drive/Midvale Avenue. The properties along Wilshire Boulevard consist of commercial buildings, condominiums and apartments.
- Tunnel Reach 7: From the western end of the Westwood / UCLA Station, the tunnels will run west beneath Wilshire Boulevard constrained to the north by the Los Angeles National Cemetery and to the south by the Federal Building. They cross beneath the I-405 freeway and proceed west through the future Westwood / VA Hospital Station to the Tail Track Exit Shaft.

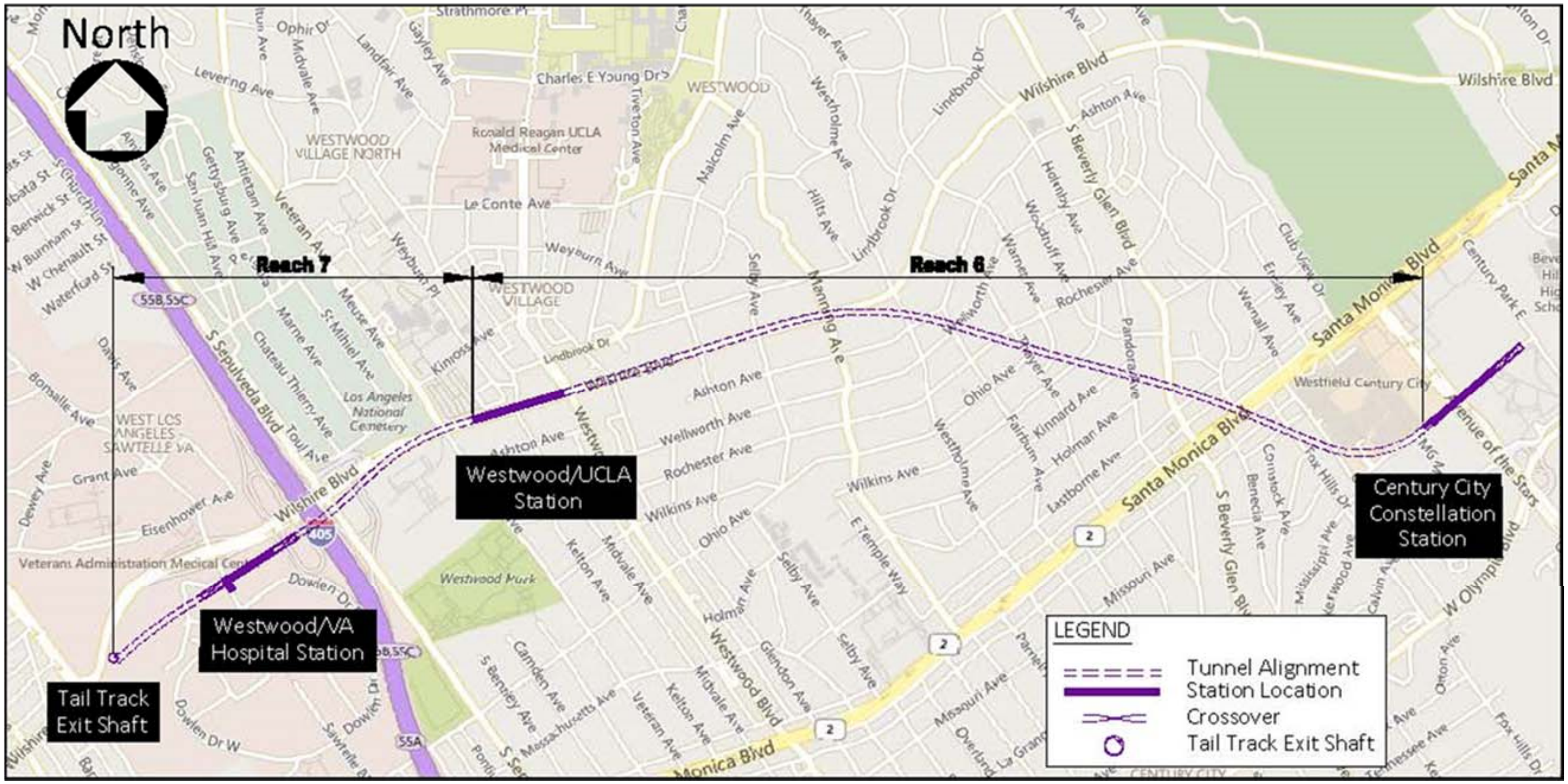
The Tunnel Boring Machine (TBM) excavates a tunnel of approximate 23.5 feet diameter - this is larger than the tunnel bores proposed for Sections 1 and 2. The lining will consists of precast concrete segments (except through Santa Monica Fault Zone where a special lining will be installed. In addition, the pillar width between tunnels in Section 3 varies and is less than one tunnel diameter at some locations of the tunnel alignment.

It is expected that the direction of operation of TBM will be from west to east. TBM will begin operation from Tail Track shaft in the vicinity of the VA Hospital Station, extend in easterly direction toward the Century city Constellation Station. The following elements will also be constructed as part of the tunneling for Reaches 6 and 7.

- Cross Passages: Cross passages connecting the east and west bound tunnels are spaced about 750 feet apart (800 feet maximum). For the Section 3 tunnel alignment, there are 14 cross passages. One of the cross passages located at a low point will also serve as a sump structure.
- Tail Track Exit Shaft: The shaft excavation will be located on the Army Reserve Site. Tunnels will be driven from the shaft to the Century City / Constellation Station.

Two stations, not part of the Tunnel Contract C1151, will be constructed after the tunnels are driven. Since tunnels will be driven prior to station excavation, building impacts due to tunneling through the station area are addressed in this report. This report does not address building protection during station excavation and construction at Westwood / UCLA Station and Westwood / VA Hospital Station; further details are available in Building and Adjacent Structure Protection Report - Cut and Cover Excavation to be issued (Metro, 2017b).

Figure 2-1: Westside Purple Line Extension Alignment



2.2 Project Geology

Southern California's Peninsular Ranges and Transverse Ranges geomorphic provinces form the geologic setting for the project. Each province has its own distinct structural and geomorphic features with the Santa Monica and Hollywood faults being the boundary between them. The Peninsular Ranges province (to the south) is characterized by elongated northwest-southeast trending geologic structures such as the Newport-Inglewood fault zone. In contrast, the Transverse Ranges province (to the north) has east-west trending geologic structures such as the Santa Monica fault, the Hollywood fault, and the Santa Monica Mountains. WPLE Section 3 alignment is approximately 1 mile south of the Santa Monica Mountains.

The Los Angeles Basin occupies the northernmost portion of the Peninsular Ranges and the south part of the Transverse geomorphic provinces. This sedimentary basin is a major elongated northwest-trending structural depression filled since the middle of the Miocene Geologic Epoch with sediments up to 31,000 feet thick.

Figure 2-2 presents an idealized geologic profile along Section 3 alignment using information contained in GDRs for Tunnel reaches 6 and 7 of Section 3 (Metro, 2017c and 2017d). The subsurface formations anticipated to be encountered during tunneling and shaft construction include:

- Older Alluvium: The Older Alluvium (symbol on geologic profiles: Qalo) deposits consist of sediments deposited by sheet flow and by former streams and is expected predominantly in the tunnel bore along the tunnel alignment and in shaft excavation. Less than about 20 feet thick older alluvium deposit is expected in the eastern portion of the Section 3 alignment. These deposits derive mainly from the Santa Monica Mountains to the north.
- Lakewood Formation: The Lakewood Formation (symbol on geologic profiles: Qlw) is found at the eastern end of the Section 3 tunnel alignment (east of the Santa Monica Fault zone) and in the vicinity of the Westwood/UCLA Station. The thickness of the Lakewood Formation at the east end of the alignment varies from approximately 5 feet to 60 feet and at the west end varies between 0 and 70 feet between Malcolm Avenue and Sepulveda Boulevard in Westwood.
- San Pedro Formation: Sediments of the San Pedro Formation (symbol on geologic profiles: Qsp) unconformably underlie the Lakewood Formation and Older Alluvium. The San Pedro Formation ranges from approximately 60 to at least 160 feet below ground surface and it is in excess of 100 feet thick (Metro, 2017e). The San Pedro Formation is found at the eastern end of the Section 3 tunnel alignment (east of the Santa Monica Fault zone).

The tunnels pass through the Santa Monica Fault Zone in Reach 6 in the vicinity of Santa Monica Boulevard. More detailed descriptions of the Project Geology can be found in the Geotechnical Data Reports for Tunnel Reaches 6 and 7 (Metro, 2017c and 2017d).

Shallow groundwater is found within the Younger Alluvium, Older Alluvium and Lakewood Formation. This is semi-perched water trapped in permeable zones underlain by less permeable zones (Metro, 2017e). Although the silty/clayey less permeable zones do not produce great quantities of water, they are saturated and the shallow groundwater levels define the groundwater table. The San Pedro Formation is also a source of groundwater. Groundwater under artesian pressure is found within Santa Monica Fault Zone, see Santa Monica Fault Investigation Report for Tunnel Reach 6 (Metro, 2017f).

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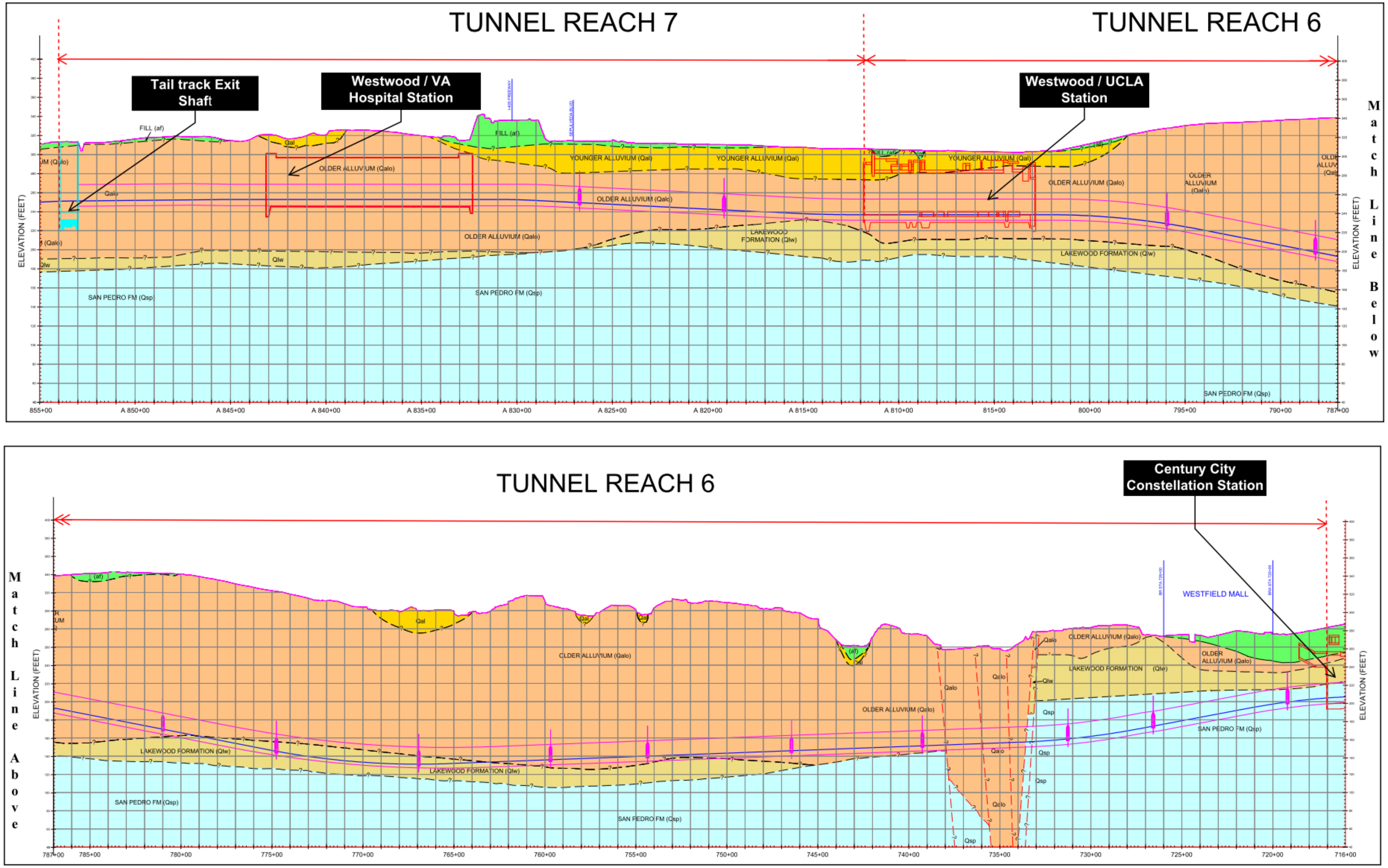
Figure 2-2: Idealized Geologic Profile along Section 3 Alignment



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3.0 BUILDING AND UTILITY SURVEY – DATA AND RESULTS

Buildings along the alignment that are either adjacent to or above the tunnels have been characterized in terms of their use, age, type of structure, height and number of basement levels. In addition, major utilities have been characterized in terms of use, type, size, and depth. All buildings and known utilities within 120 feet of the excavation limits for each tunnel have been screened to determine whether they are within the zone of influence of tunneling and if so, to determine the anticipated ground movements which may impact these structures. A conservative chosen distance of 120 feet from the excavation limits for each tunnel was selected based on the preliminary tunnel profile and is termed the "Limit of Observation".

Final designers will carry out detailed analyses of settlements when the final alignment, depth and tunneling methods and existing conditions have been determined.

3.1 Step 1 – Inventory of Buildings and Major Utilities

3.1.1 Buildings along the Project Alignment

An inventory of buildings within the Limit of Observation along the alignment has been performed and recorded in a database (see Appendix A). The buildings within the Limits of observation for each tunnel are summarized in Table 3-1.

Table 3-1: Buildings Identified along Tunnel Alignment within the Limit of Observation

Location along Alignment	Total No. of Buildings	No. of Buildings with 10 or more stories	No. of Buildings with 3 to 9 Stories
Reach 6 (from Constellation Station to Westwood/UCLA Station)	202	27	41
Reach 7 (from Westwood/UCLA Station to Tail Track Exit Shaft)	3	-	1
Total Buildings	205	27	42

Confirmation of all existing buildings along the alignment will need to be conducted at the time of final design. The following information should be verified:

- Building type, basement level and depth, age, use
- Type and depth of foundations
- Presence of Elevator Pits (including elevator pistons)
- Presence of tieback anchors

No buildings are located within the Limits of Observation of the Tail Track Exit Shaft. Therefore, settlement caused by dewatering was not evaluated in this report for the shaft. Groundwater conditions and dewatering settlement should be evaluated during final design.

3.1.2 Major Utilities along the Project Alignment

An inventory of major utilities within 120 feet of the excavation limits for each tunnel was performed and recorded in a database (see Appendix B). A total of 145 major utilities were identified along the proposed tunnel alignment. The criteria used to identify a utility as a major utility is summarized in Table 3-2.

Table 3-2: Definition of Major Utility

Type of Utility	Size of Utility	No. of Major Utilities
Gas	All	42
Water	12 inches or greater	19
Power	12 ducts or greater	4
Telecom/Cable/Fiber Optics	12 ducts or greater	2
Storm Drain	21 inches or greater	38
Sanitary Sewer	10 inches or greater	33
Oil	All	7

Confirmation and analysis of the performance of all the major utilities along and crossing the alignment will need to be conducted at the time of final design.

3.2 Step 2 – Screening of Buildings and Utilities

3.2.1 Approach

The following criteria were used for the preliminary assessment of movements to structures along the tunnel alignment:

1. Total settlement in any part of a structure to be less than ½ inch.
2. Differential settlement – settlement of one point of a structure relative to another, to be less than L/600, where "L" is the distance between the two points.

Tunneling disturbs the ground and causes ground movements and settlements to occur. Typically, the ground disturbance forms a trough to develop at the surface and the extent of the trough is referred to as "the zone of influence of tunneling." The "limits of observation" is defined as zone within 120 feet of the excavation limits of each tunnel, where tunneling has influence on ground settlement. Appendix C present the calculation methodology for tunneling-induced ground deformation also known as the Free Field Settlement Trough. To evaluate these movements and to assess whether their impact is sufficient to damage nearby buildings requires an assessment of:

1. Tunneling methods to be employed and their effect on ground movements.
2. Sensitivity of buildings to distortion and allowable limits.

Calculated settlement estimates using the methodology described in Appendix C are expected to satisfy above settlement / movement criteria based on the following parameters (using equations in Appendix C), for a tunnel outside diameter of 23.5 feet:

1. Ground loss of 0.35 percent
2. Trough width parameter (K) of 0.4 appropriate for dense sand/silt conditions (see O'Reilly and New, 1982)

The above-chosen value of percentage ground loss was based on our experience and a review of case histories wherein large-diameter TBMs were used successfully in geologic conditions similar to the conditions that will be encountered in Section 3. As shown in the Table 3-3 below, the recorded average volume loss in prior projects was on the order of 0.3 percent of tunnel volume and the average maximum settlement was less than 0.35 inches.

Table 3-3: Large-Diameter TBM Volume Loss Case Histories

Project (Year)	Location	Machine Type	Machine Diameter (feet)	Geology	Cover (feet)	Maximum Settlement (inch)	Volume Loss %
LA Metro Regional Connector Project – Reach 1A (2016)	Downtown Los Angeles	Earth Pressure Balance (EPB)	21.62	Fernando Formation with short interfaces of mixed face conditions of silt, clay, silty sand and poorly graded sands and gravel	Less than 2 tunnel diameters	0.20	0.18
Hubertus Tunnel (2004 to 2008)	The Hague, Netherlands	Slurry / Mix-shield	34.54 to 34.88	Fine Dense Dune Sands, Soft Clays and Silts, High Groundwater Table	16 to 49	0.3 to 0..4	0.18 to 0.25
Heathrow Airside Road Tunnel (2004)	London. England	Dual Mode – EPB and compressed air	30.11	Gravels over stiff, competent London clay, High Groundwater Table	16 to 53	0.2 to 0.8	0.30
M30, North and South Bypass Tunnels (2005-2008)	Madrid, Spain	EPB	49.53 to 49.86	Alluvial deposits, fissured hard clay with gypsum layers. High groundwater	20 to 213	0.2 to 0.4	0.10 to 0.40
San Paulo Metro Line 4San Paulo Metro Line 4 (2002 to 2011)	San Paulo, Brazil	EPB	31.2	Soil from altered gneiss, interbedded clay and sandy clay with gravel, interbedded stiff to hard clay with sands	80	0.3	<0.40

The Section 3 tunnels pass directly beneath a number of buildings and structures. In addition, tunnel diameter has been increased and the width of the pillar between the tunnels has been decreased in comparison with tunneling in previous sections of WPLE – Sections 1 and 2. As a result, control of ground loss is important. Therefore, a stringent ground loss requirement is used to meet the settlement criteria. The following contractual technical requirements specified for the TBM equipment are required to meet the performance criteria:

- Use of a pressurized face TBM
- Provide and use conditioners to stabilize the face while operating in the pressurized mode under all conditions described in the GBR
- Provide shield gap injection system to fill and pressurize annular void about the shield ahead of erected segments
- Perform continuous tunnel construction and with no interventions while tunneling beneath:
  - I-405 freeway / Wilshire Boulevard Interchange – Caltrans right-of-way

  - Sepulveda Boulevard between right-of-way limits
  - Santa Monica Fault Zone, and
  - Westfield Mall between right-of-way limits

- Equip TBM to allow continuous, complete backfill grouting through the tail shield of the annulus between the concrete segments and the excavated surface

3.3 Step 3 – Collection of Building and Utility Information

Following Step 2, properties and major utilities were identified for which additional information would assist the analysis and development of methods for building and utility protection. This included buildings with:

- Tiebacks that would potentially interfere with the tunnel and assessing the feasibility of construction of proposed building and utility protection involving ground improvements (Appendix D).
- Foundations and elevator pits/pistons that could potentially experience undesirable settlements due to tunnel excavations.

The criteria for evaluating the potential presence of tiebacks at adjacent buildings were as follows:

- Excavations greater than 20 feet during construction of the building.
- Excavation occurring after 1969. This is considered to be when tieback construction use began in Los Angeles for deep excavations.
- Geotechnical reports, building records or shoring plans indicating tiebacks.

