



# WESTSIDE SUBWAY EXTENSION PROJECT

Contract No. PS-4350-2000

## Building and Adjacent Structure Protection Report (Final)

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## EXECUTIVE SUMMARY

The Los Angeles County Metropolitan Transportation Authority (Metro) is currently preparing the advanced conceptual design and preliminary design for the Westside Subway Extension. As part of the design, Parsons Brinckerhoff, the design consultant for the WSE ACE/PE has investigated the structures along the proposed tunnel alignment and identified those that are within the zone of influence of tunneling and evaluated the potential effects of settlement from tunneling on the structures.

The subway tunnels extend along a corridor in west Los Angeles from the existing subway Wilshire/Western Station for the Metro Purple Line to a proposed station at the Veterans Administration Hospital in Westwood. The corridor lies within three city jurisdictions within the County of Los Angeles – the Cities of Los Angeles, Beverly Hills and West Hollywood, and unincorporated areas of Los Angeles. Within this corridor, tunneling, and station and shaft excavations may impact nearby and adjacent existing structures and buried utilities.

### Buildings Along the Alignment

Within the subway corridor, 727 separate buildings were identified as being within a corridor within 120 feet of the centerline of each track. This count includes buildings along the tunnel alignment and at stations and also includes buildings along the two options for the tunnel alignment between Wilshire/Rodeo Station and Westwood/UCLA Station (but does not count buildings twice where there is a common alignment over part of the route. A breakdown of the buildings within the corridor at stations and by tunnel reach between stations is provided in Table ES-1.

**Table ES-1: Buildings Identified along Tunnel Alignment within 120 ft of Centerline of Rail Tracks**

Location along Alignment	Total No. of Buildings	No. of Buildings with 10 or more stories	No. of Buildings with 3 to 9 Stories
Wilshire / Western Access Box	6	2	0
Wilshire / Western to Wilshire / La Brea	92	2	44
Wilshire / La Brea Station	11	1	1
Wilshire / La Brea to Wilshire / Fairfax	38	6	14
Wilshire / Fairfax Station	11	1	6
Wilshire / Fairfax to Wilshire / La Cienega	38	8	11
Wilshire / La Cienega Station	14	2	4
Wilshire / La Cienega to Wilshire / Rodeo	94	3	32
Wilshire / Rodeo Station	13	3	6
Wilshire / Rodeo to Century City Constellation - Option 1	89	5	26
Century City Constellation Station – Option 1	8	5	1
Century City Constellation to UCLA – Option 1	197	21	32
Wilshire / Rodeo to Santa Monica Blvd - Option 2	53	4	16
Santa Monica Blvd Station - Option 2	8	2	3
Santa Monica Blvd to UCLA - Option 2	203	22	23
Westwood / UCLA Station	8	6	0
Westwood / UCLA to Westwood / VA Hospital	1	1	0
Westwood / VA Hospital Station & GSA Crossover	0	0	0
Westwood / VA Hospital – Tail Track Tunnel	2	0	0

Location along Alignment	Total No. of Buildings	No. of Buildings with 10 or more stories	No. of Buildings with 3 to 9 Stories
Total Building Count (counts buildings twice where there is a common alignment over part of the route)	886	94	219

### Subsurface Conditions

Subsurface conditions beneath Los Angeles consist of a deep sedimentary basin. Tunneling and station excavation will be within Old Alluvium, Lakewood, San Pedro and Fernando Formations. Old Alluvium, Lakewood and San Pedro formations comprise heterogeneous stiff fine grained alluvial and marine deposits whereas the Fernando Formation is a more indurated material consisting of siltstones and claystones.

### Criteria for Limiting Damage to Structures

The following criteria were used for limiting movements to structures along the tunnel alignment:

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

These criteria have found acceptance on previous Los Angeles Metro Projects (Redline and MGLLE) 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 suffer insignificant levels of damage.

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 TBMs (earth pressure balance or slurry shield) provide immediate support of the ground and use proven systems for monitoring and controlling machine operations. As a result, excavated volumes can be controlled and this reduces the risk of ground loss that can cause settlement. With these types of TBMs operating in the ground conditions found at the tunnel horizon in the Los Angeles basin, it is anticipated that ground loss can be reduced to 0.5 percent or less.

### Assessment of Building Settlement Along the Tunnel Alignment

Comparing the distortions estimated with damage categories identified in reported in the technical literature, negligible damage to buildings is anticipated from tunneling. Distortions will be well below the levels of structural or functional damage and in the range where cracking of finishes does not occur or is very limited. A total of 49 buildings along the alignment are subject to settlements that could result in cosmetic damage.

From the initial screening for buildings for settlements, it was determined that none of the buildings not directly above the tunnel were subject to settlements greater than ½-inch or to distortions as severe as 1 in 600. One hundred thirty-one buildings were identified as directly above the tunnel. These buildings were all west of Rodeo Station where the tunnels no longer passed beneath public

rights-of-way. They consisted of 102 one or two story structures and 29 buildings greater than 3 stories high.

Estimates for settlement for the one and two story buildings were in the negligible to very slight categories. For the buildings more than 3 stories high, some of which had depths of cover to the tunnels of less than 80 feet, further evaluations were carried out to establish whether:

- Any below grade construction interfered with tunnel construction, for example basement levels, tiebacks or foundation piers and piles
- Settlement of basements could exceed settlement criteria and required building protection

These evaluations have not indicated a need for additional measures except at the Westfield Mall (10250 Santa Monica Boulevard). The tunnels are relatively shallow beneath the mall as they approach Century City, Constellation Station. To remediate the potential settlements, the following actions are under consideration:

- Deepening the tunnel
- Underpinning the piled foundations, where necessary
- Performing compensation grouting as the tunnels go by to prevent settlement of the buildings

## 1.0 INTRODUCTION

The Los Angeles County Metropolitan Transportation Authority (Metro) is currently preparing the advanced conceptual engineering and preliminary engineering (ACE/PE) for the Westside Subway Extension (WSE). The subway tunnels extend along a corridor in west Los Angeles from the existing subway station for the Metro Purple Line at Wilshire/Western to a proposed station at the Veterans Administration Hospital in Westwood. The corridor lies within urban areas of four jurisdictions within the County of Los Angeles – the City of Los Angeles, City of Beverley Hills, West Hollywood and unincorporated areas of Los Angeles. Within this corridor, the project may impact nearby and adjacent structures and buried utilities from tunneling and excavation works. There are more than 1,500 structures.

As part of the ACE/PE design activities, Parsons Brinckerhoff, the design consultant for the WSE is tasked (under its Statement of Work, Section 6.6.1.2 for work scope) with developing a Building Protection Program.

### 1.1 Building Protection Program

For the majority of structures within the zone of influence of tunneling, it can be anticipated that the selection and proper use of a tunneling method appropriate to the subsurface conditions encountered is sufficient to control ground movements and additional protection is generally not necessary to avoid damage to the structures.

However, in some case, and depending on tunnel size, depth tunneling method and ground conditions, and the geometry and stiffness of the structures potentially affected, such structures may require additional protection generally in the form of ground modification or underpinning. 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 along the alignment must be carried out and for buildings identified as requiring additional protection beyond the use of good tunneling practice, designs should be developed during final design to protect them using ground improvement (grouting) or underpinning methods.

During construction, it is necessary to verify that settlement levels are not in excess of those predicted and that buildings are not undergoing distortions that could cause distress. During tunneling therefore, it is prudent practice to implement a geotechnical monitoring program. The purpose of the program is to:

- Confirm that tunneling is being carried out in accordance with the technical specifications and is meeting the parameters (i.e., ground loss and K) used to predict ground movements and settlement levels. Generally, multipoint extensometers, inclinometers and surface settlement markers installed along the alignment and monitored as the TBM passes are used for this purpose.
- Verify that buildings and structures are settling and distorting within acceptable limits predicted by the settlement analysis. Settlement markers installed on buildings along the alignment and monitored as the TBM passes are used for this purpose.
- Provide a record of building or structure condition for each building along the alignment before and after tunneling to demonstrate that no damage has occurred or if it has, to identify the damage attributable to tunneling that should be fixed.

## **1.2 Building Protection Program Evaluations during ACE/PE**

The building protection program activities implemented during ACE/PE have consisted of the following:

- Identify buildings within the zone of influence of tunneling
- Assemble records of the design and as-built condition of structures potentially impacted.
- Where necessary, perform an analysis to evaluate there is a need to protect the building or structure by underpinning, jacking, isolation, grouting or other means.
- Compare alternative viable methods as to relative cost and practicality and select a course of action.
- Where necessary, inspect and survey buildings to determine feasibility of underpinning or other treatment

## **1.3 Purpose of the ACE/PE Building Protection Program Report**

This report documents the progress made, to date, during ACE and PE with this program. It provides background information and discusses the ground conditions likely to be encountered, the tunneling methods to be used and the approach to estimating ground movements from tunneling along the alignment and their possible effects on buildings. The report documents:

- Buildings along the alignment
- Available records obtained from property owners and other sources (geotechnical reports, and information from the City of Los Angeles, Building Department)
- Results of settlement predictions
- Criteria for assessing effects of tunneling on structures
- Structures identified as needing protection
- Preliminary assessment of building protection measures that should be considered

## **1.4 Background**

Although the following remarks were made over fifteen years ago and significant advances have been made in the application of state-of-the-art tunneling technologies in the United States during this period of time, they 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.<sup>1</sup>

1. 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.

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<sup>1</sup> Comments made at Tunnel Review Board meeting for Los Angeles Metro Rail System, 1994

2. 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.
3. 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 undoubtedly 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 have not entirely eliminated ground settlements and the factors listed above must be acknowledged and taken into consideration during design and construction of tunneling projects in urban areas.

Selection and use of a tunneling method that is compatible with the subsurface conditions being excavated but minimizes ground movements that could damage buildings and structures and including practical controls, including the experience of the tunneling contractor and its labor force to effectively tunnel.

## **2.0 PROJECT OVERVIEW**

The proposed extension of the Metro Purple Line subway westward from the existing Wilshire/Western Station to a proposed station at the Veteran Affairs Hospital in Westwood is located in western Los Angeles County. It lies within three city jurisdictions — those of Los Angeles, West Hollywood, and Beverly Hills plus portions of unincorporated Los Angeles County.

The subway will consist of a heavy rail transit system operated in twin tunnels with passenger stations along the alignment. Tunnels will be located within an east-west corridor, approximately following Wilshire Boulevard and will be between approximately 50 and 100 feet deep. They will be constructed using closed face tunnel boring machines with one-pass pre-cast concrete segmental linings typically installed as the final lining in the tail shield of the machines.

Oil fields and the La Brea Tar pits are located within the corridor. And, as a result, the subsurface conditions include zones where methane and hydrogen sulfide associated with the oil fields and tar impregnated sands are found. The presence of these naturally occurring subsurface gases, classified as hazardous, has presented challenges to tunnel projects in the Los Angeles region in the past and has required additional provisions for the design, construction, and operations of projects in the area. For the Metro Projects, extensive studies has been undertaken by Metro in planning and design phases since exploration for the Metro Rail Project started in the 1980s of the impacts on tunneling of methane and hydrogen sulfide.