Databases (geotechnical reports and the Los Angeles Department of Building and Safety [LADBS] database) have been researched to provide information to establish where tiebacks have been used to support deep excavations. Information was obtained from publicly available documents and plans, and occasionally from building engineers and building owners. Although a good faith effort has been undertaken to obtain information on tiebacks, complete records of their use has not been obtained. Previously installed tiebacks for properties along the tunnel alignment and currently tiebacks proposed at 2025 Avenue of the Stars are outside the excavation limits for the proposed tunnels based on available records. However, additional evaluation of the tiebacks should be performed during final design to determine the as-built location of the tiebacks to avoid impact during tunneling. As-built records from the utility owner were reviewed to estimate the depth and location of major utilities. Potholing for utilities should be performed during final design to identify a more accurate location of the existing utilities.

Information obtained from the research is available and is also summarized in a database. The Building and Utility Protection Program database is preliminary and the searches and research should be continued as the design is finalized. Final design should take into account all available information for all buildings and utilities along the alignment and take into consideration the potential impacts where data is missing.

3.4 Evaluation Summary

The estimated settlements along the alignment have been evaluated and distortions of buildings compared with damage categories developed based on case studies by Boscardin and Cording (1989) and Burland and Wroth (1974). Table A-1 and A-2 of Appendix A present the addresses of the properties along the tunnel alignment of Section 3 that are within the Limit of Observation, estimated magnitude of total and differential settlements at the ground surface in the vicinity of the properties.

3.4.1 Preliminary Analysis for Tunnels

Free field surface settlement estimate profiles for twin tunnels of diameter 23.5 feet, separated by a an average pillar width of 19.2 feet, at depths of 50 feet and 100 feet are as shown in Figure 3-1 and Figure 3-2, respectively, corresponding to a ground loss of 0.35 percent. The anticipated maximum ground settlements at depths of 50 feet and 100 feet along the centerline between the two tunnels are estimated to be 0.4 inch and 0.3 inch, respectively. Since the Section 3 tunnels range in depth from 50 to 150 feet, surface settlements can be expected to be less than ½-inch, when ground loss is maintained at less than 0.35 percent.

Figure 3-1: Estimated Settlements for Single and Twin Tunnel with Outside Diameter = 23.5 feet and Depth to Crown = 50 Feet

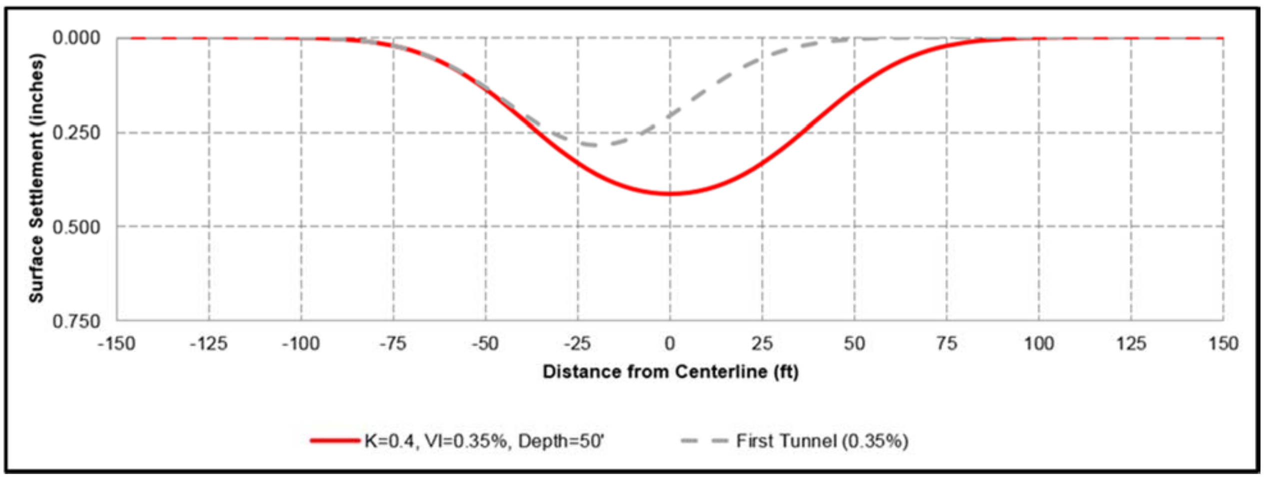
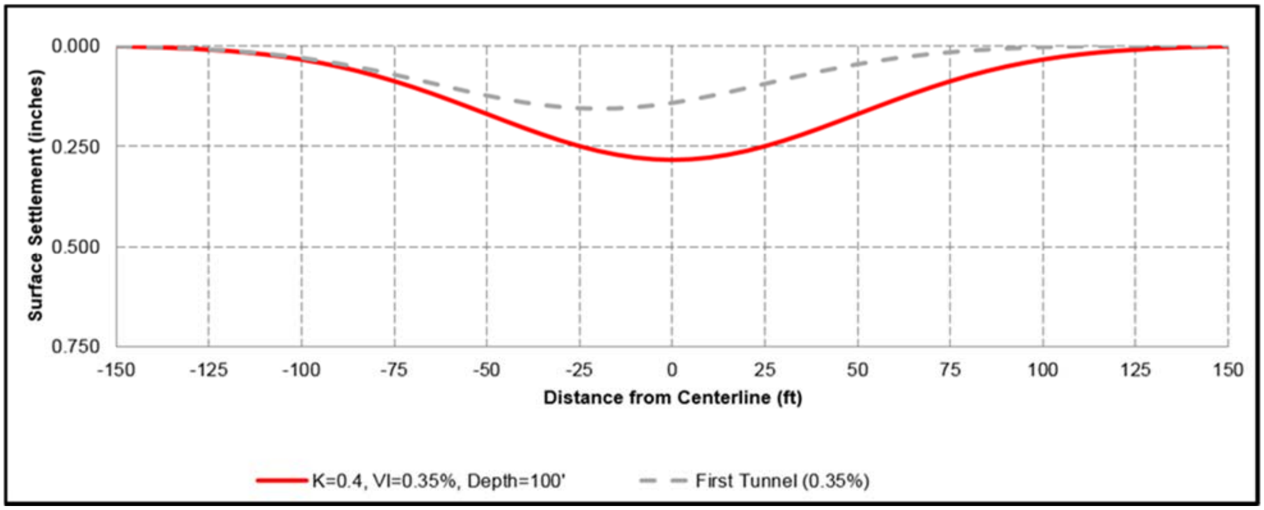


Figure 3-2: Estimated Settlements for Single and Twin Tunnel with Outside Diameter = 23.5 feet and Depth to Crown = 100 feet



3.4.2 Building and Structure Evaluation

Figure 3-3 includes the estimated surface settlements along the entire alignment. It is based on 0.35 percent ground loss and the tunnel configurations (diameter and pillar widths) described in Section 2.1. It also provides the surface settlement for each building at its closest face to the tunnels. Estimated ground surface settlements along the tunnel alignment is less than 0.5-inch. Further, estimated differential settlement between two points of the building varied from 1/3,800 to 1/5,000 (see Appendix H for results).

Some buildings along the alignment have basements. Figure 3-4 presents the estimated settlement of buildings below the basement levels along the entire alignment. At some locations, the tunnels are less than 50 feet below the foundations of existing structure basements. Generally, the settlements at the basement levels (see table A-3 of Appendix A) meet the 0.5-inch settlement criteria and the differential settlements are on the order of 1/1,000 to 1/5,000. However, they are exceeded at Westfield Mall, As a result, ground improvement is a requirement at the Westfield Mall. Detailed analyses in final design will be required to confirm estimated ground movements at buildings and utilities where mitigation measures are required, and to perform final design of protection measures.

Tunnel Reach 6

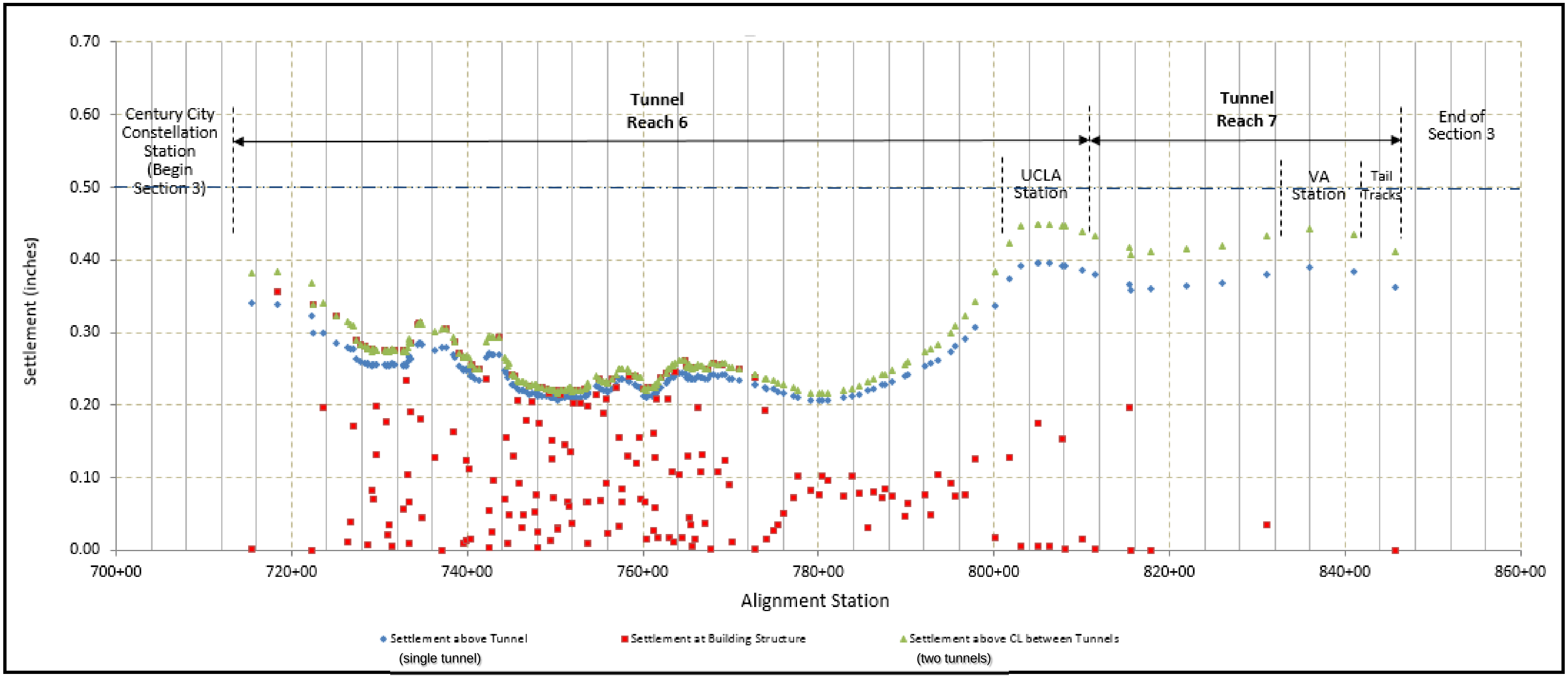
For Tunnel Reach 6 from Century City Constellation Station to Wilshire Boulevard at Manning Avenue, 178 separate buildings (of total 202 buildings in Reach 6) were identified within the Limit of Observation. Except in the area of two buildings (i.e. existing AMC Theatre and proposed Nordstrom Building) at 10250 Santa Monica Boulevard (within the Westfield Mall), the tunnels are relatively deep along this reach with surface settlements for all other buildings is below 0.5 inches. For AMC Theatre and Nordstrom buildings, the distance from basement slab to tunnel crown is about 30 feet and 40 feet, respectively; and the estimated settlement at the building basement is slightly greater than 0.5 inch. For the tunnels within the Wilshire Boulevard right-of-way west of Manning Avenue to the west end of Tunnel Reach 6, the maximum settlement and the settlement directly over each tunnel occur within right-of-way of Wilshire Boulevard and are less than 0.5 inches. For the buildings along Wilshire Boulevard that are located within the Limit of Observation, the settlements are estimated to be less than 0.5-inch as they are set back from the street.

Details related to specific structures and requirements for additional protection measures are discussed in Section 5.

Tunnel Reach 7

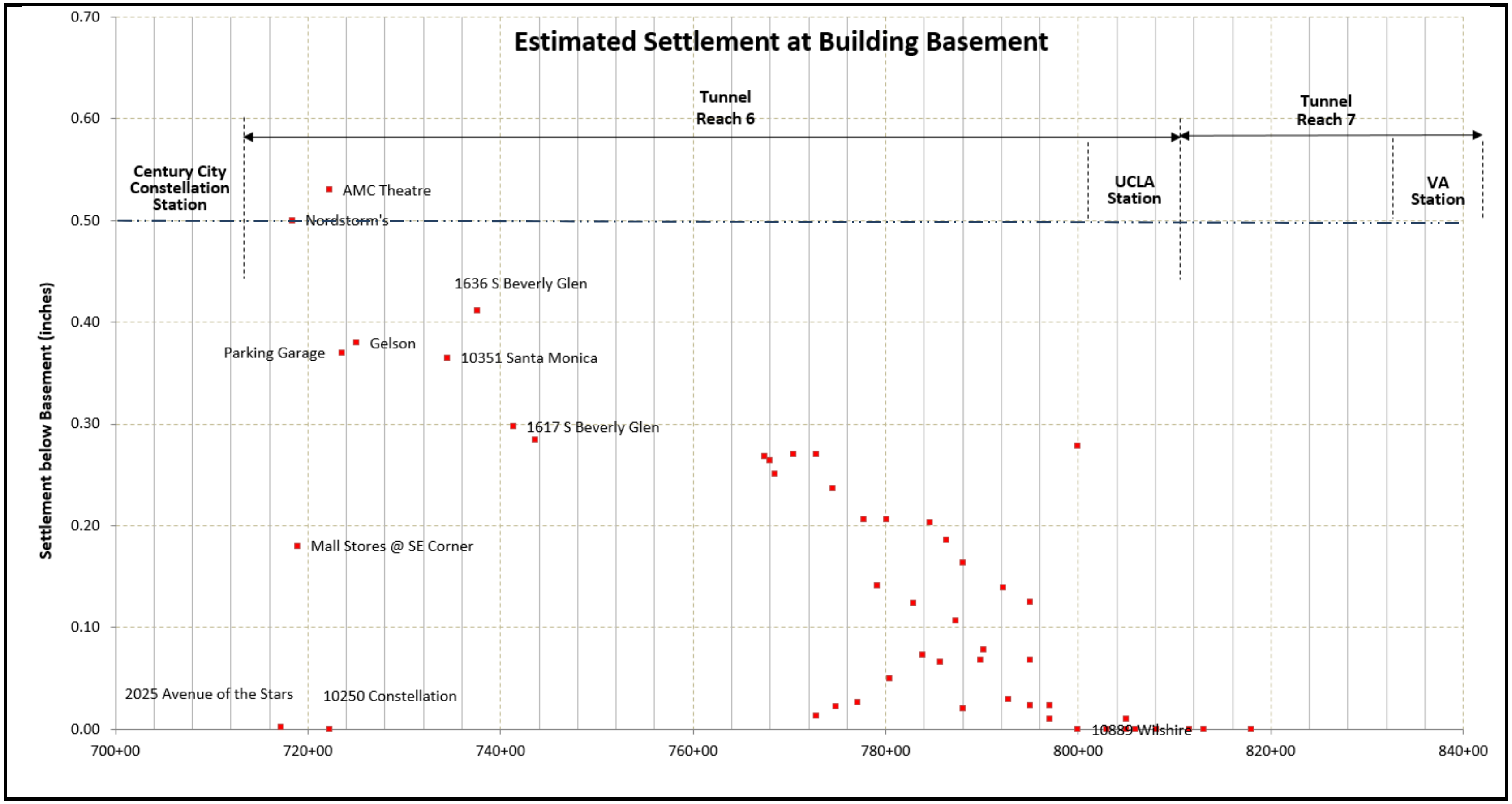
For Tunnel Reach 7 from Westwood/UCLA Station to Westwood/VA Station, only three buildings are within the Limit of Observation of tunnel excavation. The tunnels are relatively deep in this area with surface settlements for these buildings below 0.3 inch.

Figure 3-3: Surface Settlements from Tunneling along Section 3 Alignment



See Table A-1 and A-2 of Appendix A for the properties address where ground settlements are calculated

Figure 3-4: Building Basement Settlements from Tunneling along Section 3 Alignment



See Table A-3 of Appendix A for the properties address where settlements below basements are calculated

3.4.3 Utilities Evaluation

For purpose of this report, a Major utility is defined as meeting the following utility type and size:

- All size gas and oil lines
- Water lines of 12-inches or greater in size
- Power, telecom cable and fiber optics cables with 12 ducts or larger
- Storm drains of 21-inches or greater in size
- Sanitary sewer of 10 inches or greater in size

A summary of the type of major utilities is provided on the project definition drawings. A total of 145 major utilities were recorded in a database (see Appendix B) along the proposed tunnel alignment. In general, considering that the ground surface settlement shown in Figure 3-3 meet the 0.5-inch settlement criteria, it can be concluded major utilities that are located at shallower depths below ground surface will have settlements less than the project criteria of 0.5-inch. However, some of the major utilities under Sepulveda Boulevard are located at greater depths, and therefore are closer to the tunnel crown, thereby the calculated settlement below invert of the utilities will exceed project criteria of 0.5-inch. Site-specific utility protection measures for the major utilities under Sepulveda Boulevard are presented in Section 5.2.

A more detailed analysis of the ground settlement below major utilities is required in final design to evaluate the performance of the utilities and what mitigation measures are to be performed during construction. Performance requirements, criteria and mitigation measures for utilities during tunneling will require approval from the utility owner.

The criteria for utilities will need to be addressed during final design with concurrence from the utility owners and Caltrans.

3.4.4 Preliminary Analysis at Cross Passage Locations

Mined cross passages will connect the tunnels at fourteen locations. At these locations, there will be settlement from the excavation of the cross passages as well as settlements from the TBM tunneling. An estimate of the surface settlement at the cross passage locations is shown in Table 3-4, based on an estimated ground loss of 1.3 percent of excavated volume for a case of hand-mining method of excavation of soils without ground improvement. The estimates indicate that settlements greater than 0.5 inch will be experienced at some locations unless ground improvements are carried out. The ground improvement will not only reduce settlements from ground loss but will also control groundwater inflows and provide more competent ground for the construction of the connections between the cross passages and the tunnels.

Table 3-4: Estimated Surface Settlement from Tunneling and Cross Passage Excavation (without Ground Improvement)

Cross Passage Number	Station	Estimated Surface Settlement from Tunneling at Cross Passage	Estimated Surface Settlement from Cross Passage Excavation and Tunneling
CPB-42	BR 719+20	0.29	0.64
CPB-43	BR 726+77	0.21	0.49
CPB-44	BR 734+75	0.24	0.56
CPB-45	BR 742+74	0.22	0.50
CPB-46	BR 747+93	0.16	0.39
CPB-47	BR 754+36	0.17	0.41
CPB-48	BR 759+69	0.17	0.41
CPB-49	BR 766+93	0.19	0.44
CPB-50	BR 774+75	0.17	0.40
CPB-51	BR 780+99	0.16	0.37
CPB-52	BR 787+18	0.18	0.43
CPB-53	BR 795+95	0.25	0.56
CPB-54	BR 819+15	0.38	0.80
CPB-55	BR 826+71	0.41	0.84

4.0 BUILDING AND UTILITY PROTECTION PROGRAM

On most transit tunnel projects, portions of the alignments are constructed to some extent beneath buildings and utilities due to alignment refinements and minimum geometry requirements for smooth train operations. It is the contractor's ability to control and limit ground movements that allows tunneling to be accomplished successfully. Ground movements and related damage to structures and utilities can be controlled by:

1. Limiting ground movements caused by the tunneling
2. Minimize groundwater leakage into tunnel excavation
3. Improving the ground
4. Replacing ground loss, and
5. Providing protection at or on the structure, such as underpinning and reinforcement.

The primary safeguard for the protection of buildings and utilities is the selection of an appropriate tunneling method—one that minimizes ground loss and the ground movements that could affect buildings and utilities. Over the past 10 to 15 years in the U.S., pressurized, closed-face soft ground TBMs have been used to provide immediate support of the ground and use proven systems for monitoring and controlling machine operations. As a result, excavated volumes can be removed in a controlled manner. This reduces ground loss.

For the WPLE Project, closed face TBMs, Slurry Face Machines (SFM) or Earth Pressure Balance Machines (EPBM), will be required by contract. They represent the state-of-the-art equipment available for tunneling in the soft ground conditions found in Los Angeles. Machine selection will be the responsibility of the Design-Build Contractor, who will be required to configure the machine to excavate the soils encountered and minimize settlement to contract requirements with the TBMs. Such TBMs with the use of segmented concrete linings fitted with gaskets also control / minimize groundwater leakage into tunnels.

4.1 Tunneling Methods

The project tunnels will be constructed using these state-of-the-practice soft ground TBMs. The machine is contained within a circular shield that supports the ground behind the face and provides protection for the erection of the tunnel lining. It has a closed chamber behind the cutting wheel filled with the excavated soil and/or slurry. The chamber is pressurized to support the ground ahead of the tunnel and prevent inflows. The bulkhead allows a positive pressure to be applied to the tunnel face while allowing tunnel workers to work in free air (atmospheric pressure) behind the bulkhead. Maintaining a positive pressure at the tunnel face decreases the potential for ground loss and soil instability (sloughing, caving), as well as preventing infiltration of ground water.

Using SFM and EPBM, tunnel construction is a cyclic process that advances the tunnel in increments (typically 3 to 5 feet) and with the following primary operations:

1. Excavation of the tunnel face by a rotating the cutterhead and advancement of the TBM by propel jacks that react against the installed tunnel lining.
2. Maintenance of a positive face pressure counterbalancing the earth and hydrostatic loads.

3. Introduction of shield gap bentonite to fill and pressurize the annular void around the TBM shield.
4. Erection of the pre-cast concrete or fabricated steel segments to form the circular tunnel lining within the tail section of the TBM shield.
5. Continuous backfilling of the annular space between the lining and the excavated perimeter with grout injected through the tail of the TBM shield as the TBM is advanced.

The tunnel lining segments have gaskets to provide watertight joints. The complete lining rings are the structural support that maintains the safety and stability of the opening.

For the current alignment of WPLE Section 3, since the majority of the tunnel will be excavated in the Older Alluvium/Lakewood Formation and San Pedro Formation, it is anticipated that both SFMs and EPBMs can be configured to excavate the tunnels and is recommended for this project. Means and methods are typically decided by the Tunnel Contractor.

To maintain less than 0.35 percent ground loss during tunneling, additional measures are recommended including: continuous injection of bentonite around the body of the shield behind over cut, requirement of monitoring of bentonite injection system behind overcut on the shield body to fill, continuously pressurize the annular space around the shield; and additional instrumentation to confirm that continuous pressure is maintained on the face of the TBM during tunneling.

4.2 Ground Improvement Methods

Where analysis indicates that ground control by tunneling method only is not sufficient to control settlements to levels that prevent functional or structural damage to structures along the alignment, additional building and utility protection measures will be necessary. Approaches for protecting buildings and utilities subject to settlements include: compensation grouting, permeation grouting and jet grouting. Specific building and utility protection measures to be taken for specified buildings and utilities should be addressed in more detail in final design. When ground improvement is performed within the footprint of the buildings, such as 10250 Santa Monica Blvd, the grout zone will extend beyond the tunnel envelopes and additional easements required have been identified in Project Definition Drawings. In the following paragraphs, a discussion of each of the anticipated ground improvement methods for Section 3 are presented.

4.2.1 Compensation Grouting

Ground treatment using pre-conditioning and compensation grouting for protection of structures have been used in Southern California for various tunneling projects through soft ground conditions including: ((a) Metro Gold Line project and (b) Regional Connector project in the vicinity of Little Tokyo. Use of pre-condition grouting and compensation grouting performed during tunneling have been effectively used to control settlements.

Compensation grouting uses neat fluid grout to hydro-fracture in situ soils. The technique has been used to re-level structures or to protect structures from ground settlement while a tunnel machine passes below. A sleeve port pipe approximately 2-inch in diameter is grouted into a predrilled hole (approximately 4-inch to 8-inch in diameter) beneath the structure foundation to be protected. The grout is injected under pressure at strategic locations through the ports in the pipe that are typically placed at approximate spacing of 2 feet. Once the hydro-fracture pressure of the soil is exceeded, the grout fills fractures in the ground. The process results in controlled heave of the overlying soils and structures. Grout pipes on the order of 200 feet to 400 feet in length have been effectively used in the past for improving the soils to depths on the order of 50 to 70 feet.

Conceptual exhibits of compensation grouting limits for portions of the Westfield Mall building (located at 10250 Santa Monica Boulevard) and additional conceptual details of design are presented in Section 5.0. As part of final design, the design-build contractor will prepare separate shop drawings and method statements for these areas of ground improvement to protect building structures and foundations that are shown on these conceptual exhibits and PDD by compensation grouting. Such a system would require construction of temporary access shafts from where the drilling for placement of the grout pipes takes place.

4.2.2 Permeation Grouting

Ground treatment using permeation grouting involves injecting chemical or cementitious grout under pressure into the pore spaces of a geologic formation without causing excessive movement or fracturing of the soil formation. Chemical grout is a fluid that upon setting, improves the stability of the ground and/or reduces permeability of the ground, resulting in reduced ground loss due to tunneling operation. Chemical grout is typically composed of: matrix forming base materials, reactants, and accelerators or retarders such as sodium silicate. Cement grout is also used to reduce the permeability and improve the stability of coarse-grained soils. Grout is composed of Portland cement (or microfine Portland cement) and water, and may contain additives such as clay, bentonite, dispersant, retarders, flyash and accelerators as appropriate.

Areas of permeation grouting and additional conceptual details of design are presented in Section 5.0. As part of final design, the design-build contractor will prepare design, shop drawings, and method statements for these areas of ground improvement to protect building structures and foundations that are shown on these conceptual exhibits by permeation grouting.

4.2.3 Jet Grouting for Cross Passage Construction

Jet grouting is a grouting technique that is used to create stabilized soil-cement columns using fluid jets. A grout mix is delivered at high pressure through small nozzles to produce high velocity horizontal jets to cut the soil and mix it with the injected grout. Soil cement columns are formed by simultaneously rotating and withdrawing the drill rod at prescribed rates. The jet grouting process constructs soilcrete panels, full columns with specified strength and permeability.

As part of final design, the design-build contractor will prepare separate working drawings and methods statements for these areas of ground improvements to protect building structures and utilities. Such submittals will be prepared at least 90 days in advance of TBM excavation under the existing improvements involved for protection in general accordance with project specifications for jet grouting.

4.2.4 Ground Freezing for Cross Passage Construction

Ground freezing has been used successfully for cross passage construction in Europe and Hong Kong, and is now being used for the first time in the United States on the Port of Miami Tunnel. Ground freezing, the process of converting pore water to ice is accomplished by drilling a series of pipes, typically spaced approximately 1 m around the perimeter of the proposed excavation. Some subsurface soil and groundwater conditions require two rows of freeze pipes. A refrigerated coolant, ethylene glycol or calcium chloride brine, is circulated through the pipes, forming a waterproof, rock-like mass.

There are two approaches to freezing tunnel cross passages, and typically the size of the cross passages dictates the method.

Method 1: The most common approach is based on the drilling of the freeze pipes horizontally from within one of the tunnels. The drilling procedure for the horizontal pipes is somewhat complex and requires extensive drilling expertise. Prior to drilling, it is necessary to install a blow-out prevention device to withstand the hydrostatic pressure from the tunnel exterior. Alignment of the freeze pipes is essential to prevent deviation of the pipes during drilling. Once the pipes are drilled and installed a gyroscopic survey is conducted to ensure that adjacent freeze pipes have not deviated, which potentially could create a gap in the frozen earth mass. There are two approaches to refrigeration plant location. In some cases it is technically appropriate and economically feasible to place small refrigeration plants inside the tunnel, located at each individual cross passage. Some projects, however, require higher capacity ammonia refrigeration plants that must be installed and operated from outside the tunnel with the circulating coolant pumped in some cases several thousand feet.

Method 2: The second approach to drilling freeze pipes for cross passages involves drilling and installing the freeze pipes from the ground surface. The geometry of the freeze pipes in the surface approach is required when the diameter of the cross passages are too large to accommodate drilling from inside the tunnel. As with the drilling from inside, gyroscopic surveys are required to verify alignment between adjacent pipes.

There are some risks associated with ground freezing and include:

- Groundwater moving greater than one meter per day can retard or even prevent the formation of the frozen earth mass. If moving groundwater is a potential issue, it may be necessary to pre-condition the soil with grouting or deep soil mixing. While these techniques cannot provide 100 percent water cutoff, they can reduce the permeability enough to reduce flow velocities.
- Another risk associated with freezing for cross passages is disruption of power or refrigeration. When using ground freezing for this application it is imperative that backup power and refrigeration sources are available on site.
- As with any subsurface construction technique, success can only be ensured by a qualified and experienced ground freezing subcontractor as well as coordination and cooperation with the tunneling contractor.

4.3 Geotechnical Instrumentation Program

Monitoring of ground movement will provide an essential tool for confirming when the tunneling and mitigation measures are working and whether further mitigation is needed. Systematic monitoring of all buildings and major utilities within the limits of observation indicated on the project definition drawings will be required during construction.

4.3.1 Ground, Utility and Building Instrumentation

Types of monitoring instruments for monitoring building and utility distortions and damage will include a combination of the following:

1. Surface settlement markers and Extensometers (MPBX)

2. Building settlement markers (conventional and GPS)
3. Tilt meters
4. Crack monitoring gauges
5. Liquid level sensors
6. Utility monitoring points (UMP)

In order to evaluate whether a building or major utility has experienced damage, it is important that pre-construction surveys are performed to document existing conditions of each building or major utility prior to construction. Absolute and relative movements of buildings and major utilities should be monitored during construction.

Monitoring of building and major utility movements will provide Metro, and the Contractor with verification that tunnel construction is not impacting buildings and utilities. Results of monitoring would also provide a basis for remedial actions to repair buildings or utilities should it be determined tunnel construction has caused building or utility movements and damage.

4.3.2 Building and Utility Surveys

Although results of the settlement analyses indicate none to negligible damage will be imposed on the buildings and utilities, it is recommended that detailed preconstruction surveys be performed to visually inspect the interior and exterior of each building and visual survey of major utilities. The survey should include written documentation of existing conditions and be supplemented with video or still photography to provide documentation. Detailed information should be collected such as existing structural and cosmetic defects. Additional information such as width, length, and height of each building, wall and roof framing details, ceiling construction, and interior finishes should also be collected. The detailed surveys will serve as documentation of pre-construction conditions of each building and major utility in order to provide a baseline for establishing damage resulting from construction. For buildings where ground improvement programs are to be implemented, inspection of the basement sub-slab drainage and methane gas barrier systems (if any) need to be performed making sure that ground improvement program would not damage the existing conditions below the basement slabs.

All building heights used in the preliminary analyses have been estimated based on visual observations during site reconnaissance or determined from existing building plans.

4.4 Final Design Program

During final design, discussions with Caltrans, property and utility owners will be required. The detailed settlement analysis during final design should include: (a) the depth of basements and foundations for all structures within the Limit of Observation of tunneling above tunnels; (b) all structures having four or more above ground stories; (c) those having two or more basement levels; (d) those designated as historic or eligible historic; (d) those with estimated settlements greater than 0.5-inch; and (e) those with an asymmetric structural configuration that could result in damage from differential settlements.

Detailed settlement evaluation should consist of:

- Geotechnical and structural of analyses which use numerical modeling to assess the effects of construction on the buildings and utilities. Assessment of effects of construction including: excavation of tunnels, cross passages and adjacent stations and shafts, where applicable; groundwater drawdown; and vibration
- Evaluation of the need for building or utility specific criteria based on results of pre-construction surveys and preliminary settlement assessment. The specific criteria would be more stringent than the criteria used for this preliminary assessment
- Development of detailed design drawings and work plans for ground improvement and instrumentation

5.0 SITE SPECIFIC BUILDING AND UTILITY PROTECTION MEASURES

The evaluations carried out during preliminary engineering as part of the building protection program identified a number of locations where additional building and utility protection is mandatory to assure that settlements from tunneling are within the project performance criteria and thereby reduce distress to the structures.

5.1 Buildings

5.1.1 10250 Santa Monica Boulevard

Details of Building

10250 Santa Monica Boulevard is part of the Westfield Mall. The building ranges in height from three to four stories and has up to three basement levels. Several modifications to the original structure have been carried out that have required changes to the foundations. A history of the development of the site buildings is found in following documentation:

10250 Santa Monica Blvd – General Mall Areas

- Original Mall Construction
  - 1962 Structural and Architectural Plans by Welton Becket and Associates
  - 1964 Inspection of Foundation Excavations by Leroy Crandall and Associates
- Mall Expansion
  - 1975 Structural and Architectural Plans by Welton Becket and Associates
  - 1976 Inspection of Shoring, Inspection of Foundation Excavation, and Inspection and Testing of Compacted Backfill by Leroy Crandall and Associates
- Mall Renovations
  - 2003 Report of Geotechnical Consultation by MACTEC
  - 2004 Supplemental Geotechnical Consultation by MACTEC
  - 2004 Shoring Plans by Shoring Engineers
  - 2005 Structural Phase 1 Plans by Nabih Youssef and Associates
  - 2006 Structural Phase 1B Plans by Nabih Youssef and Associates
- Nordstrom's Development
  - 2015 Structural and Architectural Plans by Callison Architects, P.C.
  - 2015 Submittal No. 3 for Hydraulic Elevators

Figure 5-1 shows the overall plan and profile views of the Westfield Mall along with locations of several elevators which provide access to various buildings. A total of thirteen elevators were identified during current design for potential impacts to the proposed tunneling and ground improvement program. The details pertaining to these thirteen elevators such as type of elevator, estimated pit slab elevation and the depth of in-ground hydraulic elevator are presented in a table within this Figure. The current tunnel alignment was chosen to avoid these elevators. No shafts were found to intersect the tunnel envelopes along the tunnel alignment. However, this should be confirmed by the Design - Build Contractor and the effect of potential settlement on elevator performance should be investigated as part of the final design. This should include identifying allowable tilts to the shafts. The Final Design-build contractor should verify the locations and elevations of these elevators with in-ground hydraulic rams and make suitable recommendations for protecting in-place or remove and replace, as needed.

As shown on the tunnel profile only three elevators are known to be within one tunnel diameter of the tunnels, the tip of the in-ground hydraulic ram of the Elevator #105 will be located at about 25 feet above the crown of the tunnel. Elevator # 105 is located approximately 7 feet left of "BR" tunnel alignment and 13 feet to the right of "BL" tunnel alignment. The tip of the in-ground hydraulic ram of the Elevator #13 will be at about 4 feet above the crown of the tunnel. Elevator # 13 is located approximately 26 feet right of "BR" tunnel alignment.

Figure 5-2 and Figure 5-3 provide plan and profile views of the existing foundations along the tunnel alignment based on available architectural plans, concept plans, and as-built substructure information for the Westfield Mall. These foundations can be summarized as follows:

> <u>Spread footings</u> for the three-story parking structure with two levels of underground parking – original design
>
> <u>Belled caissons and drilled piles</u> for the three-story building that houses department and retail stores with two levels of underground parking
>
> <u>Belled caissons and drilled piles</u> for the four story building that houses the AMC Theater with two levels of underground parking - The drilled concrete piles are 18-, 24- and 30-inch diameter and were installed to depths of approximately 35 feet.

During previous renovation and rebuilding work, existing foundations and parts of some structures were left in place with some being incorporated into the new structures. It is not always clear which piles remain as part of the foundation plan for the renovated structures and which are no longer load bearing. Further, as a part of several building foundations retrofit/enhancements shown on as-built drawings, some of the foundations are reported to be connected in lateral directions using grade beams and/or basement slabs.

Due to changes that imposed heavier column loads, cast-in-place piles were also installed at some locations and caissons at others. Deep piles close to the "BR" tunnel are found at Building Grid Line K and in between Grid Lines H and J. These are approximately 15 feet and 25 feet, respectively from the proposed extrados of the BR tunnel and have pile tip elevations of El. 218. For the "BL" tunnel, the closest deep pile is between Grid Lines T and T1. It is at approximately the centerline of the pillar between the tunnels and has a tip elevation of El. 222.

Recently, two 30-inch diameter cast-in-place piles were installed in 2016. They are reported to be intended for additional support required for construction of Metro OPE exhaust and tunnel as well as exterior portico of the Mall building. The closest one of these piles is located at a horizontal clear distance of 4 feet from the "BR" tunnel envelope and therefore, is considered to clear the "BR" tunnel. Review of a note on the available drawings for Westfield Mall for this area indicate that Metro is expected to protect in-place the two 30-inch diameter CIDH piles during construction of the tunnel. It is expected that the final design-build contractor will verify the as-built location of this pile and provide mitigation to protect the piles, as needed.

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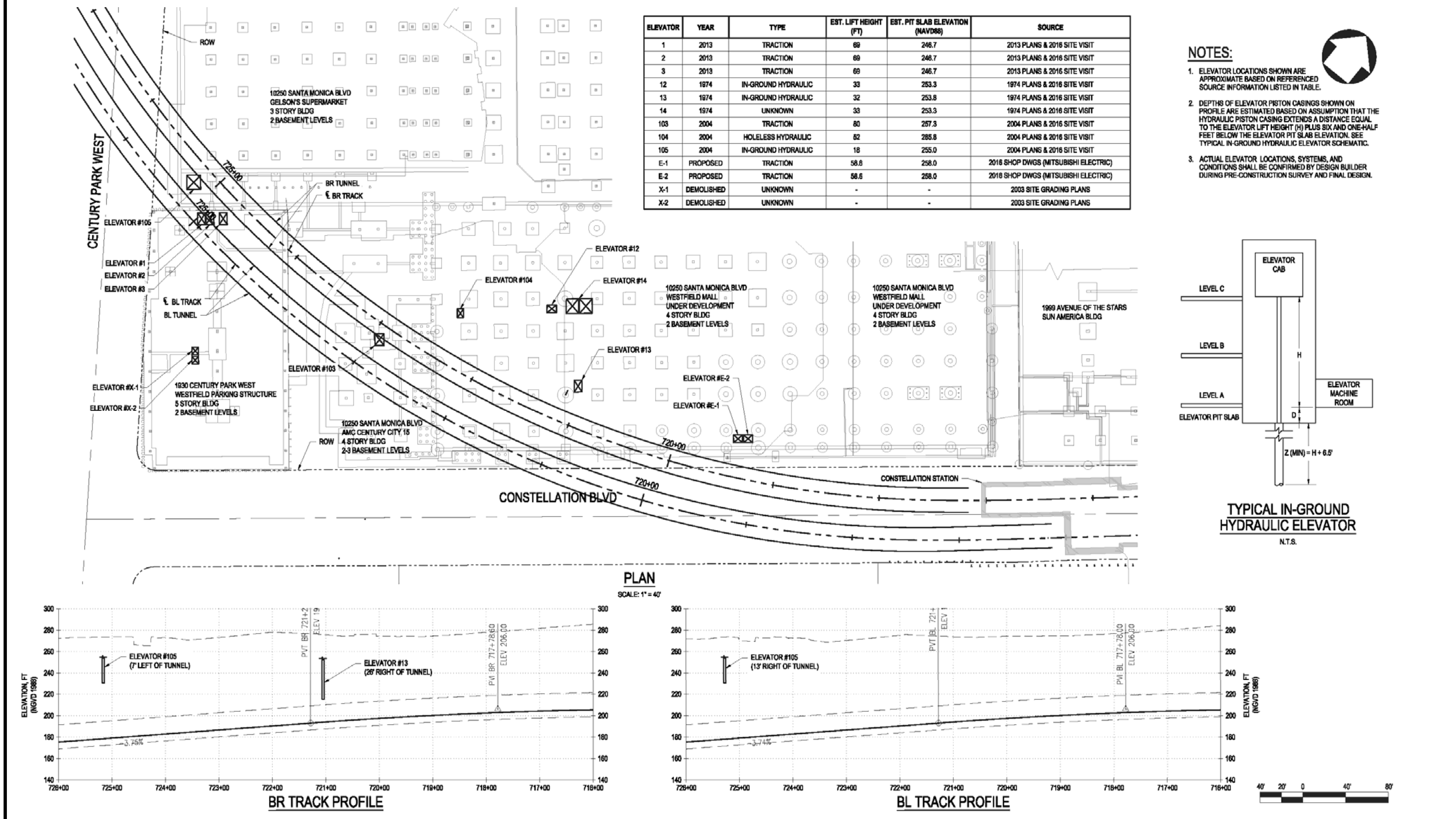
Figure 5-1: Westfield Mall Showing Building Foundations and Elevators Information Including Tunnel Plan and Profile