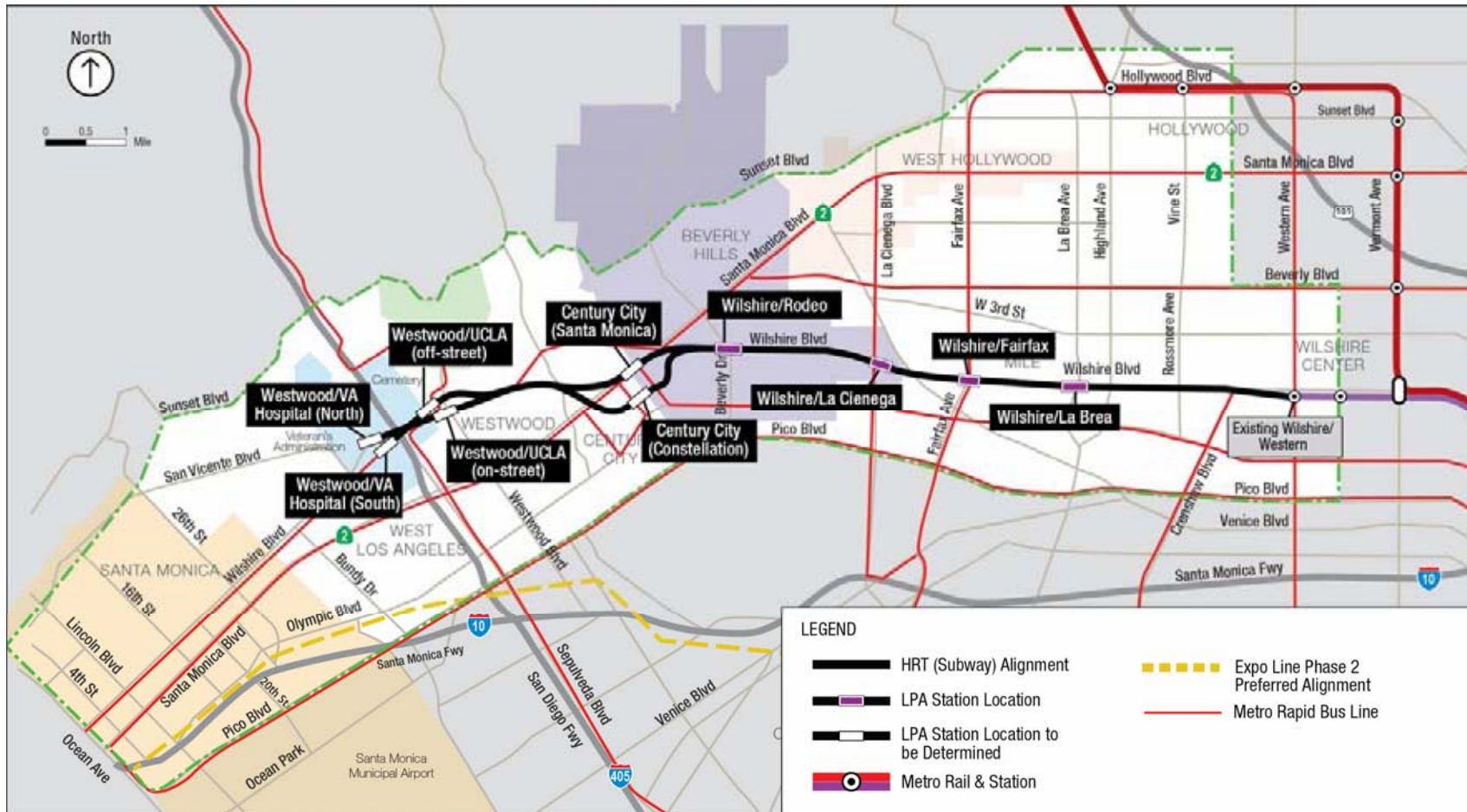
In 2005, a panel of experts assembled by the American Public Transportation Association (APTA) concluded that tunnels could be safely constructed and operated in the Wilshire Boulevard corridor given the advances in construction techniques and risk mitigation methods, improvements in gas monitoring technology, and improved attitudes with regard to safety. However, special designs are needed to assure that a tunnel lining system can be installed that will be maintain the tunnels safe during construction and operations.

### **2.1 Project Alignment**

The proposed tunnel alignment is about 8.7 miles in length from the existing Wilshire/Western Station (east to west, see Figure 2-1) and terminating at a station in Westwood near the VA Hospital. The extension would include a total of seven new stations, each serving major activity and employment centers on the Westside of Los Angeles.

Over much of the alignment the tunnels are within public rights-of-way and are not directly above buildings. However, from the intersection of McCarty Drive with Wilshire Boulevard in Humby Hills to the intersection of Wilshire Boulevard and Manning Avenue in Westwood, a distance of approximately 10,700 feet, this is not possible. Through this area, the tunnel corridor passes beneath private property, commercial buildings and the Beverly Hills High School. Within this reach, a subway station could be located on Constellation Boulevard just south of the BHHS campus.

Figure 2-1: Westside Subway Extension Proposed Tunnel Alignment



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A summary description of the alignment route is as follows:

Tunnel Reach from Wilshire/Western to Wilshire/La Brea Station – The tunnel follows beneath Wilshire Boulevard going due west from the existing Wilshire/Western station to Wilshire/La Brea Station.

Tunnel Reach from Wilshire/La Brea Station to Wilshire/Fairfax Station – The tunnel continues beneath Wilshire Boulevard going due west from Wilshire/La Brea Station to Wilshire/Fairfax Station.

Tunnel Reach from Wilshire/ Fairfax Station to Wilshire/La Cienega Station – The tunnel continues beneath Wilshire Boulevard going westwards from Wilshire/Fairfax Station to Wilshire/La Cienega Station.

Tunnel Reach from Wilshire/La Cienega Station to Wilshire/Rodeo Station – The tunnel continues beneath Wilshire Boulevard going westwards from Wilshire/La Cienega Station to Wilshire/Rodeo Station.

Between Wilshire /Rodeo Station and UCLA Station, two alternative tunnel alignments are under consideration. They are:

#### *Option 1*

Tunnel Reach from Wilshire/Rodeo Station to Constellation Station – The tunnel alignment continues west beneath Wilshire Boulevard from Wilshire/Rodeo Station to the intersection of Wilshire Boulevard and S. McCarty Drive. At the intersection, it curves south and passes through a residential neighborhood onto S. Lasky Drive. It follows S. Lasky Drive until its intersection with Young Drive. At Young drive, the alignment curves to the southwest and passes beneath the campus of the Beverly Hills High School. It continues southwesterly passing out of the City of Beverly Hills and into the Century City area of Los Angeles. Just west of Century Park East, the tunnel reaches Constellation Station.

Tunnel Reach from Century City, Constellation Station to Westwood/UCLA Station – The tunnel continues southwest beneath Constellation Boulevard before curving to the west and passing beneath Westfield Century City Shopping Center located in the heart of Century City. It then continues through a residential neighborhood crossing beneath Santa Monica Boulevard and Beverly Glen Boulevard before reconnecting with Wilshire Boulevard. It continues westwards crossing Westwood Boulevard before reaching Wilshire/UCLA (On Street Option) Station.

#### *Option 2*

Tunnel Reach from Wilshire/Rodeo Station to Century City Santa Monica Station – The tunnel alignment continues west beneath Wilshire Boulevard from Wilshire/Rodeo Station to the intersection with Santa Monica Boulevard and turns southwest to follow Santa Monica Boulevard to the Santa Monica Boulevard Station.

Tunnel Reach from Century City Santa Monica Station to Westwood/UCLA Station – The tunnel alignment continues southwest beneath Santa Monica Boulevard until it reaches the Avenue of the Stars where it veers west-south-west passing beneath residential area before turning west-north-west and continuing beneath a residential area reconnecting with Wilshire Boulevard. It then continues

westwards crossing Westwood Boulevard before reaching Wilshire/UCLA (On Street Option) Station.

Tunnel Reach from Westwood/UCLA Station to Westwood/ VA Hospital Station - The tunnel would continue westwards beneath Wilshire Boulevard passing beneath the I-405 Freeway before entering the grounds of the VA Hospital. Beyond the VA Hospital Station, there will be a short tail track tunnel that would terminate beneath the VA Property.

## 2.2 Project Geology

The Southern California region is comprised of several geologic provinces characterized by distinct structural orientations and geomorphic elements. The tunnel alignment is located near the boundary between the northwestern end of the Peninsular Ranges geomorphic province and the southern margin of the Transverse Ranges geomorphic province. The Peninsular Ranges province is characterized by elongate northwest-southeast trending geologic structures such as the nearby Newport-Inglewood fault zone. In contrast, the Transverse Ranges geomorphic province is characterized by east-west trending geologic structures such as the Santa Monica Fault, the Hollywood Fault, and the Santa Monica Mountains.

The tunnel alignment for the Project is located in the northern portion of the Los Angeles Basin, approximately 0.5 to 3 miles south of the Santa Monica Mountains. This sedimentary basin occupies the northernmost portion of the Peninsular Ranges geomorphic province. The Los Angeles Basin is a major elongated northwest-trending structural depression that has been filled with sediments up to 13,000 feet thick.

The basin is a known source of hydrocarbon deposits. Throughout the area, these deposits have been extracted commercially since the end of the nineteenth century. The rocks and soils overlying the oil fields contain naturally occurring products derived from the hydrocarbons and include methane, hexane, hydrogen sulfide and tar. Within the La Brea Tar Pits area, extensive deposits of tar-impregnated sands occur as well as localized pools of tar where the fossilized remains of trapped animals are to be found.

The subsurface formations anticipated to be encountered during tunneling include:

Artificial Fill consisting primarily of variable silts and clays with occasional sand layers and scattered man-made debris such as concrete, asphalt, and glass.

Younger Alluvium encountered primarily within the north-south trending ravines. These sediments consist predominantly of sandy to silty clays and clayey sand with subordinate layers and lenses of sandy silt and gravelly sand.

Older Alluvium consists primarily of alluvial fan materials and include consist of silts, clays, and silty/clay mixtures with layers of sands, gravelly sands, and fine gravel.

Lakewood Formation consists of shallow marine deposits. These sediments consist predominantly of light colored silty sands and poorly graded sands, with infrequent sandy silts and gravelly beds.

San Pedro Formation consists of marine deposits that the Lakewood Formation and Older Alluvium. The materials consist of interbedded gray to dark gray to greenish-gray, poorly graded sand, silty sand, and sandy silt and variable clay/silt mixtures with occasional gravelly beds.

### 3.0 TUNNEL SETTLEMENT AND ITS IMPACT ON BUILDINGS

Tunneling results in ground movements that can impact nearby buildings. To evaluate these movements and to assess their potential to damage buildings requires an assessment of:

- Tunneling method to be employed and its effect on ground movements
- Sensitivity of buildings to distort and the allowable limits for distortion

These are linked by a sequence that begins with the source and volume of the ground loss around the tunnel or excavation, and proceeds to the distribution of ground movements and volume changes throughout the soil mass and their effect on the lateral and vertical displacements at the ground surface. The slope, tilt, and change in ground slope across the structure serve as a basis for assessing angular distortions, which will also be modified by the characteristics of the building, in terms of geometry, condition, stiffness, and strength.

#### 3.1 Ground Movements caused by Tunneling

Ground movements caused by tunneling result from what is termed “ground loss”. It can take the form of a regular ground loss and of a large localized loss.

**Regular 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 from ground losses during tunneling from the following source:

1. **Face Losses** - Soil movement into the face of the TBM in the form of raveling, caving, flowing, running, squeezing, or over-excavation.
2. **Shield Losses** – Soil movement towards the shield that protects the excavated tunnel between the tunnel face and the tail of the shield where the initial support system is installed. This movement is into the void about the shield that 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.
3. **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.
4. The trough is three-dimensional and can be estimated by a Gaussian distribution (Peck, 1969) - an inverted Bell curve (see Figure 3-1). The trough represents the extent of the ground disturbed by tunneling and is referred to as “the zone of influence of tunneling”.

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

- Ground loss – 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.