ELEVATOR	YEAR	TYPE	EST. LIFT HEIGHT (FT)	EST. PIT SLAB ELEVATION (NAVD88)	SOURCE
1	2013	TRACTION	69	246.7	2013 PLANS & 2016 SITE VISIT
2	2013	TRACTION	69	246.7	2013 PLANS & 2016 SITE VISIT
3	2013	TRACTION	69	246.7	2013 PLANS & 2016 SITE VISIT
12	1974	IN-GROUND HYDRAULIC	33	253.3	1974 PLANS & 2016 SITE VISIT
13	1974	IN-GROUND HYDRAULIC	32	253.8	1974 PLANS & 2016 SITE VISIT
14	1974	UNKNOWN	33	253.3	1974 PLANS & 2016 SITE VISIT
103	2004	TRACTION	80	257.3	2004 PLANS & 2016 SITE VISIT
104	2004	HOLELESS HYDRAULIC	52	285.8	2004 PLANS & 2016 SITE VISIT
105	2004	IN-GROUND HYDRAULIC	18	255.0	2004 PLANS & 2016 SITE VISIT
E-1	PROPOSED	TRACTION	58.6	258.0	2016 SHOP DWGS (MITSUBISHI ELECTRIC)
E-2	PROPOSED	TRACTION	58.6	258.0	2016 SHOP DWGS (MITSUBISHI ELECTRIC)
X-1	DEMOLISHED	UNKNOWN	-	-	2003 SITE GRADING PLANS
X-2	DEMOLISHED	UNKNOWN	-	-	2003 SITE GRADING PLANS

NOTES:

1. ELEVATOR LOCATIONS SHOWN ARE APPROXIMATE BASED ON REFERENCED SOURCE INFORMATION LISTED IN TABLE.
2. DEPTHS OF ELEVATOR PISTON CASINGS SHOWN ON PROFILE ARE ESTIMATED BASED ON ASSUMPTION THAT THE HYDRAULIC PISTON CASING EXTENDS A DISTANCE EQUAL TO THE ELEVATOR LIFT HEIGHT (H) PLUS SIX AND ONE-HALF FEET BELOW THE ELEVATOR PIT SLAB ELEVATION. SEE TYPICAL IN-GROUND HYDRAULIC ELEVATOR SCHEMATIC.
3. ACTUAL ELEVATOR LOCATIONS, SYSTEMS, AND CONDITIONS SHALL BE CONFIRMED BY DESIGN BUILDER DURING PRE-CONSTRUCTION SURVEY AND FINAL DESIGN.

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Figure 5-2: Schematic of Foundation Plan, Profile and Settlement Profile along BR Tunnel Alignment at Westfield Mall

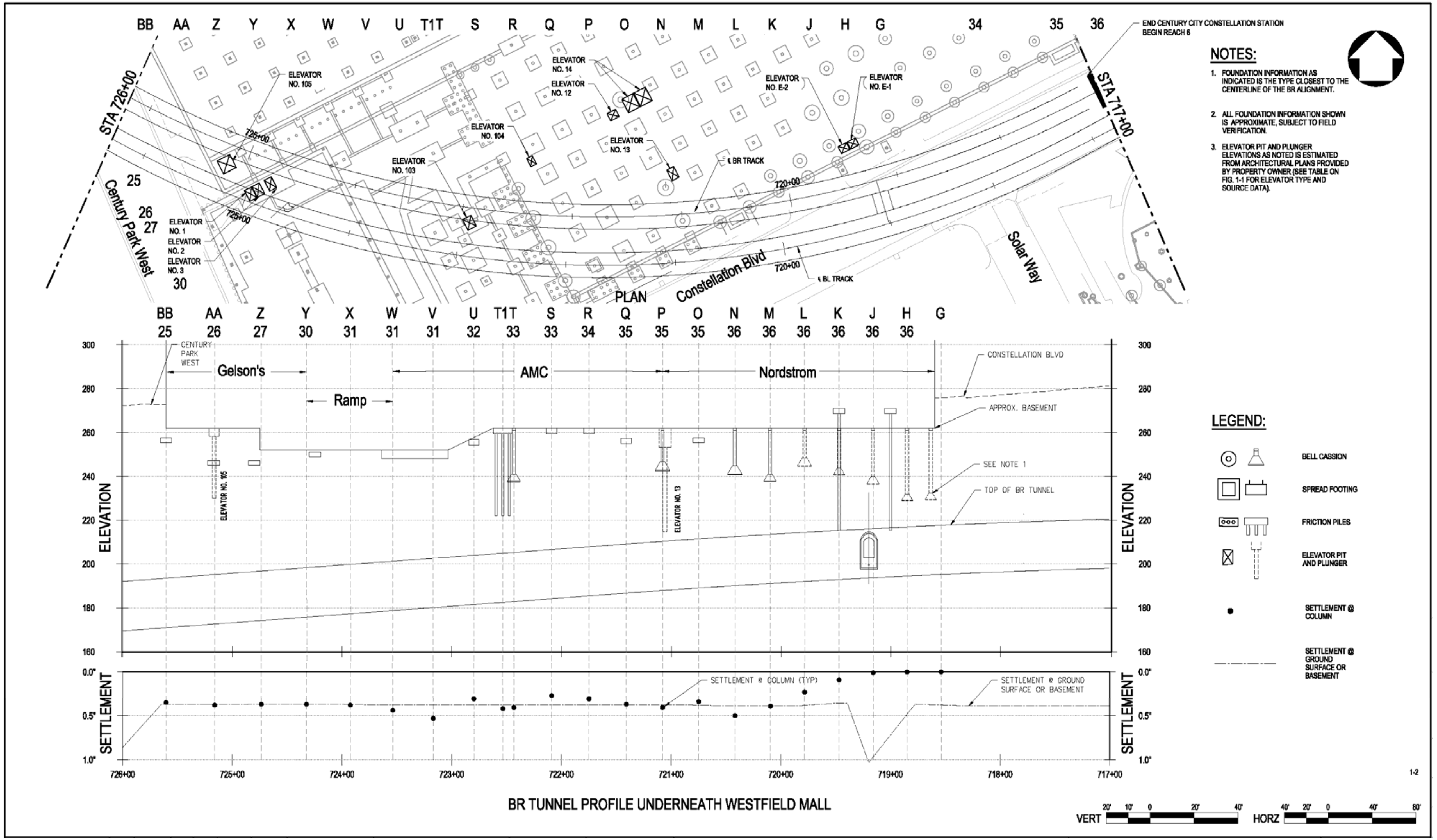

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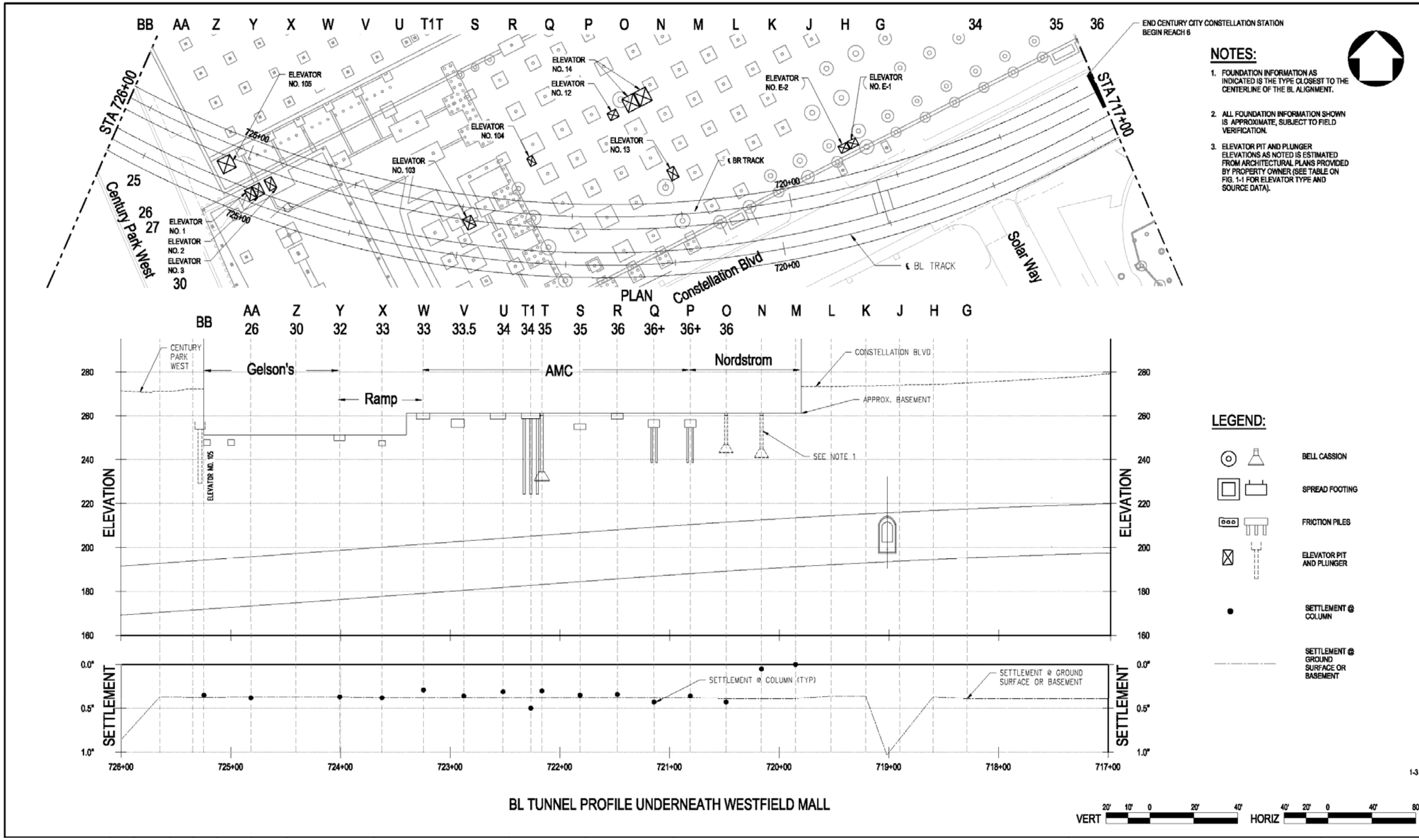
Figure 5-3: Schematic of Foundation Plan, Profile and Settlement Profile along BR Tunnel Alignment at Westfield Mall



WESTSIDE PURPLE LINE EXTENSION PROJECT

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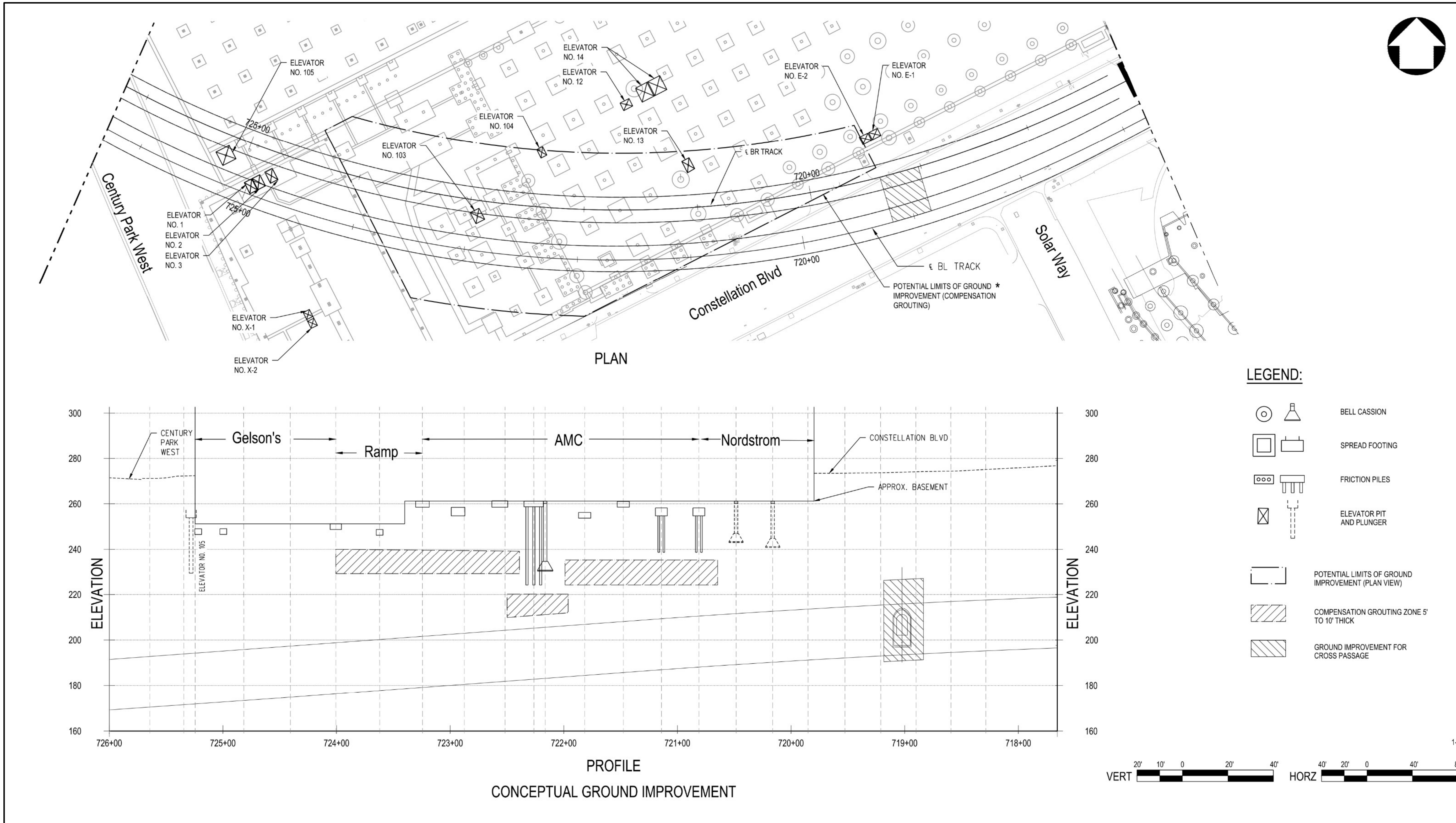
Figure 5-4: Ground Improvement Plan and Profile Concept at Westfield Mall



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Subsurface Conditions

Ground conditions beneath the building consist of: Fill, Older Alluvium, and Lakewood Formation with the tunnels primarily within the San Pedro Formation. Groundwater table at the site is approximately 40 to 50 feet below the ground surface.

Potential Impact to 10250 Santa Monica Boulevard from Tunneling

The tunnel crown is approximately 15 feet to 40 below the bottom of the majority of building piles.

Figure 5-2 and Figure 5-3 provide estimates of settlements along BR and BL tunnel alignments at column foundation location and / or at ground / basement elevation.

At the tip elevation (El. 218) of the deepest pile closest to the “BR” tunnel (building grid lines K and in between grid lines H and J), a settlement up to 1.0 inch is predicted. Elsewhere, along the tunnel alignment, settlements up to 0.53 inch are predicted for the friction piles (assumed at a depth of 2/3 the pile length) without protection measures being carried out. This exceeds the settlement allowed per Metro Design Criteria. As a result, some form of building protection measures in addition to those undertaken as part of the tunneling operations and monitoring program are required.

Protection Measures

A conceptual design for protection of 10250 Santa Monica Boulevard using compensation grouting is proposed and shown in Figure 5-4. It is envisaged that the program would consist of:

- Construction of temporary access shafts located on Constellation Boulevard and Century Park West or at the west-end of Constellation Boulevard Station
- Development of a series of horizontally drilled borings from these shafts spaced such that they provide adequate coverage for compensation grouting as the tunnels pass beneath the Westfield Mall. The length of each tunnel that will be subject to compensation grouting is anticipated to be not less than 700 feet. The width of coverage for each tunnel is anticipated to be not less than 30 feet.
- Installation of geotechnical instrumentation (liquid levels, settlement points and extensometers) to monitor ground movements before, during and following tunneling beneath the mall.
- A compensation grouting program that will maintain settlements at less than 0.5 inches
- Furthermore, an active inspection program will need to be implemented making sure the building under slab drainage system is free from slurry leakage of the tunneling activities.

Additional investigation of the as-built location of the foundations and a detailed analysis incorporating the investigation will need to be performed during final design and is expected that Figure 5-4 will be updated.

5.1.2 I-405 Freeway/Wilshire Boulevard Interchange

The tunnels cross beneath the I-405 Freeway/ Wilshire Boulevard Interchange. The structures at the interchange include:

- 20-foot-high earth embankment carrying 12 lanes of vehicular traffic running north-south

- Northbound I-405 On-Ramp bridge structure just east of I-405 (Bridge No. 53-3021S)
- Southbound I-405 Off-Ramp bridge structure just west of I-405 (Bridge No. 53-3050K)
- I-405 Southbound On-Ramp and Off-Ramp (at-grade road structure)

A Project Study Report has been prepared and submitted to the California Department of Transportation (Caltrans) for the proposed crossing beneath the I-405 Freeway/Wilshire Boulevard Interchange by the Metro tunnels. For further details relating to the study, see the Final Project Study Report/Project Report (PSR/PR: Metro, 2017a).

The PSR/PR must be reviewed by the Design-Build Contractor, a detailed analysis performed during final design of the impacts of the tunneling on the structures of the interchange performed, and a final PS&E prepared by the Design-Build Contractor for review and approval by Caltrans. The final measures adopted for tunneling beneath the I-405 and its associated structures will be subject to approval by Caltrans.

Based on the preliminary analysis, existing bridge piles for the north and south bound ramps (Caltrans bridge numbers 53-3021S and 53-3050K) are approximately 21 feet horizontally from the nearest tunnel. Figure 5-5 present schematic plan and profile views of existing foundations at the "BR" and "BL" Tunnel crossing, based on the available as-built substructure information for these two bridge structures at the time of preparation of this report. The tips of the piles are outside the zone of influence of tunneling; however, the upper parts of the piles may be subject to down-drag. Surface settlement at the base of the embankment fill is estimated to range up to 0.4 inches.

Ground conditions consist of Alluvium deposits with the tunnels in the Older Alluvium (refer to Section 6.2.1 of GBR and GDRs for soil conditions). The groundwater table at the site is estimated to be approximately 60 to 80 feet below ground surface and base of embankment. Depending on the groundwater depth, the tunnels can be partly above the groundwater table.

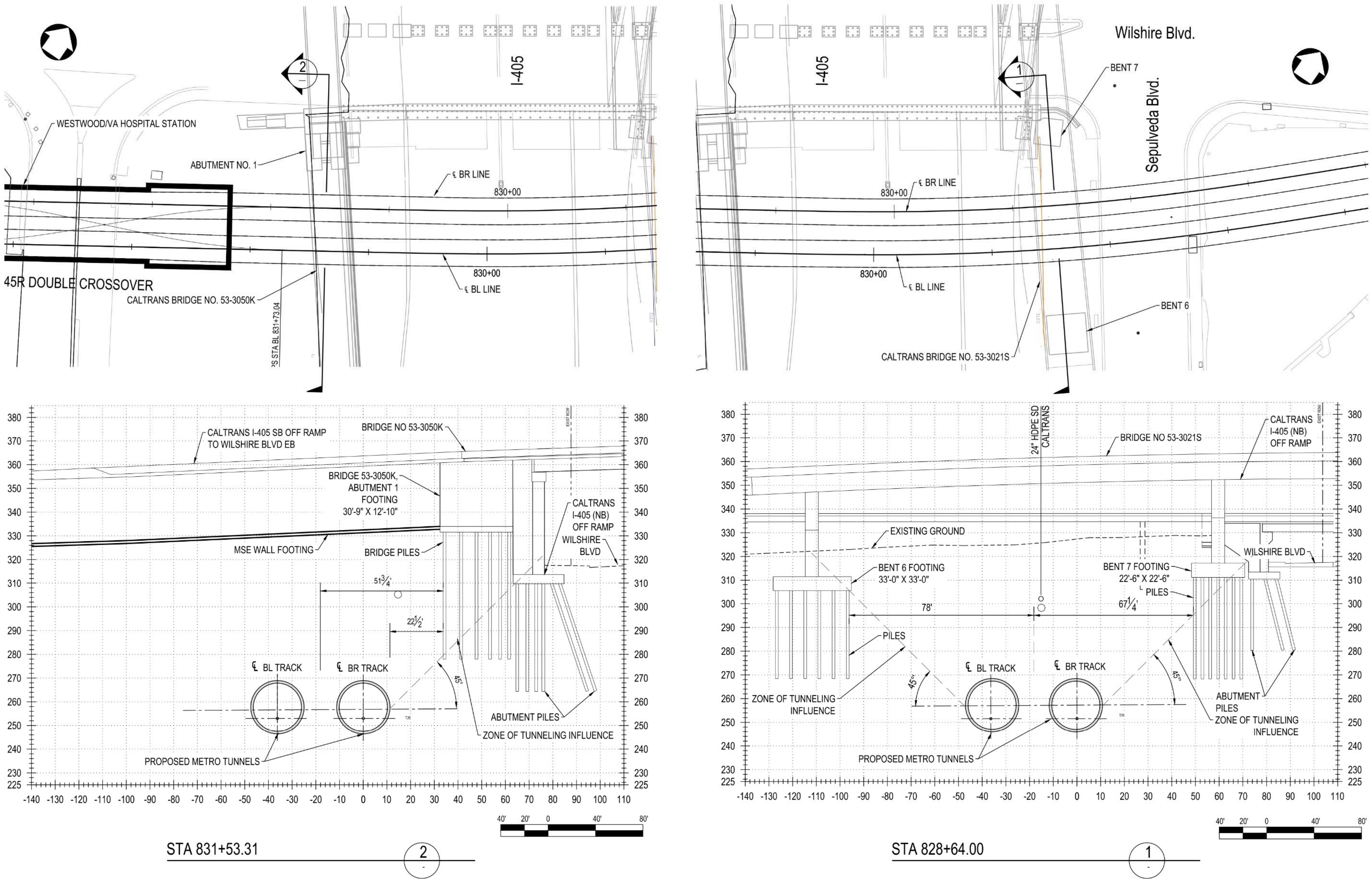
5.2 Utilities

5.2.1 Utilities within Sepulveda Boulevard

Details of Utilities

The tunnels will pass beneath Sepulveda Boulevard after crossing beneath the I-405 freeway. At the location of the crossing, the centerline of the "BR" tunnel is about 75 to 90 feet south of Wilshire Boulevard. At this location on Sepulveda Boulevard, there are numerous utilities within the right-of-way. They are listed in Table 5-1 and shown in plan and profile in Figure 5-6.

Figure 5-5: Plan and Profile View of Existing Foundations for I-405 Bridge No. 53-3021S and Bridge No. 53-3050K



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Major utilities found at the crossing include: Large storm drains; 96-inch diameter water pipe; high pressure gas lines; electrical lines; and oil pipelines. The two deepest utilities are - a 96-inch PCP MWD water line and 12' X 12.5' RCB Storm Drain owned by LACFCD. The corresponding distances to tunnel crown from the bottom of these two utilities are about 16 and 26 feet, respectively. NOTE: financial penalties are associated with the disruption of the flow in the oil pipelines.

Table 5-1: Utilities within Sepulveda Boulevard at the Tunnel Crossing

Utility Type	Owner	Size (from exist conditions)	Major or Minor Utility	As Built No..
Storm Drain	CALTRANS	24"	Major	
Electrical	LADWP	6-5", 2-4"	Minor	
Water	MWD	96"	Major	
Telecom	ACD	6-3.5"	Minor	
Telecom	GTE	4MTD	Minor	
Oil	EXXONMOBIL	16"	Major	D4A-5232
Gas	SCG	10.5"	Major	PAL 5, PAL 15
Storm Drain	COLA	36"	Major	
Electrical	LADWP	6-6",6-5",2-4"	Major	64-60B
Sewer	COLA	12"	Major	
Gas	SCG	10.75"	Major	PAL 5, PAL 15
Storm Drain	COLA	12' x 12.5'	Major	
Oil	EXXONMOBIL	10" IN 14" CSG	Major	D4A-5232
Telecom	Verizon	DUCT	Minor	
Telecom	AT&T	DUCT	Minor	
Oil	CHEVRON	8"	Major	B12340
Oil	SHELL	8"	Major	D4A-5232
Oil	MOBIL	16" IN 20" CSG	Major	
Oil	EXXONMOBIL	1016" IN 20" CSG	Major	
Electrical	SCE	7' X 14 ' VAULT	Minor	64-60B
FO	Verizon	Unknown	Minor	
FO	LEVEL 3	Unknown	Minor	
FO	MFN	Unknown	Minor	
FO	QWEST	Unknown	Minor	
FO	MFN	Unknown	Minor	
FO	QWEST	Unknown	Minor	

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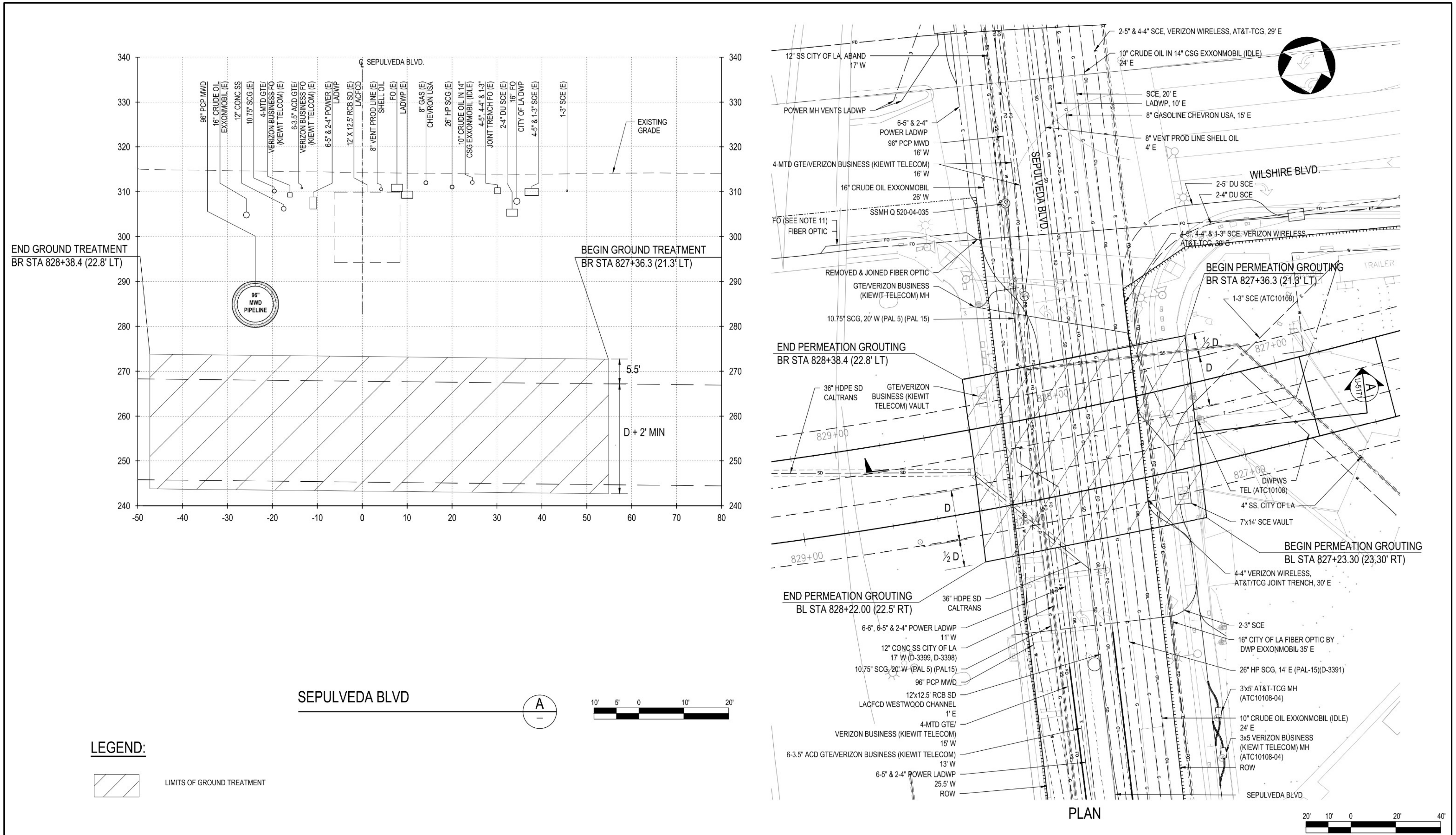
Figure 5-6: Ground Improvement Plan and Profile Concept for Utilities Protection at Sepulveda Boulevard



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Subsurface Conditions

Ground conditions beneath the Sepulveda Boulevard consist of Alluvium deposits with the tunnels in the Older Alluvium (refer to Section 6.2.1 of GBR and GDRs for soil conditions). The groundwater table at the site is estimated to be approximately 50 to 60 feet deep. Depending on the groundwater depth, the tunnels can be partly above the groundwater table.

Potential Impact to Utilities along Sepulveda Boulevard from Tunneling

The tunnel crown is approximately 40 feet below the bottom of the majority of shallow utilities (i.e. less than about 7.5 feet below grade). The two deepest utilities are - a 96-inch PCP Metropolitan Water District (MWD) water line and 12 feet X 12.5 feet RCB Storm Drain owned by Los Angeles County Flood Control District (LACFCD). The corresponding distances to tunnel crown from the bottom of these two utilities are about 16 and 26 feet, respectively.

. For above discussed two deepest utilities, calculations indicated that settlements up to 0.6 and 0.5 inch could occur at bottom elevation of utility locations. Elsewhere, along the tunnel alignment, evaluation has indicated that settlements up to 0.4 inch could occur for all other shallow utilities. This exceeds the settlement allowed per Metro Design Criteria for major utilities discussed above. As a result, some form of utility protection measures in excess of those undertaken as part of the pressure face tunneling program are required.

Protection Measures

For Sepulveda Boulevard, it is anticipated that ground modification programs such as permeation grouting are necessary to protect the utilities. A conceptual program is shown in Figure 5-6. It is envisaged that the program would consist of:

- Construction of a temporary access shaft located on east side of Sepulveda Boulevard, potentially within the Caltrans yard
- Development of a series of horizontally drilled holes from these shafts to place grout pipes and provide adequate coverage for permeation grouting, using horizontal directional drilling techniques; prior to the excavation of tunnels beneath the Sepulveda Boulevard.
- Installation of additional geotechnical instrumentation to monitor ground movements before, during and following tunneling beneath the Sepulveda Boulevard.

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APPENDIX A LIST OF PROPERTIES ALONG THE TUNNEL ALIGNMENT

APPENDIX A LIST OF PROPERTIES ALONG THE TUNNEL ALIGNMENT

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
2025	Avenue of the Stars	Proposed	47	5	-	0.00	>5,000
10250	Santa Monica Boulevard – Nordstrom	Commercial	3	2	1966	0.36 *	>5,000
	Santa Monica Boulevard – AMC	Commercial	4	2-3	2004	0.34 *	>5,000
** Settlement at Foundation Levels exceed 0.5-inch*	Santa Monica Boulevard – Gelsons	Commercial	3	2	1974	0.32 *	>5,000
10250	Constellation Blvd	Commercial	34	1-3	2002	0.00	>5,000
1930	Century Park West	Commercial	5	2	1966/2013	0.20	>5,000
1912	Fox Hills Drive	Residence	2	-	1991	0.01	>5,000
1908	Fox Hills Drive	Residence	1	-	1936	0.04	>5,000
1904	Fox Hills Drive	Residence	2	-	1937/1970	0.17	4,244
1900	Fox Hills Drive	Residence	2	-	1940/1993	0.29	4,459
1858	Fox Hills Drive	Residence	2	-	2016	0.28	4,879
1854	Fox Hills Drive	Residence	1	-	1937/1942/ 2006	0.28	>5,000
1848	Fox Hills Drive	Residence	1	-	1948/1951	0.28	4,899
1842-1844	Fox Hills Drive	Residence	1	-	1946/1965/ 2005	0.28	4,849
1830	Fox Hills Drive	Multi Family	2	-	1954	0.20	3,948
10278	Missouri Ave	Residence	3	-	2013	0.08	>5,000
1814-1824	Fox Hills Drive	Multi Family	2	-	1949	0.02	>5,000
10305	La Grange Avenue	Residence	1	-	1941	0.01	>5,000
1849	Fox Hills Drive	Residence	2	1	2012	0.07	>5,000
1843-1845	Fox Hills Drive	Residence	1	-	1939/1959	0.13	>5,000
1833-1835	Fox Hills Drive	Residence	1	-	1941/1954	0.28	>5,000
1825	Fox Hills Drive	Condo	4	1	2005	0.28	>5,000
10308	Missouri Avenue	Residence	1	-	1937	0.18	3,778
10312	Missouri Avenue	Residence	1	-	1937	0.03	>5,000
10316	Missouri Avenue	Residence	2	-	1957	0.01	>5,000
10307	Missouri Avenue	Condo	4	1	1991	0.28	>5,000
10315	Missouri Avenue	Condo	3	1	1980/1985	0.28	4,926

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address							
Number	Street	Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
10317	Missouri Avenue	Condo	3	0 - 1	1996	0.23	3,924
10323	Missouri Avenue	Residence	2	1	1965/1972	0.11	>5,000
10327	Missouri Avenue	Multi Family	2	1	1979	0.01	>5,000
10300	Santa Monica Blvd	Residence	2	-	1949	0.06	>5,000
10306	Santa Monica Blvd	Multi Family	2	-	1953	0.07	>5,000
10316	Santa Monica Blvd	Multi Family	2	-	1954	0.19	3,783
10318	Santa Monica Blvd	Multi Family	2	-	1953	0.29	>5,000
10324	Santa Monica Blvd	Multi Family	2	-	1948	0.31	4,997
10330	Santa Monica Blvd	Multi Family	2	-	1951	0.31	4,169
10340	Santa Monica Blvd	Commercial	2	1	1959	0.18	3,801
10350	Santa Monica Blvd	Commercial	3	3	1981	0.04	>5,000
10349	Santa Monica Blvd	Commercial	1	-	1949/1980	0.13	>5,000
10351	Santa Monica Blvd	Commercial	4	3 - 4	1984	0.31	>5,000
1730	Comstock Avenue	Residence	2	-	1946	0.00	>5,000
1725	Comstock Avenue	Residence	1	-	1938/1950	0.16	4,662
10360	Eastborne Avenue	Residence	1	-	1931/1935	0.29	>5,000
10364	Eastborne Avenue	Residence	1	1	1947/1962	0.27	>5,000
10370	Eastborne Avenue	Residence	1	-	1939/1942	0.27	>5,000
10374	Eastborne Avenue	Residence	1	-	1926	0.12	>5,000
10357	Eastborne Avenue	Residence	2	-	1990	0.01	>5,000
10363	Eastborne Avenue	Residence	1	-	1937	0.11	>5,000
10369	Eastborne Avenue	Residence	1	-	1937/1968	0.26	>5,000
10379	Eastborne Avenue	Residence	2	-	1925/1930	0.25	>5,000
1700-1706	S Beverly Glen Blvd	Multi Family	2	1		0.02	>5,000
1710-1720	S Beverly Glen Blvd	Multi Family	2		1961	0.01	>5,000
1636	S Beverly Glen Blvd	Condo	4	2	2010	0.25	>5,000
1622	S Beverly Glen Blvd	Multi Family	2	-	1960	0.24	3,644
1614	S Beverly Glen Blvd	Multi Family	2	-	1953	0.05	>5,000
1610	S Beverly Glen Blvd	Multi Family	3	-	1960	0.00	>5,000
1641	S Beverly Glen Blvd	Multi Family	2	-	1946	0.03	>5,000
1635	S Beverly Glen Blvd	Multi Family	3	-	1950/1955	0.10	>5,000
1617	S Beverly Glen Blvd	Condo	5	1-2	1988	0.29	4,349

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
1611	S Beverly Glen Blvd	Multi Family	5	2	2011	0.15	4,864
1557	S Beverly Glen Blvd	Condo	5	1	1974	0.05	>5,000
1628	Pandora Avenue	Residence	2	1	2009	0.01	>5,000
1624	Pandora Avenue	Residence	1	-	1938	0.07	>5,000
1620	Pandora Avenue	Residence	2	-	1936/1953	0.13	>5,000
1616	Pandora Avenue	Residence	1	-	1936/1942	0.24	>5,000
1608	Pandora Avenue	Residence	2	-	2006	0.24	>5,000
1604	Pandora Avenue	Residence	2	-	1938/1946	0.21	>5,000
1600	Pandora Avenue	Residence	2	-	1927/1989	0.09	>5,000
1522	Pandora Avenue	Residence	1	-	2007	0.03	>5,000
1621	Pandora Avenue	Residence	1	-	1928	0.05	>5,000
1615	Pandora Avenue	Residence	2	-	1928/1987	0.18	>5,000
1511	Pandora Avenue	Residence	1	-	1929	0.00	>5,000
1513	Pandora Avenue	Residence	1	-	1924/1926	0.05	>5,000
10436	Kinnard Avenue	Residence	2	1	2014	0.23	>5,000
10442	Kinnard Avenue	Residence	2	-	1973	0.21	>5,000
10448	Kinnard Avenue	Residence	1	-	1928/1932	0.08	>5,000
10454	Kinnard Avenue	Residence	1	-	1926	0.03	>5,000
10437	Kinnard Avenue	Residence	2	-	1939/1961	0.18	>5,000
10443	Kinnard Avenue	Residence	1	-	1928/1935	0.22	>5,000
10447	Kinnard Avenue	Residence	1	-	1938/1940	0.22	>5,000
10451	Kinnard Avenue	Residence	1	-	1924/1926	0.22	>5,000
10455	Kinnard Avenue	Residence	1	-	1935	0.15	>5,000
10459	Kinnard Avenue	Residence	1	-	1935	0.07	>5,000
10465	Kinnard Avenue	Residence	1	-	1931	0.03	>5,000
10469	Kinnard Avenue	Residence	2	-	2015	0.03	>5,000
10450	Wilkins Avenue	Residence	2	-	2003	0.01	>5,000
10454	Wilkins Avenue	Residence	1	-	1930/1936	0.13	>5,000
10458	Wilkins Avenue	Residence	2	-	1990	0.22	>5,000
10462	Wilkins Avenue	Residence	1	-	1932	0.22	>5,000
10466	Wilkins Avenue	Residence	1	-	1928	0.21	>5,000
10470	Wilkins Avenue	Residence	1	-	1938	0.15	>5,000