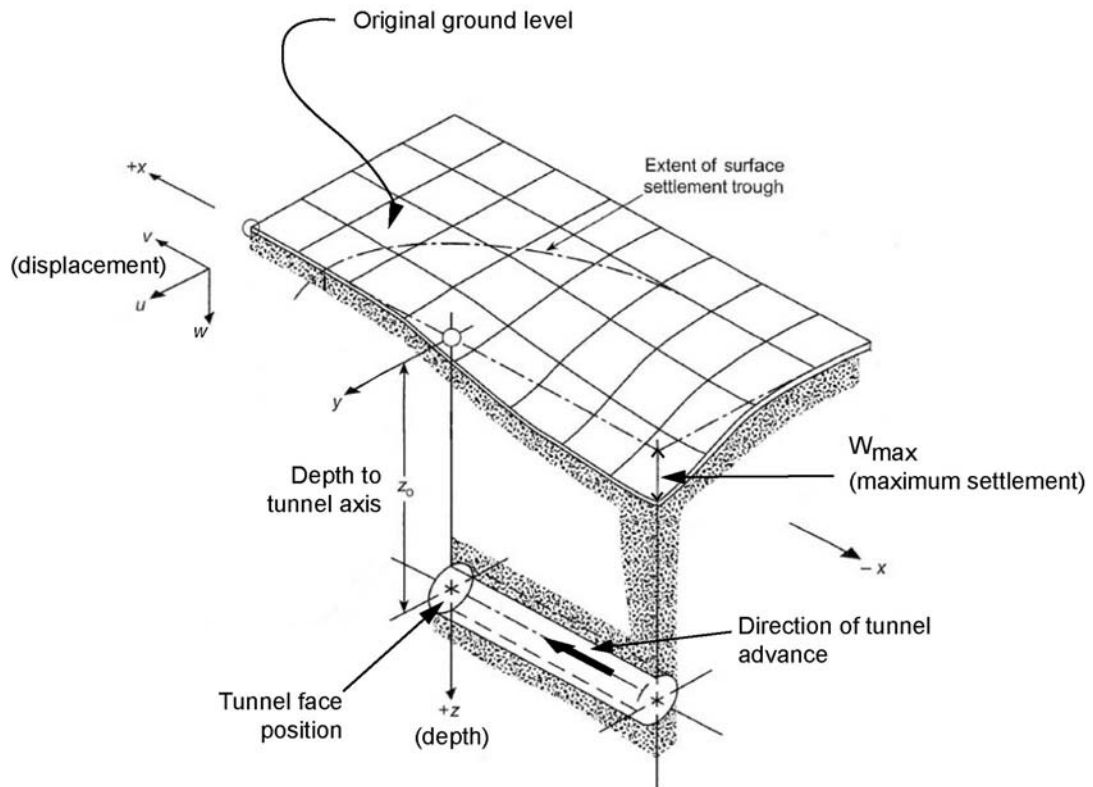
- Trough width parameter – an assessment of the subsurface conditions encountered that relate to the width of the settlement trough and the severity of the shape of the gaussian distribution curve.

Once these parameters are estimated, the settlement surface – sometimes termed the free-field settlement surface - can be defined from the formulae provided in Appendix A. These are based on the analysis by O'Reilly and New, 1982 and provide displacements in both the transverse and longitudinal directions.

**Large 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 unpredictable and often result from poor tunneling practice. They can be associated with:

- Encountering underground obstructions are encountered, such as boulders, old pile foundations, and abandoned wells, and
- 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
- Start-up, stoppage, and restart of mining operations

These types of losses can result in relatively narrow chimneys developing in the ground that can reach the ground surface. Such large ground losses that result in sinkholes have always been relatively rare events although when they do occur, they are widely reported. However today, with the use of state-of-the-art soft ground TBMs that have pressurized closed chambers at the face, the opportunity for inadequate support of the face to develop is further limited and sinkholes have become even rarer.

**Figure 3-1: Three Dimensional Settlement Above an Advancing Tunnel (Burland et al., 2001)**


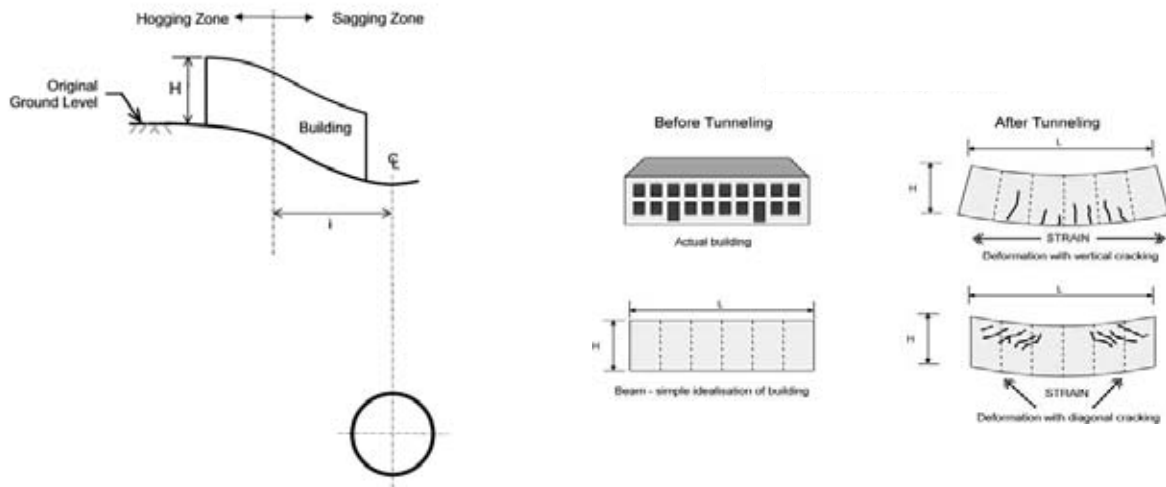
### 3.2 Impacts to Buildings from Tunneling

As the ground moves, buildings located within the zone of influence of tunneling will settle and potentially distort.

Generally, a uniform settlement will not cause damage but a differential settlement across a building can cause distress

Differential settlement is typically expressed as a ratio (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 3-2 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 3-2: Deformation Modes and Cracking Patterns for Buildings**


The structural analysis to assess building performance resulting from ground movements caused by tunneling uses the approach proposed by Boscardin and Cording (1989). This is conservative as it does not take into account the stiffness of the building that can modify ground surface movements and the strains induced into the structure (Potts and Addenbrooke, 1996). With the approach:

- Settlement of a building's foundation follows the "free-field settlement surface" condition (see Appendix A for settlement calculation approach)
- 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

And, 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 (Figure 3-3)

The state of strain 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.

### 3.3 Damage Effects to Buildings from Tunneling

Building distress effects depend on the intensity of the movements and the assessment of the degree of damage that will take place. However, any assessment to an existing building is somewhat subjective. The sensitivity of a structure to distress and its functional significance are primary factors to be considered when determining the cost of pre-emptive measures or required repairs. Other factors that may require consideration include: concern for litigation; market value; building age; construction materials condition; type and function; and location within the settlement trough.

### 3.3.1 Damage Classifications

In an effort to provide a framework for classifying damage, Skempton and MacDonald (1956) developed a classification that used 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 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 3-1, 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 3-1 have also been presented in a chart as shown Figure 3-3. 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., 2001).

Where the results indicate that settlement will result in strains falling into categories within Risk Categories 0 and 1, additional analyses is not necessary and damage will very likely be cosmetic and insignificant.

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. Should the results from these analyses confirm that settlements are projected to 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).

**Table 3-1: Building Damage Classification<sup>1</sup>**

Risk Category	Degree of Damage	Description of Typical Damage and Likely Forms of Repair for Typical Masonry Buildings	Approx. Crack Width <sup>2</sup> (in)	Maximum Tensile Strain (%)	Maximum Slope of Ground <sup>3</sup>	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

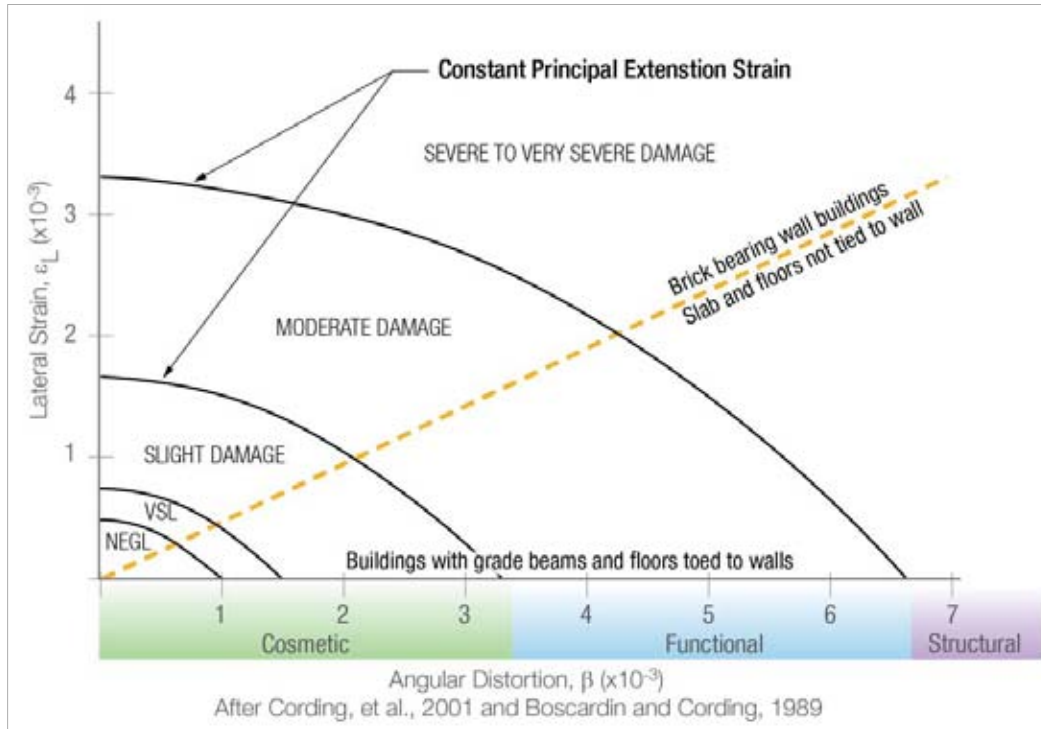
**Notes:**

<sup>1</sup> The table is based on the work of Burland et al (1977), as reproduced in Cording & Boscardin (1989). It includes typical maximum tensile strains for the various damage categories (column 5).

<sup>2</sup> Crack width is only one aspect of damage and should not be used on its own as a direct measure of it.

<sup>3</sup> 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.

Figure 3-3: Damage Categories (Cording et al., 2001)



### 3.3.2 Approach to Limiting Impacts of Westside Subway Extension

Using these damage categories, an assessment of the allowable limits for structure deformations caused by tunneling can be estimated for a twin bore subway system in the soft ground conditions found in Los Angeles. As a result of such estimates and the experience gained with tunneling in Los Angeles, the following criteria have been established for limiting movements to structures:

- Total settlement in any part of a structure less than 1/2 inch
- Differential settlement - settlement of one point of a structure relative to another, less than  $L/600$ , where “L” is the distance between the two points

These criteria have found acceptance on previous Los Angeles Metro Projects (Redline and MGLLE) 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 suffer insignificant levels of damage.

### 3.3.3 General Performance of Building Systems

Most structures deform in some combined mode of bending and shearing. And, in real structures, the foundation and soil offer considerable restraint. As previously indicated the performance of buildings varies widely and is somewhat subjective, the following is a summary of general concepts related to building dimension effects.