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
10474	Wilkins Avenue	Residence	1	-	1938	0.07	>5,000
10478	Wilkins Avenue	Residence	2	1	2003	0.04	>5,000
10461	Wilkins Avenue	Residence	2	-	1929/1944	0.06	>5,000
10465	Wilkins Avenue	Residence	2	-	1990	0.13	>5,000
10469	Wilkins Avenue	Residence	1	-	1938	0.20	>5,000
10473	Wilkins Avenue	Residence	2	-	1938	0.22	>5,000
10479	Wilkins Avenue	Residence	2	-	1928/1939	0.20	>5,000
10491	Wilkins Avenue	Residence	1	-	1942/1948	0.07	>5,000
10499	Wilkins Avenue	Residence	2	1	2007	0.01	>5,000
1428	Warner Avenue	Residence	2	-	1947	0.07	>5,000
1434	Warner Avenue	Residence	2	-	1927	0.20	>5,000
1440	Warner Avenue	Residence	1	1	1925/1949	0.22	>5,000
1413	Warner Avenue	Residence	1	-	1935	0.02	>5,000
1419	Warner Avenue	Residence	2	-	1931/1936	0.09	>5,000
1427	Warner Avenue	Residence	2	1	2003	0.19	>5,000
1431	Warner Avenue	Residence	2	1	2014	0.24	>5,000
1441	Warner Avenue	Residence	2	-	1927	0.21	>5,000
1510	Thayer Avenue	Residence	2	-	1939/1950	0.07	>5,000
1500	Thayer Avenue	Residence	1	-	1928/1931	0.21	>5,000
1418	Thayer Avenue	Residence	1	-	1925	0.23	>5,000
1414	Thayer Avenue	Residence	1	-	1937/1942	0.24	>5,000
1410	Thayer Avenue	Residence	1	-	1937	0.22	>5,000
1406	Thayer Avenue	Residence	2	-	1952	0.15	>5,000
10490	Rochester Avenue	Residence	1	-	1931	0.07	>5,000
1421	Thayer Avenue	Residence	1	-	1948/1984	0.03	>5,000
1415	Thayer Avenue	Residence	2	-	1927	0.08	>5,000
1413	Thayer Avenue	Residence	2	-	1926	0.13	>5,000
1409	Thayer Avenue	Residence	2	-	1951	0.24	>5,000
1403	Thayer Avenue	Residence	1	-	1926	0.24	>5,000
1343	Thayer Avenue	Residence	2	1	2007	0.16	>5,000
1337	Thayer Avenue	Residence	1	-	1931	0.07	>5,000
1331	Thayer Avenue	Residence	2		1976	0.02	>5,000

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
10514	Rochester Avenue	Residence	1	-	1934	0.12	>5,000
10520	Rochester Avenue	Residence	1	-	1939/1970	0.07	>5,000
10511	Rochester Avenue	Residence	1	0	1939/1965	0.22	>5,000
10515	Rochester Avenue	Residence	1	-	1926/1957	0.22	>5,000
10521	Rochester Avenue	Residence	1	-	1924/1940/ 1970/2016	0.22	>5,000
10527	Rochester Avenue	Residence	2	-	2016	0.16	>5,000
10531	Rochester Avenue	Residence	2	-	1937	0.06	>5,000
10537	Rochester Avenue	Residence	2	-	1939	0.02	>5,000
10526	Wellworth Avenue	Residence	1	-	1936	0.03	>5,000
10530	Wellworth Avenue	Residence	1	-	1940	0.13	>5,000
10534	Wellworth Avenue	Residence	1	-	1929/1940	0.21	>5,000
10538	Wellworth Avenue	Residence	1	-	1926/1936	0.24	>5,000
10544	Wellworth Avenue	Residence	1	-	1935/1941	0.24	>5,000
10548	Wellworth Avenue	Residence	2	-	2016	0.21	4,672
10550	Wellworth Avenue	Residence	1	-	1935	0.01	>5,000
10531	Wellworth Avenue	Residence	1	-	1934	0.02	>5,000
10539	Wellworth Avenue	Residence	1	-	1939	0.11	>5,000
10543	Wellworth Avenue	Residence	1	-	1934/1943	0.25	4,803
10551	Wellworth Avenue	Residence	2	-	1959	0.26	>5,000
10557	Wellworth Avenue	Residence	1	-	1929/1956	0.13	>5,000
10563	Wellworth Avenue	Residence	1	-	1929/1939	0.04	>5,000
10567	Wellworth Avenue	Residence	2	-	1989	0.01	>5,000
1254	Fairburn Avenue	Residence	1	-	1925/1940	0.10	>5,000
10576	Ashton Avenue	Residence	2	-	2016	0.02	>5,000
1251	Fairburn Avenue	Residence	2	1	1935/1988	0.25	>5,000
10584	Ashton Avenue	Residence	1	-	1928/1938	0.25	>5,000
10588	Ashton Avenue	Residence	1	-	1924/1940	0.25	>5,000
10592	Ashton Avenue	Residence	1	-	1924/1935	0.20	4,484
10596	Ashton Avenue	Residence	1	-	1924/1940	0.11	>5,000
1250	Westholme Avenue	Residence	1	-	1939	0.04	>5,000
10577	Ashton Avenue	Residence	1	-	1941	0.01	>5,000
10581-10583	Ashton Avenue	Multi Family	2	-	1954	0.05	>5,000

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
10585-10587	Ashton Avenue	Multi Family	2	-	1936/1949	0.13	>5,000
10595	Ashton Avenue	Condo	4	1	1990	0.25	>5,000
1230	Westholme Avenue	Condo	4	1	2004	0.26	>5,000
10601	Ashton Avenue	Condo	3	0	1988	0.26	>5,000
10605	Ashton Avenue	Multi Family	2	0	1950	0.12	>5,000
10611	Ashton Avenue	Condo	3	1	1982	0.09	>5,000
10613	Ashton Avenue	Multi Family	2	-	1951	0.01	>5,000
10580	Wilshire Boulevard	Condo	27	3	1988	0.00	>5,000
10590	Wilshire Boulevard	Condo	16	4	1976	0.11	>5,000
10600	Wilshire Boulevard	Multi Family	6	3	1988	0.25	>5,000
10636	Wilshire Boulevard	Multi Family	7	2	1989	0.24	>5,000
10660	Wilshire Boulevard	Condo	17	3	1980/1993	0.19	>5,000
10601	Wilshire Boulevard	Condo	20	3	1982	0.00	>5,000
10635	Wilshire Boulevard	Multi Family	6	0	1957	0.02	>5,000
10645	Wilshire Boulevard	Condo	5	0 - 1	1955/1970	0.03	>5,000
10655	Wilshire Boulevard	Multi Family	5	0	1955/1960	0.04	>5,000
1116-1126	Manning Avenue	Multi Family	3	-	1941	0.05	>5,000
10700	Wilshire Boulevard	Condo	6	2	2010	0.07	>5,000
10724	Wilshire Boulevard	Condo	15	3	1989	0.10	>5,000
10740	Wilshire Boulevard	Condo	18	0	1972/1990	0.10	>5,000
10701	Wilshire Boulevard	Condo	21	4	1964/1972	0.10	>5,000
10717	Wilshire Boulevard	Multi Family	12	1	1951/1956	0.08	>5,000
10727	Wilshire Boulevard	Condo	22	3	2001	0.08	>5,000
10747	Wilshire Boulevard	Condo	12	3	1972	0.08	>5,000
10750	Wilshire Boulevard	Condo	17	4	1980	0.10	>5,000
10776	Wilshire Boulevard	Condo	22	4	2010	0.03	>5,000
10790	Wilshire Boulevard	Condo	18	4	1979	0.08	>5,000
10751	Wilshire Boulevard	Condo	12	2	1972	0.08	>5,000
10777	Wilshire Boulevard	Proposed	7	2	2013	0.08	>5,000
10787	Wilshire Boulevard	Condo	15	1 - 2	1962/1970	0.07	>5,000
10795	Wilshire Boulevard	Condo	7	1 - 2	2001	0.08	>5,000
10800	Wilshire Boulevard	Condo	23	3	2005	0.05	>5,000

Table A-1: Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
10822	Wilshire Boulevard	Church	2	-1	1938/1949	0.05	>5,000
10840	Wilshire Boulevard	Commercial	3	3	1971/2000	0.10	>5,000
10850	Wilshire Boulevard	Commercial	13	2	1971	0.09	>5,000
10866	Wilshire Boulevard	Commercial	16	1	1986	0.08	>5,000
10801	Wilshire Boulevard	Church	2	1	1940	0.06	>5,000
10833-a	Wilshire Boulevard	Multi Family	6	3	2010	0.08	>5,000
10833-b	Wilshire Boulevard	Multi Family	6	3	2000	0.08	>5,000
10877	Wilshire Boulevard	Commercial	23	4	1989	0.13	>5,000
10880	Wilshire Boulevard	Commercial	23	4-5	1969	0.02	>5,000
10889-10899	Wilshire Boulevard	Commercial	14	2 - 5	1961	0.13	>5,000
10900	Wilshire Blvd	Commercial	15	4	1980	0.01	>5,000
10920	Wilshire Blvd	Commercial	18	4	1980	0.01	>5,000
10940	Wilshire Blvd	Commercial	22	5	1988	0.01	>5,000
10901-10921	Wilshire Blvd	Commercial	11	1	1962	0.18	>5,000
10951	Wilshire Blvd	Parking Lot	-	-	-	0.15	>5,000
1100	Veteran Ave	Parking Lot	-	-	-	0.01	>5,000
10960	Wilshire Blvd	Commercial	23	2	1971	0.00	>5,000
10980	Wilshire Blvd	Parking Structure	8	2	1971	0.00	>5,000

Table A-2: Properties within Limit of Observation along WPLE Tunnel Reach 7

Building Information						Building Surface Settlement	
Building Address		Use	Estimated Stories	Levels Below Ground	Year Built	At Building (inches)	Differential (1/x)
Number	Street						
10990	Wilshire Blvd	Commercial	17	8	1988	0.00	>5,000
11000	Wilshire Blvd	Government	17	1		0.00	>5,000
950	S Sepulveda Blvd	Cemetery	-	-	-	0.20	>5,000
-	I-405	Highway	-	-	-	0.04	>5,000
11360	Wilshire Blvd	Hospital	2	-		0.00	>5,000
1250	Federal Ave	Government	2	-		0.00	>5,000

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Table A-3: Basement Settlement for Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information							Dist FromAlign. Ctline to FOB							Building Settlement (Basement/Foundation)			
Location	No.	Street	Use	Est. Story	Levels Basement Below Ground	Year Built	Approx. Station	Dist From Align. Ctline to FOB	Dist From Align. Ctline to Front Edge of Basement	Dist From Align. Ctline to Back Edge of Basement	Depth to TOR from Surface	Depth to Springline from Basement/ Deep Foundation(s)	Pillar Width	Ground Surface At Tunnel	Ground Surface Above CL between tunnels	At Building/ Foundation	Differential
								ft		ft	ft	ft	ft	in	in	in	1/x
Reach 6	2025	Avenue of the Stars	Proposed	47	7	New	717+25	48	40	200	77	22	13.66	0.35	0.40	0.03	10000
Reach 6	10250	Santa Monica Blvd - Gen Store	Commercial (West Field)	4	2	1966	718+90	65	65	283	77	25	16.70	0.34	0.38	0.00	10000
Reach 6	10250	Santa Monica Blvd - Nordstrom	Commercial	3	2	1974	718+36	0	0	60	77	51	19.73	0.32	0.37	0.46	1647
Reach 6	10250	Constellation Blvd	Commercial	34	3	2002	722+25	100	102	402	78	42	20.18	0.32	0.37	0.00	10000
Reach 6	10250	Santa Monica Blvd - AMC	Commercial	4	2 - 3	2004	722+25	0	0	60	90	41	20.62	0.30	0.34	0.54	1350
Reach 6	1930	Century Park West - Parking	Commercial	5	2	1966	723+59	0	0	60	88	41	21.50	0.30	0.34	0.36	2771
Reach 6	10250	Santa Monica Blvd - Gelson's	Commercial	3	2	1974	725+06	0	0	60	95	69	16.55	0.30	0.34	0.40	2260
Reach 6	10330	Santa Monica Blvd	Condo	5	2	New	734+00	0	0	60	60	34	16.55	0.28	0.31	0.36	2861
Reach 6	10351	Santa Monica Blvd	Commercial	3	4	1984	737+61	0	0	60	107	61	16.55	0.28	0.31	0.41	2146
Reach 6	1636	S Beverly Glen Blvd	Condo	4	1 - 2	2010	741+33	0	0	75	136	105	16.55	0.23	0.25	0.30	4196
Reach 6	1617	S Beverly Glen Blvd	Condo	5	0 -2	1988	743+64	0	0	80	113	111	16.55	0.27	0.29	0.28	4583
Reach 6	10595	Ashton Ave	Condo	4	1	1990	767+42	0	0	80	135	119	16.55	0.24	0.25	0.27	5162
Reach 6	1230	Westholme	Condo	4	1	2004	768+00	0	0	70	134	122	16.55	0.24	0.26	0.26	5492
Reach 6	10590	Wilshire Blvd	Condo	16	4	1976	768+49	72	33	217	132	86	16.55	0.24	0.26	0.25	8807
Reach 6	10600	Wilshire Blvd	Multi Family	6	2	1988	770+40	0	0	60	136	119	16.55	0.23	0.25	0.27	5475
Reach 6	10601	Wilshire Blvd	Condo	21	3	1982	772+79	182	90	340	140	104	16.55	0.23	0.24	0.05	10000
Reach 6	10636	Wilshire Blvd	Multi Family	7	2	1989	772+83	12	3	60	140	114	16.55	0.23	0.24	0.28	4868
Reach 6	10660	Wilshire Blvd	Condo	16	3	1980	774+52	38	26	180	144	116	16.55	0.22	0.24	0.24	7663
Reach 6	10645	Wilshire Blvd	Condo	5	1	1955	774+81	123	123	261	146	130	16.55	0.22	0.23	0.02	10000
Reach 6	10700	Wilshire Blvd	Condo	9	2	2010	777+12	110	88	208	153	127	16.55	0.21	0.22	0.07	10000
Reach 6	10701	Wilshire Blvd	Condo	21	4	1964	777+72	79	40	231	155	109	16.55	0.21	0.22	0.21	10000

Table A-3: Basement Settlement for Properties within Limit of Observation along WPLE Tunnel Reach 6

Building Information							Dist FromAlign. Ctline to FOB							Building Settlement (Basement/Foundation)			
Location	No.	Street	Use	Est. Story	Levels Basement Below Ground	Year Built	Approx. Station	Dist From Align. Ctline to FOB	Dist From Align. Ctline to Front Edge of Basement	Dist From Align. Ctline to Back Edge of Basement	Depth to TOR from Surface	Depth to Springline from Basement/ Deep Foundation(s)	Pillar Width	Ground Surface At Tunnel	Ground Surface Above CL between tunnels	At Building/ Foundation	Differential
								ft		ft	ft	ft	ft	in	in	in	1/x
Reach 6	10717	Wilshire Blvd	Multi Family	12	1	1951	779+12	60	60	205	158	142	16.55	0.21	0.22	0.14	10000
Reach 6	10727	Wilshire Blvd	Condo	22	3	2001	780+10	93	37	200	159	123	16.55	0.21	0.22	0.21	9500
Reach 6	10724	Wilshire Blvd	Condo	15	3	1989	780+45	115	97	280	159	123	16.55	0.21	0.22	0.05	10000
Reach 6	10747	Wilshire Blvd	Condo	12	3	1972	782+88	93	65	212	156	120	16.55	0.21	0.22	0.12	10000
Reach 6	10750	Wilshire Blvd	Condo	17	4	1980	783+80	105	84	248	154	108	16.55	0.21	0.22	0.06	10000
Reach 6	10751	Wilshire Blvd	Condo	12	3	1972	784+62	65	40	235	151	115	16.55	0.22	0.23	0.20	10000
Reach 6	10776	Wilshire Blvd	Condo	22	4	2008	785+70	121	80	222	147	101	16.55	0.22	0.23	0.07	10000
Reach 6	10777	Wilshire Blvd	Multi Family	7	2	1954	786+34	87	45	233	145	119	16.55	0.22	0.24	0.19	10000
Reach 6	10787	Wilshire Blvd	Condo	15	2	1962	787+33	90	70	208	141	115	16.55	0.23	0.24	0.11	10000
Reach 6	10790	Wilshire Blvd	Condo	18	4	1979	788+00	100	74	260	140	67	16.55	0.23	0.24	0.03	10000
Reach 6	10795	Wilshire Blvd	Condo	7	2	2001	788+00	70	52	222	137	118	16.55	0.23	0.25	0.16	10000
Reach 6	10800	Wilshire Blvd	Condo	23	3	2005	789+82	110	77	215	132	96	16.55	0.24	0.26	0.07	10000
Reach 6	10801	Wilshire Blvd	Church	1	1	1940	790+14	80	80	140	130	114	16.55	0.24	0.26	0.08	9850
Reach 6	10833-a	Wilshire Blvd	Multi Family	2	3	2000	792+17	81	55	177	122	86	16.55	0.25	0.27	0.14	10000
Reach 6	10822	Wilshire Blvd	Church	2	1	1938	792+78	100	100	263	120	104	16.55	0.26	0.28	0.03	10000
Reach 6	10840	Wilshire Blvd	Commercial	3	3	1971	795+00	76	75	193	117	62	16.55	0.26	0.28	0.02	10000
Reach 6	10850	Wilshire Blvd	Commercial	13	2	1971	795+00	72	75	195	110	84	16.55	0.27	0.30	0.07	10000
Reach 6	10833-b	Wilshire Blvd	Multi Family	6	3	2000	795+00	80	55	177	106	70	16.55	0.28	0.31	0.12	10000
Reach 6	10866	Wilshire Blvd	Commercial	16	1	1986	797+00	74	74	250	100	51	16.55	0.29	0.32	0.01	10000
Reach 6	10877	Wilshire Blvd	Commercial	20	4	1989	797+00	49	40	305	92	29	16.55	0.31	0.34	0.13	10000
Reach 6	10880	Wilshire Blvd	Commercial	23	5	1969	800+00	78	78	350	77	30	16.55	0.34	0.38	0.00	10000

Table A-3: Basement Settlement for Properties within Limit of Observation along WPLE Tunnel Reach 6 and 7

Building Information							Dist FromAlign. Ctline to FOB							Building Settlement (Basement/Foundation)			
Location	No.	Street	Use	Est. Story	Levels Basement Below Ground	Year Built	Approx. Station	Dist From Align. Ctline to FOB	Dist From Align. Ctline to Front Edge of Basement	Dist From Align. Ctline to Back Edge of Basement	Depth to TOR from Surface	Depth to Springline from Basement/ Deep Foundation(s)	Pillar Width	Ground Surface At Tunnel	Ground Surface Above CL between tunnels	At Building/ Foundation	Differential
								ft		ft	ft	ft	ft	in	in	in	1/x
Reach 6	10889-10899	Wilshire Blvd	Commercial	11	2	1961	800+00	45	33	105	143	42	12.25	0.23	0.24	0.28	3111
UCLA Station	10900	Wilshire Blvd	Commercial	16	4	1980	803+00	90	85	225	66	22	11.75	0.39	0.45	0.00	10000
UCLA Station	10920	Wilshire Blvd	Commercial	18	4	1980	805+00	84	84	250	66	18	11.25	0.39	0.45	0.00	10000
UCLA Station	10901-10921	Wilshire Blvd	Commercial	11	1	1962	805+00	45	43	121	66	22	11.25	0.39	0.45	0.01	10000
UCLA Station	10940	Wilshire Blvd	Commercial	22	5	1988	806+00	85	85	410	66	10	11.25	0.39	0.45	0.00	10000
UCLA Station	10960	Wilshire Blvd	Commercial	23	2	1971	808+10	96	96	206	67	14	11.25	0.39	0.45	0.00	10000
UCLA Station	10980	Wilshire Blvd	Commercial	8	2	1971	811+50	94	94	334	69	16	12.25	0.38	0.43	0.00	10000
Reach 7	10990	Wilshire Blvd	Commercial	17	8	1988	813+00	96	96	250	69	12	16.49	0.36	0.41	0.00	10000
Reach 7	11000	Wilshire Blvd	Government	17	1		817+94	179	179	265	69	53	15.83	0.36	0.41	0.00	10000
	I-405 (Bent 8)		Highway Bridge				828+40	68		88	66	22.5	13.84	0.38	0.43	0.00	10000
	I-405 (Bent 7)		Highway Bridge				828+40	82		103	66	22.5	13.84	0.38	0.43	0.00	10000
I-405 (53-3050K Bridge Ftg.			Highway Bridge				831+30	54		80	79	33.5	13.84	0.35	0.39	0.00	

APPENDIX B MAJOR UTILITIES

APPENDIX B MAJOR UTILITIES

Location	Utility	Owner	Size (from existing conditions)	Material Makeup
Century Park West	Water	DWPWS	12"	
	Sewer	COLA	10"	VCP
	Storm Drain	COLA	27"	RCP
	Gas	SCG	3"	Steel
	Storm Drain	COLA	21"	RCP
Fox Hills Drive Crossing Missouri Avenue	Gas	SCG	3"	Steel
	Gas	SCG	2"	Steel
Alley Parallel to Santa Monica Boulevard	Gas	SCG	2"	Steel
Santa Monica Boulevard	Water	DWPWS	12"	
	Water	MWD	28"	
	Water	DWPWS	28"	
	Water	DWPWS	12"	
	Water	MWD	29.5"	
Comstock Avenue	Storm Drain	COLA	18"	RCP
	Storm Drain	COLA	24"	RCP
	Sewer	COLA	10"	CONC
	Storm Drain	COUNTY OF LA	30"	RCP
	Gas	SCG	3"	Steel
	Storm Drain	COUNTY OF LA	24"	RCP
North Alley Parallel to Santa Monica Boulevard	Gas	SCG	6"	Steel
	Sewer	COLA	10"	CONC.
	Storm Drain	COLA	30"	RCP
Eastborne Avenue	Gas	SCG	2"	Steel
Beverly Glen Boulevard	Storm Drain	COUNTY OF LA	36"	RCP
	Gas	SCG	4"	Steel
Pandora Avenue	Gas	SCG	3"	Steel
Kinnard Avenue	Gas	SCG	2"	Steel
	Gas	SCG	2"	Steel
Wilkins Avenue	Gas	SCG	2"	Steel
Warner Avenue	Gas	SCG	2"	Steel
Thayer Avenue	Gas	SCG	4"	Steel
	Water	DWPWS	12"	
	Sewer	COLA	21"	VCP
Rochester Avenue	Sewer	COLA	21"	VCP
	Gas	SCG	2"	Steel
	Sewer	COLA	18"	
Wellworth Avenue	Gas	SCG	3"	Steel
Fairburn Avenue	Storm Drain	COLA	60" x 48"	RCP
	Gas	SCG	1 1/4"	Steel
	Sewer	COLA	18"	VCP
Ashton Avenue	Gas	SCG	3"	Steel
	Sewer	COLA	18"	VCP
Westholme Avenue	Sewer	COLA	18"	VCP
	Storm Drain	COLA	18"	RCP
	Storm Drain	COLA	6.5' x 7.75'	
	Sewer	COLA	12"	CONC.
Along Wilshire Boulevard from Westholm to Manning Avenue	Gas	SCG	2"	Steel
	Gas	SCG	8"	Steel
Along Wilshire Boulevard from Westholm to Glendon Avenue	Water	DWPWS	12"	
Manning Avenue	Water	DWPWS	36"	

Location	Utility	Owner	Size (from existing conditions)	Material Makeup
	Gas	SCG	6"	Steel
	Gas	SCG	6"	Steel
	Water	DWPWS	12"	
Along Wilshire Boulevard Between Manning and Selby Avenue	Gas	SCG	3"	Steel
	Gas	SCG	2"	Steel
Along Wilshire Boulevard Between Manning and Glendon Avenue	Gas	SCG	6"	Steel
Malcolm Avenue	Gas	SCG	4"	Steel
Glendon Avenue	Water	DWPWS	12"	Asbestos Cement
	Gas	SCG	3"	Steel
	HP-Gas	SCG	6"	Steel
Wilshire Boulevard between Westwood Boulevard and Glendon Avenue	SS	COLA	15"	VCP
	Water	DWPWS	36"	MPCC
	Gas	SCG	6"	Steel
Westwood Boulevard	Water	DWPWS	36"	MPCC
	HP-Gas	SCG	3"	Steel
	Water	DWPWS	42"	MPCC
	SS	COLA	39"	VCP
Wilshire Boulevard between Gayley Avenue and Westwood Boulevard	SD	COLA	7' x 6'	RCP
	Water	COLA	12"	Steel
	SS	COLA	12"	VCP
	SS	COLA	27"	VCP
	SS	COLA	15"	VCP
	SD	COLA	30"	RCP
	SS	COLA	15"	VCP
		SCG	6"	-
	Electrical	DWPPS	VAULT	-
	SD	COLA	30"	RCP
	Water	DWPWS	12"	Steel
	Gas	SCG	6"	Steel
Gayley Avenue	SD	COLA	48"	RCP
	SD	COLA	60"	CONC
	Gas	SCG	8"	Steel
	SS	COLA	18"	VCP
	SS	COLA	12"	VCP
	SS	COLA	27"	VCP
	Gas	SCG	8"	Steel
	SS	COLA	30"	VCP
Midvale Avenue	SD	COLA	30"	RCP
	SD	COLA	7.5' x 7'	RCP
	SD	COLA	9.5' x 6'	RCB
	SS	COLA	12"	VCP
	SS	COLA	15"	VCP
Wilshire Boulevard between Veteran Avenue and Gayley Avenue	Telecom	AT&T	10' x 4.5' x 8.3'	PVC
	SD	LACFCD	8'-10" x 10'-6"	RCB
	SS	COLA	27"	VCP
	SS	COLA	18"	VCP
	SS	COLA	24"	VCP
	SD	LACFCD	8.8' x 10.5'	RCB
	Gas	SCG	10"	Steel
	SS	COLA	24"	VCP
	SS	COLA	12"	CONC
	Gas	SCG	10"	Steel
Veteran Avenue	Gas	SCG	8"	Steel

Location	Utility	Owner	Size (from existing conditions)	Material Makeup
	SD	LACFCD	6.3' x 7.5'	RCB
	SS	COLA	12"	VCP
	Gas	SCG	2"	Steel
	Telecom	Verizon	10' x 10' x 6'	PVC
	Gas	SCG	8"	Steel
	SD	LACFCD	9.25' x 12'	RCB
	Gas	SCG	9"	Steel
Wilshire Boulevard between I-405 and Veteran Avenue	Gas	SCG	8" HP	
	Sewer	COLA	30"	
	Electrical	SCE	4'x6', 6'x7'	
	Sewer	COLA	30"	
Northbound I-405 On Ramp	Storm Drain	Caltrans	24"	
	Storm Drain	Caltrans	24"	
Not identified in the spreadsheet	Storm Drain	Caltrans	24"	
Sepulveda Boulevard	Water	MWD	96"	
	Oil	EXXONMOBIL	16"	
	Gas	SCG	10.5"	
	Storm Drain	COLA	36"	
	Electrical	LADWP	6-6",6-5",2-4"	
	SS	COLA	12"	
	Gas	SCG	10.75"	
	Oil	EXXONMOBIL	10" in 14" casing	
	Oil	CHEVRON	8"	
	Oil	SHELL	8"	
	Oil	MOBIL	16" in 20" casing	
	Electrical	SCE	7' X 14 ' Vault	
	Oil	COLA	16"	
Wilshire Boulevard / VA Hospital	Storm Drain	CALTRANS	18"	
	Sewer	COLA	18"	
	Storm Drain	CALTRANS	18"	
	Gas	BRIGHTBURN	8"	
	Oil	BRIGHTBURN	6"	
	Sewer	VA	10"	
	Water	VA	12"	
	Storm Drain	CALTRANS	36" RCP	
	Storm Drain	CALTRANS	30" HDPE	
	Storm Drain	CALTRANS	24" HDPE	
	Storm Drain	CALTRANS	18" RCP	
Wilshire Boulevard / Bonsall Avenue	Storm Drain	CALTRANS	21" RCP	
	Storm Drain	CALTRANS	18" RCP	
	Storm Drain	CALTRANS	24" RCP	
	Storm Drain	CALTRANS	24" RCP	
	Water	DWPWS	84" RCP	
Wilshire Boulevard / Pedestrian Underpass	Storm Drain	CALTRANS	21" RCP	

APPENDIX C FREE FIELD SETTLEMENT THROUGH CALCULATION METHODOLOGY

APPENDIX C FREE FIELD SETTLEMENT THROUGH CALCULATION METHODOLOGY

Tunneling disturbs the ground and causes ground movements and settlements to occur. Typically, the ground disturbance forms a trough to develop at the surface and the extent of the trough is referred to as “the zone of influence of tunneling”.

To evaluate these movements and to assess whether their impact is sufficient to damage nearby buildings requires an assessment of:

7. Tunneling methods to be employed and their effect on ground movements.
8. Sensitivity of buildings to distortion and allowable limits.

C.1 GROUND MOVEMENTS CAUSED BY TUNNELING

Ground movements caused by tunneling result from what is termed “ground loss”.

C.2 EXPECTED GROUND LOSS

Expected ground loss occurs as the tunnel is advanced and, although controllable, cannot be completely eliminated. For soft ground tunneling, it typically appears at the ground surface as a trough paralleling the tunnel. The trough forms as a result of ground losses from the following sources:

9. Face Losses: Soil movement into the face of the TBM in the form of raveling, caving, flowing, running, squeezing, or over-excavation.
10. Shield Losses: Soil movement into the void around the shield. The shield protects the excavated tunnel between the tunnel face and the tail of the shield where the initial support system is installed. The void around the shield is the result of overcutting and of shield actions such as plowing, pitching, or yawing. Overcutting the excavation is necessary to assist in steering the shield and also to reduce the friction and thereby the thrust required to advance the shield.
11. Tail Losses: Soil movement toward the installed tunnel lining as the shield is shoved forward. Although the void behind the lining is backfilled with grout, soil can fill the void if backfill grouting is delayed or only partially completed.

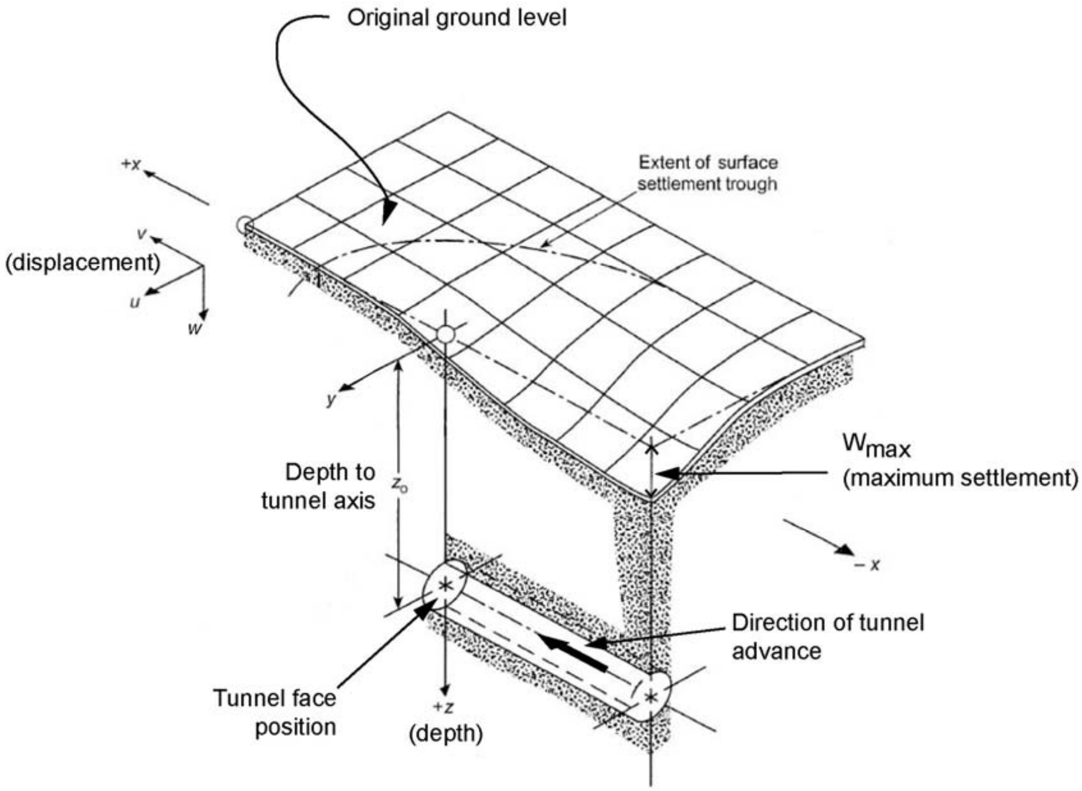
The trough that develops from the ground losses is three-dimensional and can be estimated by a Gaussian distribution (Peck, 1969) - an inverted Bell curve as shown on Figure C-1.

The magnitude of the settlement depends on the size of the excavation, its depth, the method of tunneling as well as the soil conditions. The parameters that define the settlement are:

12. Ground loss is defined as a fraction (generally reported as a percentage) of the tunnel volume excavated. It can vary up to several percent and depends upon the method of excavation and the ground’s stand-up time.
13. Trough width parameter (K) is defined as an assessment of the subsurface conditions encountered that relate to the width of the settlement trough and the severity of the shape of the Gaussian distribution curve.

Once these parameters are estimated, the settlement surface, sometimes termed the free-field settlement surface, can be defined using the analysis by O'Reilly and New, 1982 in terms of displacements in the transverse and longitudinal directions relative to the tunnel's longitudinal axis.

Figure C-1: Three-Dimensional Settlement above an Advancing Tunnel (Burland et al., 2001)



C.3 LOCALIZED GROUND LOSS

Localized ground loss in soft ground tunneling occurs when the face is inadequately supported in ground that can collapse, ravel, run, flow or squeeze. Such losses are rare and result from poor tunneling practice, they can also be associated with:

14. Encountering underground voids or obstructions, such as boulders, old pile foundations, and abandoned wells, and
15. Excavation of the tunnel face in mixed face conditions (e.g. soft silt overlying dense gravel) results softer material entering the working chamber more readily than the harder or denser material
16. Start-up, stoppage, and improper restart of mining operations

These types of losses can result in relatively narrow chimneys developing in the ground that can reach the ground surface. Ground losses that result in sinkholes are relatively rare events, although when they do occur, they are widely reported. The use of state-of-the-art soft ground TBMs that have pressurized closed chambers at the face along with continuous monitoring of TBM parameters greatly assists in reducing such events.

C.4 SETTLEMENT CALCULATION

Settlement estimates take into account the anticipated volume of ground lost during the tunneling process. For a single tunnel in soft ground conditions, it is typically assumed the volume of surface settlement is equal to the volume of lost ground with any volume change due to bulking or compression not estimated or included in the calculations. The shape of the settlement trough perpendicular to the direction of tunnel advance resembles that of an inverted bell-shaped probability curve.

The settlement trough ahead of the advancing face, is of similar shape, but is a transient feature that is continually adjusted as the tunnel advances.

For parallel tunnels, the settlement trough is calculated separately for each tunnel and then summed. Figure C-2 illustrates in two dimensions, the settlement trough shape and extent of surface settlement with respect to an advancing tunnel (O'Reilly and New 1982) with Figure C-3 and Figure C-4 providing the formulae used to predict through parameters (Lake et al, 1992).

Figure C-2: Terminology for Ground Loss and Tunneling Settlement

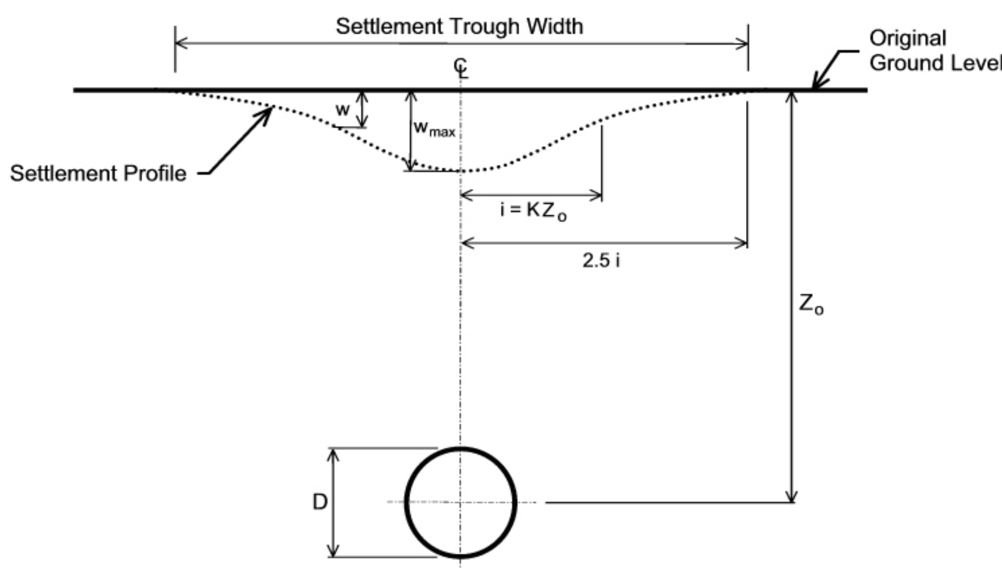
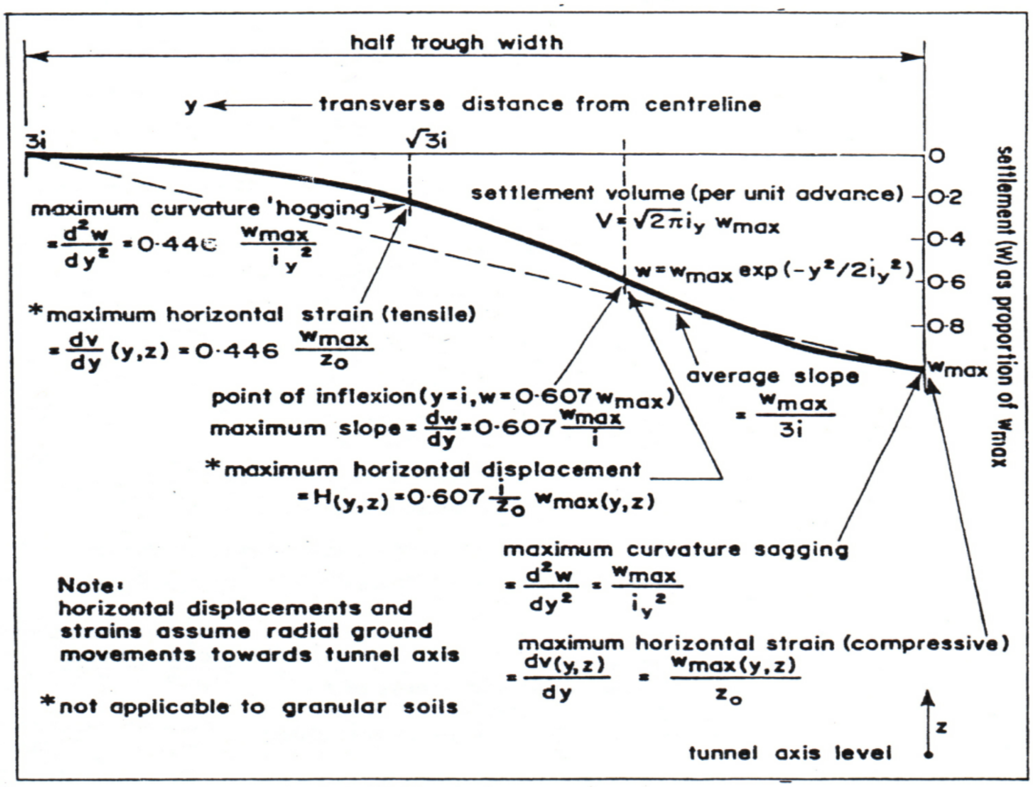


Figure C-3: Theoretical Formulae for Settlement



$$w_{\max} = \frac{0.313 V_L (D)^2}{K z_o}$$

w_{max}	- Maximum settlement	w	- Settlement at distance
'y'	- from tunnel centerline	z_o	- Depth to tunnel springline
K	- Trough width parameter	V_L	- Volume loss
D	- Tunnel diameter	i	- Distance to point of inflection

Where w_{max} is the settlement at the center of the trough, x is the distance from the centerline and, i, is the distance from the center to the point of inflection.