Length to Width (L/W) Ratio: - If the length of a structure is small with respect to the width of the settlement zone, then the angular distortion should be estimated from the change in slope of the

ground surface profile over the length of the structure. The magnitude of the angular distortion for such a structure will be smaller than the magnitude of the average slope of the settlement zone.

If the structures are large and extend beyond the zone of significant ground movements caused by the excavation, then the angular distortion can be assumed equal to the average slope of the settlement profile.

Length to Height (L/H) Ratio: - For L/H less than one, the first observable cracking will be controlled by shear related deformations. And shear deformations are responsible for most damage to masonry bearing wall buildings from imposed distortions from nearby excavations. On the field diagonal tension-related cracking nearly always occurs before bending related cracking. As a consequence, angular distortion, a measure of shear strain, is an appropriate parameter to correlate building behavior, particularly if modified to account for the effects of horizontal strain.

For structures with L/H less than about one, the first signs of damage will be in the form of diagonal tension cracking.

Buildings with Grade Beam Foundations – The assumptions that the lateral strains in the building are roughly the same as the lateral strains in the ground is reasonable as long as there is no tensile reinforcement in the footing or the walls.

However, grade beam foundations can have significant horizontal stiffness. And for such a condition, the horizontal strain induced in the structure by ground movements will be significantly less than the horizontal strain in the soil mass. Horizontal ties in the form of reinforced grade beams are effective as a means of controlling strains and distortions in both bearing-wall and frame structures.

## 4.0 APPROACHES TO BUILDING PROTECTION

Ground movements and damage to structures can be controlled by:

- (a) Limiting ground movements caused by the tunneling
- (b) Improving the ground
- (c) Replacing ground loss, and
- (d) Providing protection at or on the structure, such as underpinning and reinforcement.

### 4.1 Tunneling Methods

On most transit tunnel projects, significant portions of the alignments are constructed beneath buildings. The ability to control and limit ground movements allows this to be done safely. 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. 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 controlled and this reduces the risk of ground loss and allows timely response to the conditions encountered during tunneling. These machines provide a safer work environment than open-face shields and minimize ground loss and settlement of the ground surface.

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

Two types of pressure face TBMs are used worldwide: Slurry Face Machines (SFM) and Earth Pressure Balance Machines (EPBM). Using SFM and EPBM, tunnel construction is a cyclic process that advances the tunnel in increments (typically 4 to 5 feet) and with the following primary operations:

- Excavation of the tunnel face by a rotating cutterhead and advancement of the TBM by propel jacks that react against the installed tunnel lining.
- Erection of the pre-cast concrete segments to form the circular tunnel lining within the tail section of the TBM shield.
- 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. Seals between the shield and the lining ring inside the TBM tail shield prevent the grout from flowing back to the inside of the shield.

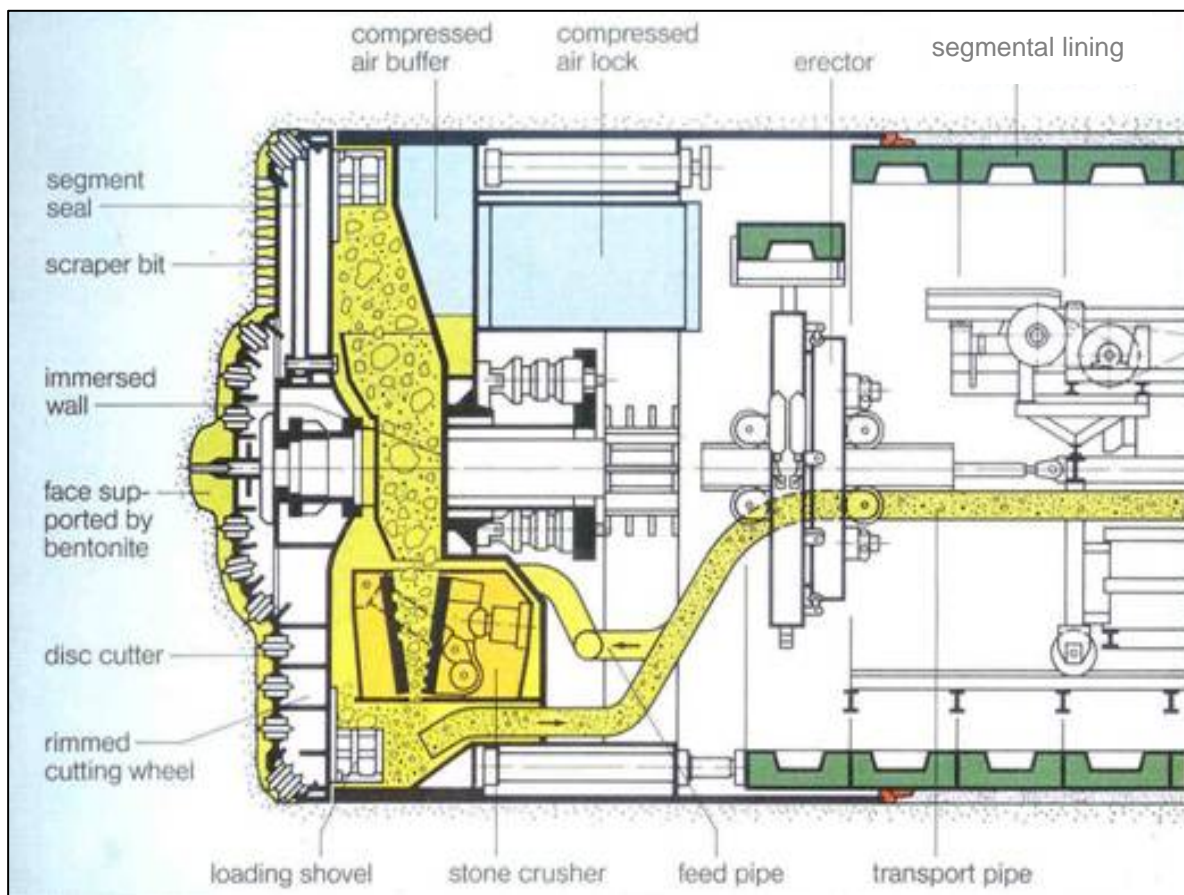
The tunnel lining segments have gaskets to provide watertight joints. The complete lining rings are the structural support that maintains the safety and stability of the opening.

### 4.1.1 Slurry Face Machine (SFM)

The SFM, shown in Figure 4-1, applies fluid pressure to the tunnel face through the excavation chamber through pressurized bentonite slurry. Other fluid conditioners may be added depending on the soil conditions encountered. While the fluid maintains positive pressure at the tunnel face, the slurry is continually circulated through the excavation chamber to facilitate removal of excavated material (i.e., spoils) from the face as the tunnel progresses. Suspended in slurry, the spoils are pumped from the chamber to a separation plant at the ground surface where they are separated from the slurry, allowing the treated slurry to be returned and reused in the excavation chamber.

Since the slurry system is always enclosed in the TBM's cutting chamber and in pipelines into and out of the tunnel, exposure of workers to the excavated soil is eliminated. Thus, the slurry system is well suited for ground that contains contaminants and hazardous gases. These materials can be removed at the surface where ventilation can be more easily provided.

**Figure 4-1: Schematic Section of a Slurry Face Machine**

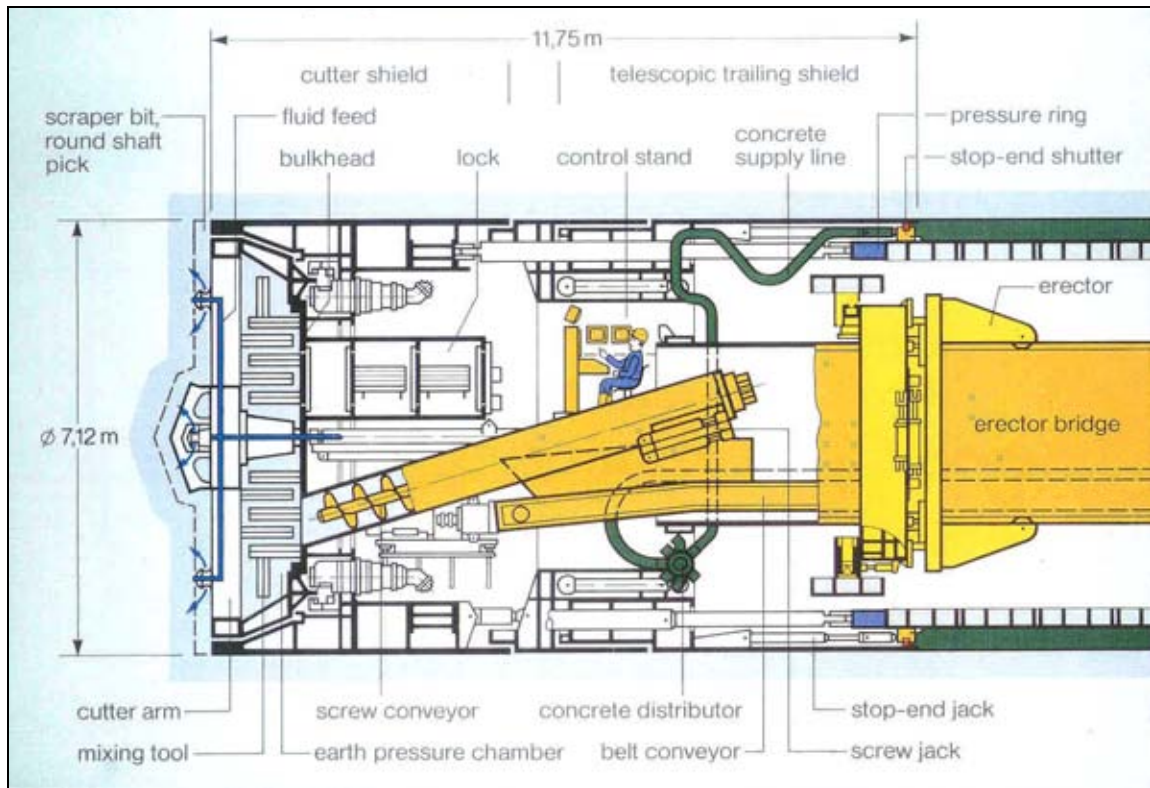


Soil conditions in which a SFM are best suited are coarser-grained soils (sands and gravels). However with advances in soil/slurry separation techniques, the range of grain sizes that can be excavated using SFMs has increased to include finer-grained materials. The separation equipment required and the cost of treatment increases for the finer-grained materials.

### 4.1.2 Earth Pressure Balance Machine (EPB)

With an EPBM, excavated material is allowed to fill the excavation chamber as the tunnel advances. Face pressure is controlled by balancing the rate of advance of the EPBM with the rate of discharge of the excavated material.

**Figure 4-2: Schematic Section of an Earth Pressure Balance Machine**



Soil conditioners, such as bentonite, foam, and polymers, are added to the chamber to improve workability and reduce wear on the machine. Excavated material emerges from the screw conveyor as a thick paste and is emptied onto a conveyor belt or into muck cars for transport to the surface. Figure 4-2 shows a schematic of an EPBM of the type used on the MGLEE Project.

The soil conditions for which the EPBM is best suited are finer grained (sand, silt, and clay) materials. However, with advances in methods for conditioning soils, the range of grain sizes that can be excavated using EPBMs has increased to include coarser-grained materials.

### 4.1.3 Machine Selection for WSE

Particle or grain size distribution of the soil to be excavated is critical to machine selection. Manufacturers of both SFMs and EPB machines provide grain size distribution envelopes for which the machines will perform optimally. The range of soil conditions for which the machines operate can be increased by use of soil conditioners and manipulation of separation technologies can enhance the range of materials to lower.

For the current alignment, the majority of the tunnel will be excavated in the Older Alluvium/Lakewood Formation and San Pedro Formation. It is anticipated that both SF and EPB

TBMs can be configured to excavate the tunnels for the Westside Project. Means and methods are typically decided by the Tunnel Contractor and this is recommended for this project. Specifications should be written for the tunneling contract to provide the constraints to tunneling particularly to ensure that ground loss is minimized thereby assuring that damage to buildings is minimized. The selection of the type of closed face TBM should be made by the Contractor to support its approach to tunneling.

## 4.2 Ground Improvement Methods

Should studies indicate that ground control by means of the tunneling method is not sufficient to control settlements to levels that prevent functional or structural damage to structures along the alignment, additional building protection measures will be necessary. Approaches for protecting buildings subject to settlements that are likely to cause damage include: permeation grouting, compensation grouting, compaction grouting, jet grouting, and underpinning. These methods, and their appropriate application, are described below. Specific building and utility protection measures to be taken for specified buildings should be addressed in more detail in final design.

### Permeation Grouting

Permeation grouting is a ground modification technique that fills pore spaces in soil with grout. Permeation grouting is most often used to decrease permeability, limit settlement by increasing the cohesion of the soil, and thus reduce ground loss during tunneling. Various materials are used for this type of grouting, including ordinary Portland cement, microfine cement, bentonite, and most often sodium silicate. Grout penetrability in a granular medium is tied to soil pore space size. It is, however, difficult to measure representative pore size, so a soil's permeability ( $k$ ) is the best parameter to use for grout selection. The types of soil in which permeation grouting is usually effective include gravels and sands to silty sands and silt.

Permeation grouting has been successfully injected on many underground projects through the use of pipes installed from the ground surface. If sleeve-port-pipes are utilized, grouting can be repeated in the same hole, and grouts of different compositions may be used. This is especially useful if a wide variation in soil permeability is anticipated.

Portland cement grout can be used to grout gravel and coarse sand. Microfine cement (cement with small particle sizes and high surface areas in the range of 500 to 1000 m<sup>2</sup>/kg) can penetrate fine sands where pores are too small for conventional cement grouts. Other conditioners and/or additives may be used to facilitate grouting.

### Compaction Grouting

Compaction grouting involves injection of a very stiff mortar-like grout into subsurface soils in a closely controlled manner. The material is typically sand with minimal cement and water for binder. The objective is to displace and densify soil in place. The shape of the grout mass is usually spherical (a bulb) or cylindrical depending on the amount of grout hole open during any given injection sequence. The primary uses of compaction grouting are to improve soil properties and/or compensate for voids, usually as a preventative and/or remedial measure for structure movement in response settlement.

Compaction grout is injected under high pressure through a steel pipe, which can be installed from the surface or from within subsurface excavations, such as a shaft or from within a tunnel. Pipes installed from the surface are usually installed in advance of underground excavation. Although

compaction grout can be installed from within a tunnel under construction, the compaction grouting can interrupt the normal cycle of tunneling which can lengthen the construction schedule. Compaction grout holes are typically spaced on a grid of 6 to 12 feet.

### **Jet Grouting**

Jet grouting is a ground improvement method that consists of injecting fluids at high pressure and flow rates into the ground to segregate the soil particles and mix the material with a cement grout. The fluids are typically injected into the ground through a rotating string of drill rods connected with a special grouting monitor that is fitted with nozzles positioned horizontally or slightly inclined from the horizontal. The high pressure fluids are used to break-up the in-situ soil fabric and erode a portion of the soil material. The cementing agent, which is typically cement grout, is mixed with the remaining soil particles to form a hardened mixture of grout and soil. The process is basically an erosion/replacement process that forms a mixture of soil and grout that has a high strength and low permeability. The jet grouted elements formed through the process consist of many different shapes including cylindrical columns, panels and planar elements. The elements can be overlapped to form a row, or continuous mass of grouted soil, or can be installed as discrete elements.

### **Compensation Grouting**

The principle of compensation grouting involves carefully controlled injection of grout between underground excavations and structures requiring protection. For tunnel applications, the pipes for grouting are installed above the intended tunnel position, in advance of tunneling. Monitoring of both structure and ground movements is essential for timing of grout injection. Grout can be injected repeatedly via sleeve-port-pipes, and can take place before, during, and after tunneling activity by reusing the sleeve-port-pipes. Often a “preconditioning” phase of grouting is carried out before tunneling to stiffen the ground and produce a slight heave in structures above.

Grout mixes used for compensation grouting are varied. Generally, relatively fluid cement and bentonite grouts are injected which induce fracturing of the ground and mostly propagate horizontally depending on geologic bedding. The injected grout serves to replace soil lost during tunneling, but can also result in densification of soil around the grout lenses. An advantage of compensation grouting is the wide range of soil conditions in which it can be applied, from hard clays and very dense sands to very soft clays and very loose sands.

### **Underpinning**

Underpinning is a general term for installation of new foundations under an existing building foundation for the purpose of supporting building loads deeper into the ground or alternate location not subject to settlement. The methods of underpinning vary, and may not be feasible for structures situated directly over the tunnel. The methods used for underpinning are dependent on geotechnical conditions, access to foundations (from the ground surface or within building basements), existing types of building foundations, type of building structure, and magnitude of the building loads.

Traditional underpinning involves hand excavation of pits underneath existing foundations followed by backfill with concrete. This type of underpinning is costly, labor intensive, and generally disruptive. Other methods have been developed to transfer the foundation loads using augered caissons, which are less labor intensive. For any type of underpinning, there is the risk of settlement to the structure in the process of attempting to protect the structure.



### **4.3 Protection from Ground Movements Related to Open-Cut Construction**

Building protection around open-cut excavations will also be required when the building is in the zone of influence of the open-cut. Protection of the building will require proper open-cut trench shoring design. Where necessary, grouting and underpinning (as described above) of the surrounding soils may be required to prevent adverse impacts to the affected buildings. More detailed discussion of protection methods for open cut construction is provided in a separate report.

## **5.0 BUILDING SURVEY AND EVALUATION - APPROACH**

The steps described in this section were used to identify and characterize the buildings and structures within the project corridor that could be impacted by the tunnels and then to evaluate their performance with respect to tunnel/structure interactions.

### **5.1 Step 1 - Inventory of Buildings**

An inventory of buildings along the alignment has been recorded in a database maintained by the project (see Appendix B). The information collected has included:

#### Building Identification

Using plans from aerial surveys carried out for the project, the following information was identified:

1. Buildings located along the tunnel route
2. Footprint of each building
3. Building square footage

#### Publicly Available Information

Using publicly available property rolls for Los Angeles, the following information was collected for buildings along the tunnel route;

1. Address of property
2. Property owner
3. Year of construction

#### Building Characteristics

Researching computerized databases and carrying out visual inspections from the street, the following information was collected, where available:

1. Number of stories
2. Number of basement levels
3. Occupancy and usage in terms of:
  4. Commercial
  5. Educational
  6. Single Family Residence
  7. Condominium – defined as a subdivision of air space with each subdivision assigned a parcel number per living unit.
  8. Multi Family Residence – defined as “a parcel with more than one living unit”

9. Historic status
10. Visual documentation – photographs

## **5.2 Step 2 – Screening for Buildings**

Having reviewed the subsurface conditions along the alignment and the proposed methods of tunneling, the parameters needed to assess the settlement trough resulting from tunneling - K and percent ground loss - were established and settlement profiles were estimated along the tunnel alignment.

### Free-Field Settlement Analysis

From the settlement analysis:

1. Contour map of estimated settlements ( $\frac{1}{4}$ -inch,  $\frac{1}{2}$ -inch and 1-inch levels) along the tunnel alignment was superimposed on the civil drawings to establish buildings subject to settlement
2. Buildings subject to estimated settlements greater than  $\frac{1}{2}$ -inch were identified
3. Angular distortion for the buildings identified in 2. above were estimated

## **5.3 Step 3 – Collection of Building Information**

### As built and Site Specific Information

For multistory buildings identified as subject to deformations in excess of  $\frac{1}{4}$ -inch, contact property owners and property managers to request as-built and site specific information, such as:

1. Plans and any available information to document: floor plan layouts for column locations
2. Foundation layouts and types of foundations
3. Type of construction; and excavation information, i.e., use of temporary or permanent tiebacks for support of basement excavations
4. Geotechnical reports describing soil conditions and proposed foundation and excavation support systems
5. Type of construction

If necessary, this information would be used to assist in refining the analyses of building settlements.

Other databases (geotechnical reports and the Los Angeles Building Department database) have been researched to establish where tiebacks have been used to support deep excavations. Although a good faith effort has been undertaken to obtain information on tiebacks, records of their use as temporary support may not be fully complete or easily discovered and a complete record of in-place tiebacks along the alignment may not have been established. This may require additional investigations to be made during final design to fill in gaps in the records and even additional field investigations or exploratory work during construction to assure that tiebacks do not adversely affect construction activities.

For some of the surveyed structures, it was not possible to obtain information on building foundations. Further investigation of some building foundations may be necessary during subsequent design phases.

#### **5.4 Step 4 – Building Evaluations**

Future surveys may be needed to establish:

- **Structural Support System:** Information related to the above ground structural system of the buildings may be needed for detailed analyses. This will include the vertical and lateral support system, exterior wall construction, roofing, and floor system.
- **Condition of Building (Existing Cracks or Structural Distress):** Surveys will be necessary to identify all visible cracks or distress, and to gather additional information that can provide an indirect measure of past structural performance.

## 6.0 BUILDING SURVEY – DATA AND RESULTS

Appendix B identifies the buildings along the alignment either adjacent to or above the tunnels. These buildings have been investigated to characterize them in terms of their use, age, type of structure, height and whether they have basement levels. All buildings have been evaluated to determine whether they are within the zone of influence of tunneling and if so, the level of settlement to which they could be subject. For buildings potentially subject to more than ½-inch of settlement, additional analyses have been carried out.

### 6.1 Step 1 - Inventory of Buildings

#### 6.1.1 Buildings along Project Alignment

The number of buildings within 120 feet from the centerline of the rail track for each tunnel reach and at stations is summarized in Table 6-1:

**Table 6-1: Buildings Identified along Tunnel Alignment within 120 ft from Centerline of Rail Tracks**

Location along Alignment	Total No. of Buildings	No. of Buildings with 10 or more stories	No. of Buildings with 3 to 9 Stories
Wilshire / Western Access Box	6	2	0
Wilshire / Western to Wilshire / La Brea	92	2	44
Wilshire / La Brea Station	11	1	1
Wilshire / La Brea to Wilshire / Fairfax	38	6	14
Wilshire / Fairfax Station	11	1	6
Wilshire / Fairfax to Wilshire / La Cienega	38	8	11
Wilshire / La Cienega Station	14	2	4
Wilshire / La Cienega to Wilshire / Rodeo	94	3	32
Wilshire / Rodeo Station	13	3	6
Wilshire / Rodeo to Century City Constellation - Option1	89	5	26
Century City Constellation Station – Option 1	8	5	1
Century City Constellation to UCLA – Option 1	197	21	32
Wilshire / Rodeo to Santa Monica Blvd - Option 2	53	4	16
Santa Monica Blvd Station - Option 2	8	2	3
Santa Monica Blvd to UCLA - Option 2	203	22	23
Westwood / UCLA Station	8	6	0
Westwood / UCLA to Westwood / VA Hospital	1	1	0
Westwood / VA Hospital Station & GSA Crossover	0	0	0
Westwood / VA Hospital – Tail Track Tunnel	2	0	0
<b>Total Building Count</b>	<b>886</b>	<b>94</b>	<b>219</b>

NOTE: The Tunnel Reach from Wilshire/Rodeo Station to Westwood/UCLA Station via Constellation Station (Option1) and from Wilshire/Rodeo Station to Westwood/UCLA Station via Santa Monica Blvd (Option 2) follow the same alignment over part of their routes. 159 buildings are common to both options and are not counted twice in the total building count giving a total of 727 buildings along alignment.