The volume of the settlement trough is given by: $V_s = 2.5 i w_{max}$

Typical steps for estimating settlements are as follows:

17. Determine depth from ground surface to tunnel springline, z_0.
18. Calculate distance to point of inflection on settlement curve using trough width parameter, K = 0.4:

$$i = Kz_0$$

where i = Distance to point of inflection

K = Trough width parameter

Z_0 = Depth to tunnel springline

19. Calculate maximum settlement at the center of the trough,

$$w_{\max} = \frac{V_L \pi (r)^2}{2.5i}$$

where V_L = Volume of Ground Loss (%)

r = radius of excavated tunnel

Calculate settlement, w, at each point along settlement trough:

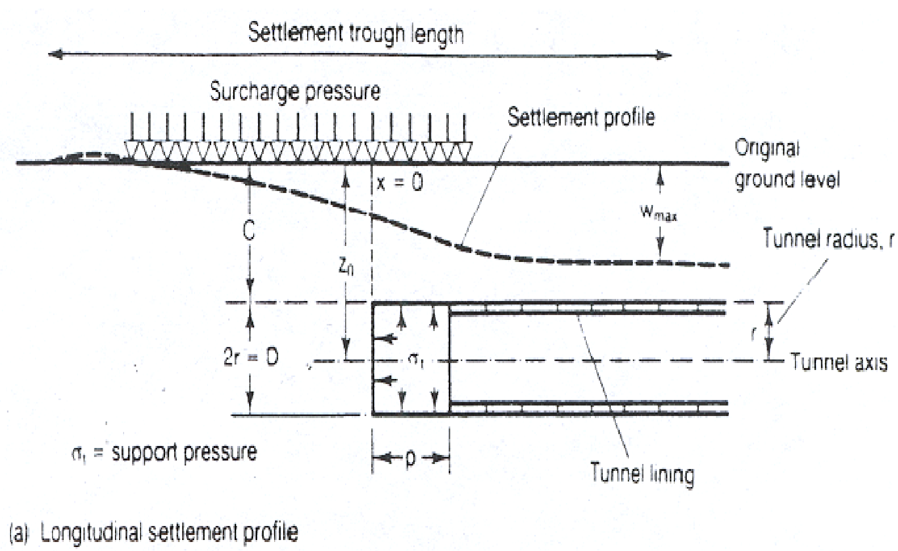
$$w = w_{\max} \exp\left(-y^2 / 2i\right)$$

where w_{max} = settlement at the center of the trough

y = distance from tunnel centerline

Lateral movements are assumed to be directed towards the tunnel centerline, equal in magnitude to the settlement multiplied by the ratio of the offset distance divided by the tunnel depth.

Figure C-4: Theoretical Formulae for Longitudinal Settlement Trough

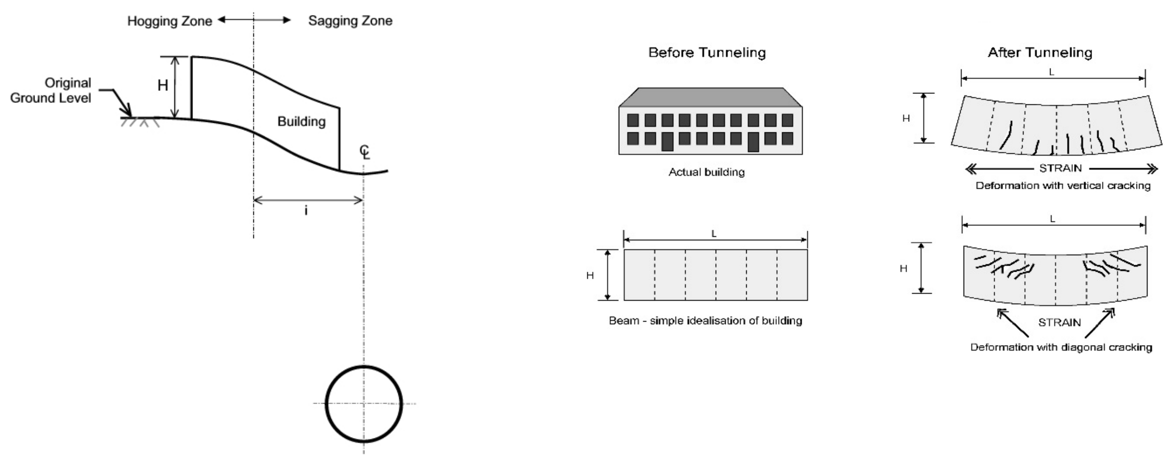


C.5 IMPACTS TO BUILDINGS FROM TUNNELING

As the ground moves, buildings located within the zone of influence of tunneling will settle and potentially distort. Generally, a uniform settlement does not cause damage but a differential settlement across a building can cause distress. Differential settlement is typically expressed as a ratio (for example 1:600), or fraction (1/600), indicating the ratio of the differential vertical movement between two points of interest to the horizontal distance between them. Figure C-5 shows schematically diagonal and vertical cracking typically found in buildings that have experienced differential settlement.

- Horizontal strain in the ground is assumed equal to the horizontal building strain and is calculated as the first derivative of the assumed lateral movement.
- Buildings behave as deep beams - a simple approach establishing a framework for relating settlement, building movement, and structural performance of the building. This follows the work of Burland and Wroth, 1974 and Boscardin and Cording, 1989.

Figure C-5: Deformation Modes and Cracking Patterns for Buildings



The typical approach to assess building performance resulting from ground movements caused by tunneling was proposed by Boscardin and Cording (1989). This is conservative as it does not take into account the stiffness of the building that reduces the strains induced into the structure (Potts and Addenbrooke, 1996). For the approach:

- Settlement of a building's foundation follows the "free-field settlement surface" condition
- Magnitude of ground movements and strains are based on the building's location within the settlement trough. The structural elements of a building are strained by the ground movement acting along its base

The strain state within a structural element or bay of the building is determined by:

- Lateral strain - extension of the base divided by the base length

- Shear strain or angular distortion - average settlement slope across the structural element minus the tilt of the element

This approach has application to building distortions over a broad range of L/H values. However if necessary, separate values of lateral strain may be estimated for the lower and upper portions of the building to account for bending strains or for the reduction in the lateral strain due to the stiffness of the upper floors. Note: the lateral strain in the upper levels of a building may also increase due to a convex (hogging) soil profile.

C.6 DAMAGE EFFECTS TO BUILDINGS FROM TUNNELING

Building distress effects depend on the extent of the movements. Other factors that may require consideration in determining damage effects include: building age; construction materials condition; type and function (and its sensitivity to movement); and location within the settlement trough.

C.7 DAMAGE CLASSIFICATIONS

In an effort to provide a framework for classifying damage, Skempton and MacDonald (1956) developed a classification that uses three general categories:

- Architectural damage – This affects the appearance of the structure, and is usually related to cracks or separations in panel walls, floors and finishes. Cracks in plaster walls greater than 0.5 mm wide and cracks in masonry or rough concrete walls greater than 1 mm wide are threshold levels where damage is noticed and reported by building occupants
- Functional damage – This affects structure use and is exemplified by jammed doors, windows excessively cracked, falling plaster, tilting of walls and floors and other damage that would require nonstructural repair to return the building to its full capacity
- Structural damage – This affects the stability of the structure, usually related to cracks or distortions in primary support elements such as beams, columns and load bearing walls

Damage can also be assessed from the strain levels - lateral strain and shear strain induced into a given structural unit and this approach was adopted to provide Table C-1, Building and Structural Damage Classification (Boscardin and Cording, 1989). It relates damage levels to angular distortion and lateral strain within parts of a building. The categories identified in Table C-1 have also been presented in a chart as shown Figure C-6. The boundaries between damage categories are set to represent a constant principal extension strain, determined as a combination of angular distortion and lateral strain (Cording et al., 2010).

Where the results indicate that settlement will result in strains falling into categories within Risk Categories 0 and 1, additional analyses are generally not necessary and damage is considered likely to be cosmetic and insignificant based upon previous experience and case studies.

Where the results indicate that settlement will result in strains falling into categories outside of Risk Categories 0 and 1, then additional analyses should be carried out using more refined methods. They may be modeled taking into account local subsurface ground conditions, the geometry of the buildings and the foundations as well as expected tunneling excavation sequencing.

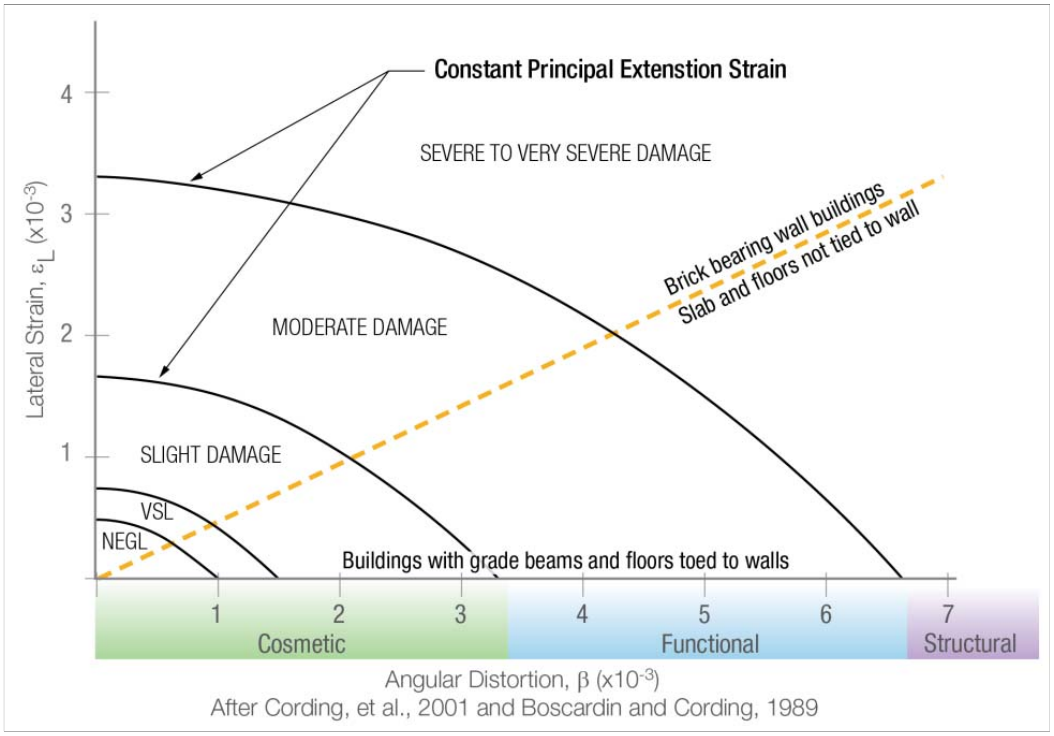
Table C-1: Building Damage Classification[1]

Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width[2] (in)	Maximum Tensile Strain (%)	Maximum Slope of Ground[3]	Maximum Building Settlement (in)
0	Negligible	Hairline cracks	< 0.004	< 0.05	< 1:900	< 0.1
1	Very Slight	Fine cracks easily treated during normal redecoration. Perhaps isolated slight fracture in building. Cracks in exterior brickwork visible upon close inspection.	0.004 to 0.04	0.05 to 0.075	1:900 To 1:600	< 0.5
2	Slight	Cracks easily filled. Redecoration probably required. Several slight fractures inside building. Exterior cracks visible: some repointing may be required for weather-tightness. Doors and windows may stick slightly.	0.04 to 0.2	0.075 to 0.15	1:600 to 1:300	0.5 to 0.75
3	Moderate	Cracks may require cutting out and patching. Recurrent cracks can be masked by suitable linings. Re-pointing and possibly replacement of a small amount of exterior brickwork may be required. Doors and windows sticking. Utility services may be interrupted. Weather-tightness often impaired.	0.2 to 0.6; or no. of cracks greater than 3	0.015 to 0.3	1:300 to 1:150	2 to 3
4	Severe	Extensive repair involving removal and replacement of sections of walls, especially over doors and windows required. Windows and frames distorted. Floor slopes noticeably. Walls lean or bulge noticeably, some loss of bearing in beams. Utility services disrupted.	0.6 to 1.0; also depends on no. of cracks	Greater than 0.3	Greater than 1:150	> 3
5	Very Severe	Major repair required involving partial or complete reconstruction. Beams lose bearing, walls lean badly and require shoring. Windows broken by distortion. Danger of instability.	> 1.0; also depends on no. of cracks	Greater than 0.3	Greater than 1:150	> 3

Notes:
[1] The table is based on the work of Burland et al (1977), as reproduced in Cording and Boscardin (1989). It includes typical maximum tensile strains for the various damage categories (column 5).
[2] Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.
[3] Columns 6 and 7 indicate the free-field settlement trough slopes and are based on the methods of Rankin (1987). Risk Categories using the Rankin method are approximately equivalent to those proposed by Burland, although in some cases there may be significant differences.

Should the results from these analyses confirm that settlements exceed allowable amounts, then, the analyses should be performed to evaluate protecting the buildings by changing the tunneling method (i.e., elevated face pressure for TBM tunneling) or modifying the ground (i.e., permeation grouting, jet grouting, ground freezing and compaction or compensation grouting or underpinning methods).

Figure C-6: Damage Categories (Cording et al., 2010)



APPENDIX D TIEBACK AND FOUNDATION SURVEY

APPENDIX D TIEBACK AND FOUNDATION SURVEY

Table D-1: Summary of Buildings with Tieback Located within Limit of Observation

Building Count	Location	Building Address		Number of Stories	Number of Basements	Year Built	Within Tunnel Envelop
		Number	Street				
1	Reach 6	2025	Avenue of the Stars	47	7	Proposed	Uncertain
2		10250/10270	Constellation Boulevard	34	1-3	2002	No
3		10350	Santa Monica Blvd	3	3	1981	No
4		10351	Santa Monica Blvd	3	3-4	1984	No
5		10600	Wilshire Boulevard	6	3	1988	No
6		10601	Wilshire Boulevard	21	3	1982	No
7		10636	Wilshire Boulevard	7	2	1989	No
8		10660	Wilshire Boulevard	16	3	1980	No
9		10700	Wilshire Boulevard	9	2	2010	No
10		10724	Wilshire Boulevard	15	3	1989	No
11		10727	Wilshire Boulevard	22	3	2001	No
12		10750	Wilshire Boulevard	17	4	1980	No
13		10776	Wilshire Boulevard	22	4	N/A	No
14		10777	Wilshire Boulevard	3	2	1954	No
15		10790	Wilshire Boulevard	18	4	1979	No
16		10800 (formerly 10808)	Wilshire Boulevard	23	3	2005	No
17		10833	Wilshire Boulevard	6	3	2000	No
18		10840	Wilshire Boulevard	3	3	1971	No
19		10850	Wilshire Boulevard	13	2-3	1971	No
20		10877	Wilshire Boulevard	20	4	1989	No
21		10880	Wilshire Boulevard	23	4-5	1969	No
22		10889-10899	Wilshire Boulevard	14	2	1961	No
23	Westwood / UCLA Station	10900	Wilshire Boulevard	15	4	1980	No
24		10920	Wilshire Boulevard	18	4	1980	No
25		10940	Wilshire Boulevard	22	5	1988	No

Table D-2: Summary of Foundation Survey

Building Address		Number of Stories	Number of Basements	Year Built	Foundation Type	Lowest Elevation of Foundation (feet)	Approximate Distance from Tunnel Excavation Limits	
Number	Street						Horizontal Distance from Alignment Centerline (feet)	Vertical Distance from Top of Rail to Nearest Foundation (feet)
2025	Avenue of the Stars	47	7	Proposed	Mat	226	30	9
10250	Santa Monica Boulevard – Nordstrom	3	2	1966	Spread footings w/isolated caissons	233	0	30
	Santa Monica Boulevard - AMC	4	2-3	2004	CIP piles / caissons / spread footings	224	0	24
	Santa Monica Boulevard – Gelsons	3	2	1974	Spread footings	252	0	73
10250	Constellation Boulevard	34	1-3	2002	CIP piles	174	2280	-26
1930	Century Park West	5	2	1966	Spread footings	244	14	62
1900	Fox Hills Drive	2	-	1940			3	112
1858	Fox Hills Drive	2	-	1936			0	115
1854	Fox Hills Drive	1	-	1937	Wall footings	1 foot below grade	0	117
1848	Fox Hills Drive	1	-	1948			0	119
1842/1844	Fox Hills Drive	1	-	1946	Footings	1 foot below grade	0	120
1833/1835	Fox Hills Drive	1	-	1954			6	121
1825	Fox Hills Drive	4	1	2005	Spread/ Soldier Piles during construction	178	5	109
10307	Missouri Avenue	4	1	1991	Spread Footing	262	0	121
10315	Missouri Avenue	3	-	1980		267	0	110
10316	Santa Monica Boulevard	2	-	1954		260	12	110
10318	Santa Monica Boulevard - Building	2	-	1953	Footings	270	0	116
	Santa Monica Boulevard – Sign	-	-	1988	Caissons	253	0	71
10324	Santa Monica Boulevard	2	-	1948		260	0	105
10330	Santa Monica Boulevard	5	2	Proposed	Footings	235.5	17	104
10351	Santa Monica Boulevard	3	3-4	1984	Spread Footing	220	0	107
10360	Eastborne Avenue	1	-	1931	Wall Footing	267	9	115
10364	Eastborne Avenue	1	1	1947	Isolated Footings/retaining wall	256	0	107
10370	Eastborne Avenue	1		1936		274	10	126
10369	Eastborne Avenue	1	-	1937	Footing	273	23	132
10379	Eastborne Avenue	2	1	1925	Footing	281	0	135

Table D-2: Summary of Foundation Survey

Building Address		Number of Stories	Number of Basements	Year Built	Foundation Type	Lowest Elevation of Foundation (feet)	Approximate Distance from Tunnel Excavation Limits	
Number	Street						Horizontal Distance from Alignment Centerline (feet)	Vertical Distance from Top of Rail to Nearest Foundation (feet)
1636	S Beverly Glen Blvd	5	2	2010	Spread/ Soldier Pile during construction	250	0	102
1617	S Beverly Glen Blvd	5	1-2	1988	Spread	259	0	111
1608	Pandora Avenue	2	-	2006	Wall Footing	296	0	142
1616	Pandora Avenue	1	-	1936	Wall Footing	294	0	141
10436	Kinnard Avenue	2	1	2014	Footings	291	0	141
10442	Kinnard Avenue	2	-	1973		302	15	150
10443	Kinnard Avenue	1	-	1928	Footings	304	16	153
10447	Kinnard Avenue	1	-	1938		306	0	154
10451	Kinnard Avenue	1	-	1924		307	0	154
10458	Wilkins Avenue	2	-	1990		308	23	155
10462	Wilkins Avenue	2	-	1932		309	0	156
10466	Wilkins Avenue	1	-	1928		309	0	156
10473	Wilkins Avenue	2	-	1938		310	0	156
10479	Wilkins Avenue	2	-	1928		310	12	156
1440	Warner Avenue	1	-1	1925	Footing	292	0	154
1431	Warner Avenue	2	1	2014		297	0	144
1441	Warner Avenue	2	-	1927		295	19	142
1410	Thayer Avenue	2	-	1937	Footing	291	29	140
1500	Thayer Avenue	1	-	1928	Wall Footing	306	19	150
1418	Thayer Avenue	2	-	1925	Footing	302	0	148
1414	Thayer Avenue	2	-	1937	Footing	294	0	145
1409	Thayer Avenue	2		1951		302	9	138
1403	Thayer Avenue	3	1	1926	Footing	305	3	141
10511	Rochester Avenue	3	-	1939	Footing	305	7	144
10515	Rochester Avenue	2	-	1926	Footing	316	0	152
10521	Rochester Avenue	1	-	1924		314	2	153
10527	Rochester Avenue	2	-	2016	Footing	310	20	142
10534	Wellworth Avenue	2	-	1929	Footing	307	0	143
10538	Wellworth Avenue	1	-	1926	Footing	304	0	143
10544	Wellworth Avenue	1	-	1935	Footing	301	0	139
10543	Wellworth Avenue	1	-	1934	Footing	294	11	130
10551	Wellworth Avenue	2	-	1959	Footing	298	0	128

Table D-2: Summary of Foundation Survey

Building Address		Number of Stories	Number of Basements	Year Built	Foundation Type	Lowest Elevation of Foundation (feet)	Approximate Distance from Tunnel Excavation Limits	
Number	Street						Horizontal Distance from Alignment Centerline (feet)	Vertical Distance from Top of Rail to Nearest Foundation (feet)
1251	Fairburn Avenue	2	1	1935	Footing	290	0	123
10584	Ashton Avenue	1	-	1928		300	0	134
10588	Ashton Avenue	1	-	1924		302	9	134
10595	Ashton Avenue	4	1	1990	CIP drilled pile	291	0	123
1230	Westholme Avenue	4	1	2004	Spread/CIP drilled pile (north side of bldg.)	288	0	188
10601	Ashton Avenue	4	-	1988	Spread footing	298	24	129
10600	Wilshire Boulevard	6	3	1988	Spread footing / Caisson shoring during construction	290 (Caisson to El.278)	0	114
10636	Wilshire Boulevard	7	2	1989	Spread footing/ Caisson shoring during construction	306 (Caisson to El. 288)	12	116