A total of 727 separate buildings were identified along the alignment. 648 were associated with the tunnel reaches and 79 with the stations and box locations. The count includes buildings along alternative alignments between La Cienega Station and UCLA Station.

Of the buildings within the corridor, 93 buildings were identified as more than ten stories above ground and 219 buildings as being between 3 and 9 stories high. Some buildings with basements were identified but this list is not necessarily complete and efforts to identify basement levels in buildings are ongoing. Property descriptions were provided by means of a visual survey conducted between the months of January and July 2011 by WSE project staff.

## 6.2 Step 2 – Screening of Buildings

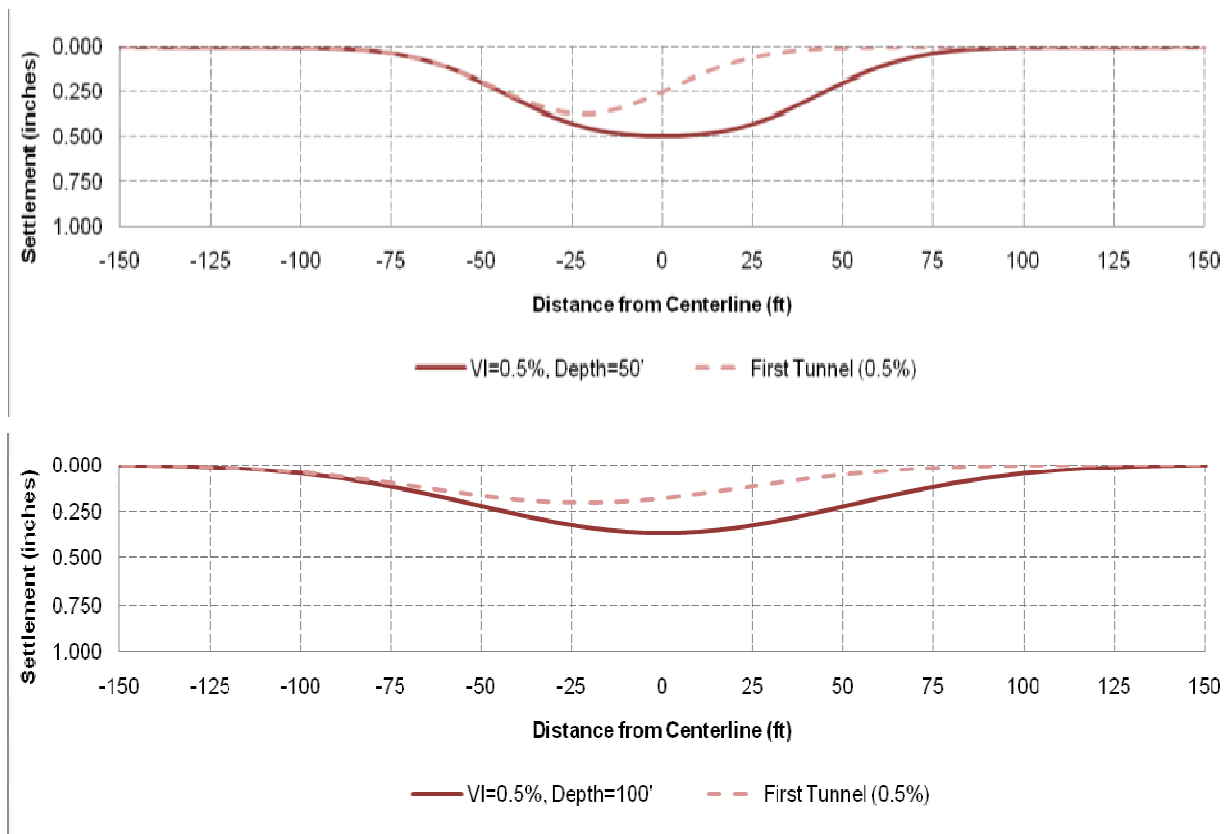
### 6.2.1 Tunneling Parameters for Settlement Analysis

Recent experience of pressurized closed face TBMs, tunneling through the dense alluvial deposits indicate that ground loss in the field will be less than 0.5 percent. As a result, the following parameters were used to estimate settlements:

- Ground loss of 0.5 percent
- Ground width of 0.4 appropriate for dense sand/silt conditions (see O'Reilly and New, 1982)

Settlement estimates for twin tunnels using the parameters described above give free field settlements profiles at depths of 50 feet and 100 feet as shown in Figure 6-1 for 0.5 percent level of ground loss. These profiles indicate that for the tunnel depths for the Westside Subway Extension, settlements can be expected to be less than ½-inch

**Figure 6-1: Estimated Settlements for 50 and 100 Foot Tunnel Depth (to crown) at 0.5 % Ground Loss**



### 6.2.2 Screening for Building Settlement

For the initial screening, contour maps of estimated settlements at ¼-inch, ½-inch and 1-inch levels were superimposed on the alignment plans. Using this approach, it was determined that as measured at grade, none of the 648 buildings along the tunnel alignment were subject to settlements greater than ½-inch or to distortions as severe as 1 in 600.

However, 131 buildings were identified as directly above the tunnel. These buildings were all west of Rodeo Station where the tunnels were no longer able followed beneath public rights-of-way. The buildings are in the City of Beverly Hills and the Century City and Westwood areas of Los Angeles. Through this area, two alignment options are still under consideration. A summary breakdown of the buildings in provided in Table 6-2.

**Table 6-2: Buildings above Tunnel**

Station/Reach	Story	# of 3-9 Story	Story	Parking Lots	Total
<b>Option 1</b>					
Rodeo to Century City, Constellation	14	10	0	0	24
Constellation to Westwood/UCLA	62	14	0	0	76
<b>Option 2</b>					
Wilshire/Rodeo to Santa Monica Blvd	7	3	0	0	10
Santa Monica Blvd. to Westwood/UCLA	58	9	1	0	68
VA Hospital – Tail Track Tunnel	2	0	0	0	2

NOTE: Totals include 49 buildings that are common to both alignment options

They consisted of 102 one or two story structures and 29 buildings greater than 3 stories high. Since the estimates for settlement for the one and two story buildings were in the negligible to very slight categories as indicated in Table 3-1 and were at least 80 feet above the tunnels, further investigations of these buildings were not considered necessary.

For the buildings more than 3 stories high, some of which had depths of cover to the tunnels of less than 80 feet, further evaluations were carried out to establish whether:

- Any below grade construction interfered with tunnel construction, for example basement levels, tiebacks or foundation piers and piles
- Settlement of basements could exceed settlement criteria and required building protection

For these evaluations, information is being collected from the property owners of the 29 buildings identified for further evaluation. These buildings are described in Appendix C.

### 6.3 Step 3 – Collection of Building Information

Following the screening of buildings along the alignment, 152 properties were identified for which additional information would assist the subway design. To obtain information for these properties, their owners were contacted and requests made for information on the buildings.

1. Tiebacks that would interfere with either the tunnel or the stations structures (Appendix D)
2. Buildings that have foundations that could interfere with station excavations
3. Buildings that lay above the tunnel route

The information received from Owners is being maintained as part of the project files and updated by the Parsons Brinckerhoff Project Team as it becomes available.

The Building Protection Program is not yet complete and the program should be continued such that as the design is finalized, available information for all buildings along the alignment is taken into account.

## 6.4 Building Evaluation

With the exception of the structures at the Westfield Mall (10250 Santa Monica Boulevard), none of the 29 structures more than 3 stories high have settlements that exceed the specified ½-inch and 1 in 600 distortion criteria. Comparing the distortions estimated with damage categories identified in Table 3-1 and Figure 3-3 indicates that negligible damage is anticipated from tunneling on the buildings. Distortions are well below the levels of structural or functional damage and in the range where cracking of finishes does not occur or is very limited.

The Westfield Mall is subject to further evaluation as the tunnel is shallow beneath the Mall as they approach Constellation Station and actions will depend on the information provided by the property owner for the mall under Section 6.3.

Westfield Mall foundation plans have been received and are being reviewed. Given the proximity of the tunnels to the mall foundations for the AMC Cinema, building protection measures are likely to be required. Under consideration at this time are:

- Deepening the tunnel
- Underpinning the piled foundations, where necessary
- Performing compensation grouting as the tunnels go by to prevent settlement of the buildings

## 7.0 BUILDING PROTECTION PROGRAM

### 7.1 Building Monitoring

Systematic monitoring of all buildings within the zone of influence of tunneling may not be required. It is recommended a priority system be implemented during construction for monitoring of buildings.

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

1. Surface settlement/heave gauges
2. Building settlement markers (conventional and GPS)
3. Tilt meters
4. Crack monitoring gauges

In order to evaluate whether a building has experienced damage, it is important pre-construction surveys be performed to document existing conditions of each building prior to construction. It is also critical both absolute and relative movements of buildings be monitored during construction so that claims of building damage can be attributed to tunnel or pipeline construction, and in order to verify buildings protected by ground improvement measures are working or if ground improvement should be implemented to mitigate excessive movements.

Monitoring of building movements will provide the Owner, Building Owner, Engineer, and Contractor with verification that tunnel construction is not impacting the building. Results of monitoring would also provide a basis for remedial actions to repair buildings should it be determined tunnel or pipeline construction have caused building movements and/or damage.

### 7.2 Building Surveys

Although results of the structural analyses indicate negligible damage will be imposed on a majority of buildings, it is recommended detailed building surveys should be performed to visually inspect interior and exterior of each building. The survey should include written documentation of existing conditions and be supplemented with video or still photography to provide visual documentation. Detailed information should be collected such as 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 should also serve as documentation of pre-construction conditions of each building in order to provide a baseline for establishing damage resulting from construction.

All building heights used in the structural analyses have been estimated based on visual survey or determined from existing building plans. Detailed building surveys should also include an optical survey of building heights in order to establish accurate values of "H" for use in the structural calculations.

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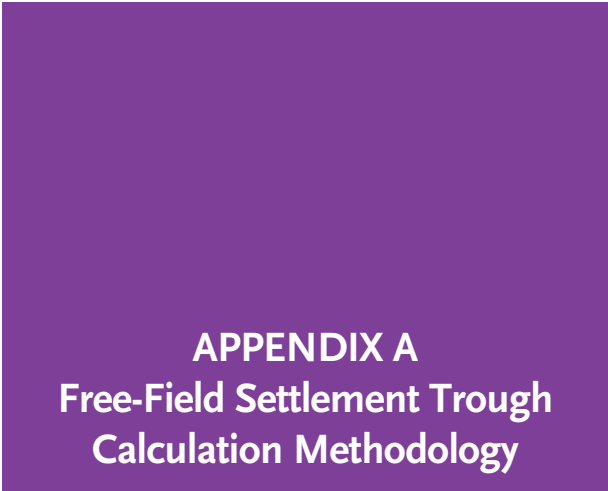
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**APPENDIX A**  
**Free-Field Settlement Trough**  
**Calculation Methodology**

## 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 only a transient feature. Figure A-1 illustrates the settlement trough for a single tunnel.

For parallel tunnels, the settlement trough is calculated separately for each tunnel and then and then summed.

**Figure A-1: Settlement Trough for a Single Tunnel**

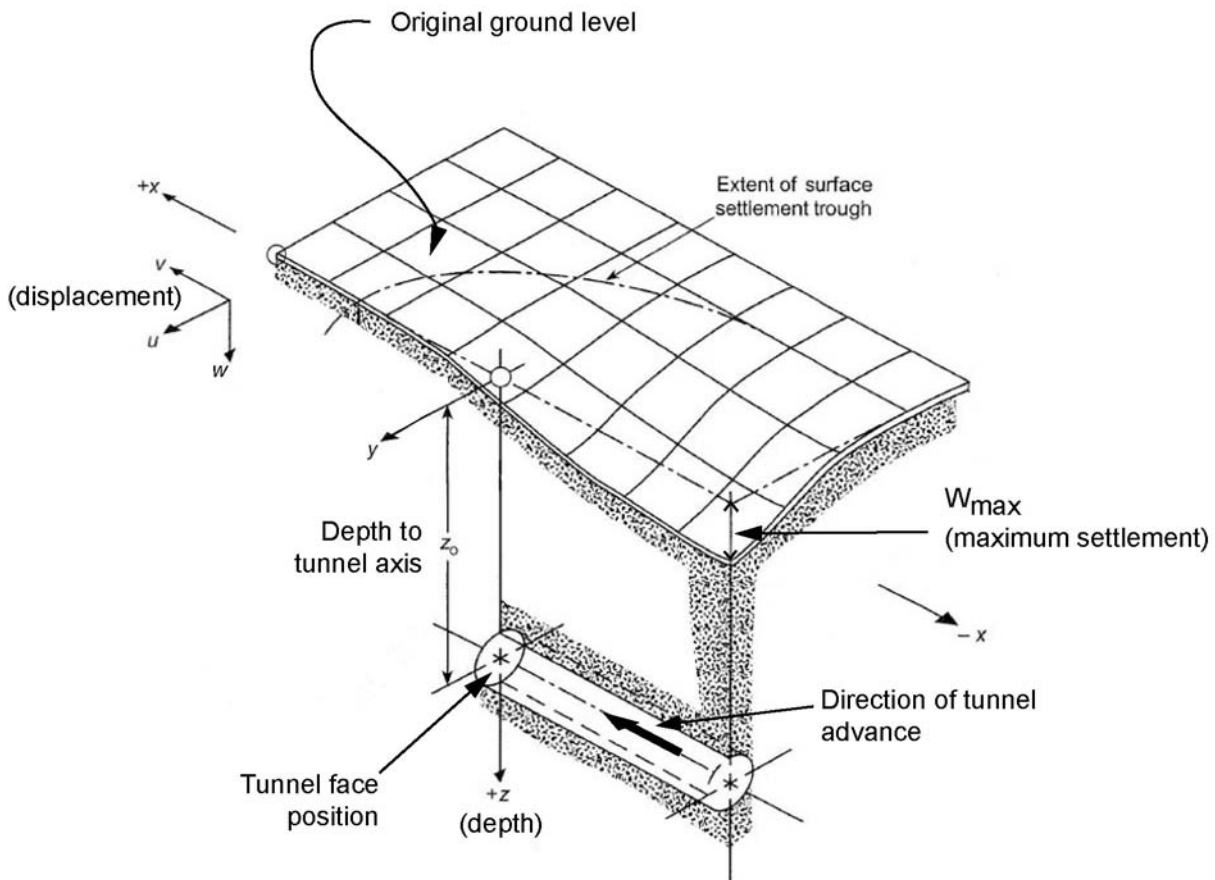
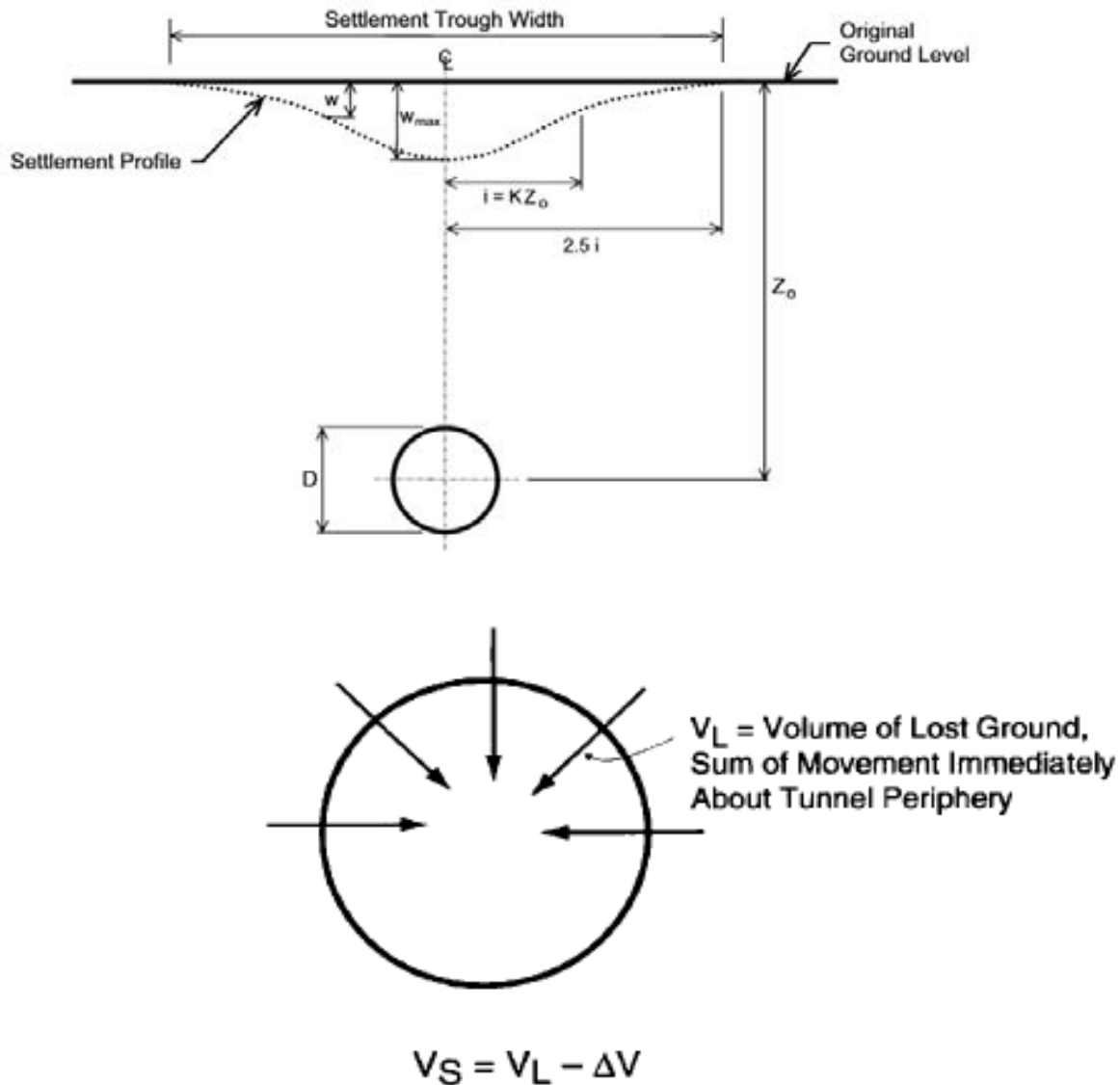
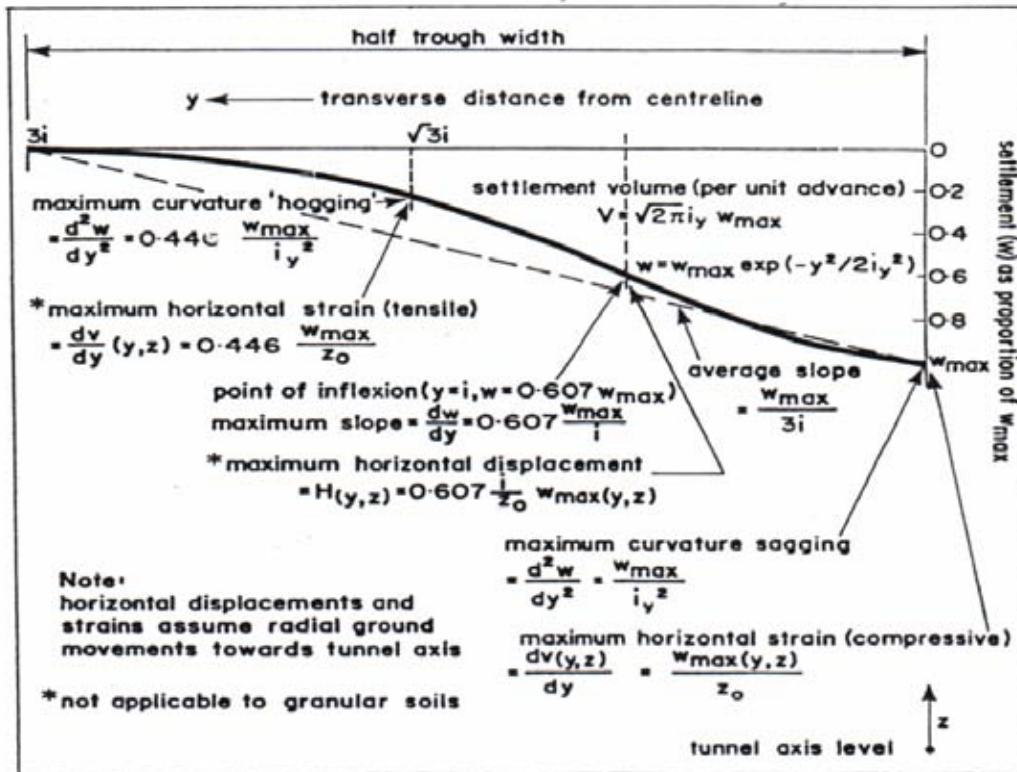


Figure A-2 illustrates in two dimensions, the settlement trough shape and extent of surface settlement with respect to an advancing tunnel (Burland, 2001) with Figure A-3 and Figure A-4 providing the formulae used to predict through parameters.

**Figure A-2: Terminology for Ground Loss and Tunneling Settlement**



**Figure A-3: Theoretical Formulae for Settlement**


$$i = Kz_0 \quad w_{\max} = \frac{0.313V_L(D)^2}{Kz_0} \quad w = w_{\max} \exp(-y^2/2i)$$

- |            |                          |       |                                   |
|------------|--------------------------|-------|-----------------------------------|
| $w_{\max}$ | - Maximum settlement     | $w$   | - Settlement at distance          |
| 'y'        | from tunnel centerline   | $z_0$ | - Depth to tunnel springline      |
| K          | - Trough width parameter | $V_L$ | - Volume loss                     |
| D          | - Tunnel diameter        | $i$   | - Distance to point of inflection |

The shape of the settlement trough approximates the normal probability curve and the vertical displacement at any point being given by:

$$S = S_{\max} \cdot \exp(-x^2/2i^2)$$

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

Unless some other detailed analysis is performed the value of  $i$  is typically taken as:  $i = 0.5$

The volume of the settlement trough is given by:

$$V_s = 2.5 \cdot i \cdot S_{\max}$$

Typical steps for estimating settlements are as follows:

4. Determine depth from ground surface to tunnel springline,  $Z_0$ .
5. Calculate distance to point of inflection on settlement curve using trough width parameter,  $K = 0.4$ :

$$i = 0.5 z_0$$

6. 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

7. Calculate settlement,  $w$ , at each point along settlement trough:

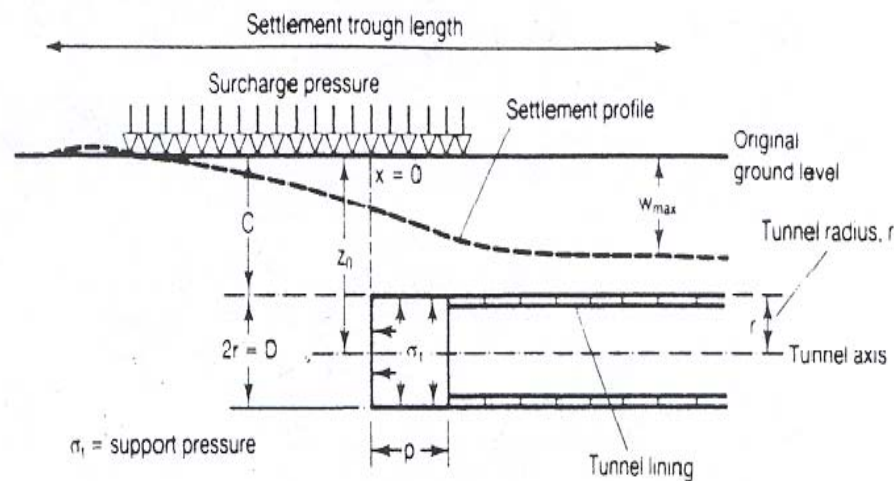
$$w = w_{\max} \exp(-y^2 / 2i)$$

where

$y$  = 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 A-4: Theoretical Formulae for Longitudinal Settlement Trough**



(a) Longitudinal settlement profile



**APPENDIX B**  
**List of Properties along Tunnel Alignment**

Appendix B - List of Properties around Station/Crossover Excavations

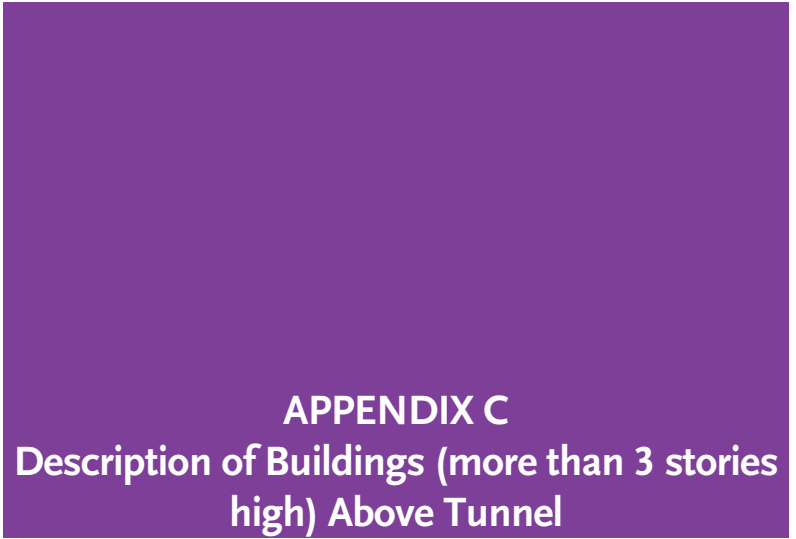
Station	Address	APN	Building Characteristics				Zone of Influence (ft)	Preliminary Screen (Within the Zone of Influence?)	δ Max. Building Settlement (in)	S Differential Settlement	δ>1/2" or S>1/600?	Lateral Wall Deflection at Building Base (in)	Building Distortion	Lateral Strain	Principal Strain	Risk Category	Remarks	
			No. of Stories	Distance From Excavation (ft)	Building Base Depth (ft)	Building Width (ft)												
Wilshire/Western	3818 Wilshire Blvd, Los Angeles	5093005006	1	26	12	52	110	Yes	0.80	0.0011	Yes	0.91	0.00080	0.00069	0.00088	2		
	3820 Wilshire Blvd, Los Angeles	5093005005	1	23	12	80	110	Yes	0.86	0.0009	Yes	0.91	0.00083	0.00069	0.00089	2		
	3828 Wilshire Blvd, Los Angeles	5093005004	1	37	12	39	110	Yes	0.60	0.0010	Yes	0.91	0.00069	0.00069	0.00084	2		
	3839 Wilshire Blvd, Los Angeles	5503031018	1	87	0	100	122	Yes	0.12	0.0003	No	0.75	0.00027	0.00051	0.00055	1		
Wilshire/La Brea	5150 Wilshire Blvd, Los Angeles	5507025021	5	13	6	68	163	Yes	1.13	0.0010	Yes	0.81	0.00063	0.00041	0.00058	1		
	5201 Wilshire Blvd, Los Angeles	5507023029	1	31	0	67	170	Yes	0.89	0.0008	Yes	0.75	0.00053	0.00037	0.00051	1		
	5200 Wilshire Blvd, Los Angeles	5507024010	7	14	24	129	142	Yes	1.06	0.0007	Yes	0.98	0.00069	0.00058	0.00074	1	Vacant land (Future building)	
	5174 Wilshire Blvd, Los Angeles	5507025018	1	13	0	110	170	Yes	1.13	0.0008	Yes	0.75	0.00060	0.00037	0.00054	1		
	5220 Wilshire Blvd, Los Angeles	5507024009	No Building														Vacant land	
	5209 Wilshire Blvd, Los Angeles	5507023017	1	37	0	91	170	Yes	0.81	0.0007	Yes	0.75	0.00051	0.00037	0.00050	0		
	5217 Wilshire Blvd, Los Angeles	5507023018	12	27	16	158	151	Yes	0.89	0.0006	Yes	0.90	0.00060	0.00050	0.00064	1		
	5318 Wilshire Blvd, Los Angeles	5089001026	2	10	10	130	158	Yes	1.16	0.0007	Yes	0.85	0.00065	0.00045	0.00062	1	Building to be removed	
	5151 Wilshire Blvd, Los Angeles	5507022016	5	33	9	153	159	Yes	0.83	0.0006	Yes	0.84	0.00055	0.00044	0.00057	1		
	5301 Wilshire Blvd, Los Angeles	5508007900	1	37	0	142	170	Yes	0.81	0.0005	Yes	0.75	0.00051	0.00037	0.00050	0	Building to be removed	
	5115 Wilshire Blvd, Los Angeles	5507021035	9	32	25	177	141	Yes	0.77	0.0006	Yes	0.99	0.00059	0.00059	0.00071	1		
	5126 Wilshire Blvd, Los Angeles	5507026020	1	31	0	46	170	Yes	0.89	0.0009	Yes	0.75	0.00053	0.00037	0.00051	1		
	711 La Brea Ave, Los Angeles	5089001027	1	14	0	123	170	Yes	1.12	0.0007	Yes	0.75	0.00060	0.00037	0.00053	1	Building to be removed	
Wilshire/Fairfax	6000 Wilshire Blvd, Los Angeles	5086010031	No Building														Parking Lot	
	6010 Wilshire Blvd, Los Angeles	5086010003	5	30	0	60	144	Yes	0.86	0.0009	Yes	0.75	0.00063	0.00043	0.00060	1	Building to be removed	
	6018 Wilshire Blvd, Los Angeles	5086010002	2	32	0	56	144	Yes	0.83	0.0009	Yes	0.75	0.00062	0.00043	0.00059	1	Building to be removed	
	6030 Wilshire Blvd, Los Angeles	5086010001	4	26	0	108	144	Yes	0.92	0.0007	Yes	0.75	0.00065	0.00043	0.00061	1	Building to be removed	
	6060 Wilshire Blvd, Los Angeles	5086009014	3	38	33	150	108	Yes	0.53	0.0006	Yes	1.13	0.00063	0.00087	0.00097	2	On pile foundation	
	6100 Wilshire Blvd, Los Angeles	5088002046	16	37	64	138	74	Yes	0.18	0.0004	No	1.48	0.00042	0.00166	0.00169	3		
	6120 Wilshire Blvd, Los Angeles	5088002034	No Building														Parking Lot	
	6122 Wilshire Blvd, Los Angeles	5088002035	1	33	0	37	144	Yes	0.81	0.0010	Yes	0.75	0.00061	0.00043	0.00059	1		
	Not Known	5088002036	No Building															Parking Lot
	6067 Wilshire Blvd, Los Angeles	5508017007	4	30	31	225	110	Yes	0.67	0.0007	Yes	1.10	0.00070	0.00083	0.00096	2	LACMA West	
	5905 Wilshire Blvd, Los Angeles	5508016901	5	43	14	121	129	Yes	0.60	0.0006	Yes	0.91	0.00058	0.00059	0.00071	1	LACMA East on piles	
	6101 Wilshire Blvd, Los Angeles	5510027035	1	32	10	83	133	Yes	0.79	0.0008	Yes	0.86	0.00065	0.00054	0.00069	1		
	6111 Wilshire Blvd, Los Angeles	5510027003	1	23	0	97	144	Yes	0.97	0.0008	Yes	0.75	0.00067	0.00043	0.00061	1	Building to be removed	
	6121 Wilshire Blvd, Los Angeles	5510027040	1	24	0	128	144	Yes	0.95	0.0007	Yes	0.75	0.00066	0.00043	0.00061	1		
6133 Wilshire Blvd, Los Angeles	5510027005	3	23	0	89	144	Yes	0.97	0.0008	Yes	0.75	0.00067	0.00043	0.00061	1			
Wilshire/La Cienega	8383 Wilshire Blvd, Beverly Hills	4334022081	10	27	32	193	111	Yes	0.72	0.0007	Yes	1.11	0.00072	0.00083	0.00097	2		
	8401 Wilshire Blvd, Beverly Hills	4334022061	1	18	0	95	146	Yes	1.05	0.0009	Yes	0.75	0.00068	0.00043	0.00062	1		
	8421 Wilshire Blvd, Beverly Hills	4334022062	2	18	0	137	146	Yes	1.05	0.0007	Yes	0.75	0.00068	0.00043	0.00062	1		
	8423 Wilshire Blvd, Beverly Hills	4334022060	2	18	0	123	146	Yes	1.05	0.0007	Yes	0.75	0.00068	0.00043	0.00062	1		
	8447 Wilshire Blvd, Beverly Hills	4334021060	6	17	0	126	146	Yes	1.07	0.0007	Yes	0.75	0.00069	0.00043	0.00062	1	Building to be removed	
	8471 Wilshire Blvd, Beverly Hills	4334021059	1	17	0	99	146	Yes	1.07	0.0008	Yes	0.75	0.00069	0.00043	0.00062	1	Building to be removed	
	8501 Wilshire Blvd, Beverly Hills	4334018072	3	109	35	273	108	No										
	8300 Wilshire Blvd, Beverly Hills	4333030001	1	30	0	112	146	Yes	0.86	0.0006	Yes	0.75	0.00062	0.00043	0.00059	1		
	8364 Wilshire Blvd, Beverly Hills	4333030130	3	15	0	148	146	Yes	1.10	0.0007	Yes	0.75	0.00070	0.00043	0.00062	1		
	8400 Wilshire Blvd, Beverly Hills	4333029015	1	13	0	72	146	Yes	1.13	0.0010	Yes	0.75	0.00071	0.00043	0.00063	1		
	8412 Wilshire Blvd, Beverly Hills	4333029016	No Building															Parking lot
	8420 Wilshire Blvd, Beverly Hills	4333029017	1	19	0	132	146	Yes	1.03	0.0007	Yes	0.75	0.00068	0.00043	0.00062	1		
	8430 Wilshire Blvd, Beverly Hills	4333029018	7	15	12	231	133	Yes	1.07	0.0008	Yes	0.88	0.00075	0.00056	0.00075	1		
	8484 Wilshire Blvd, Beverly Hills	4333028015	10	8	42	210	100	Yes	0.99	0.0009	Yes	1.22	0.00090	0.00102	0.00119	2		
8500 Wilshire Blvd, Beverly Hills	4333027028	13	72	15	237	130	Yes	0.27	0.0004	No	0.92	0.00038	0.00059	0.00065	1			

Station	Address	APN	Building Characteristics				Zone of Influence (ft)	Preliminary Screen (Within the Zone of Influence?)	δ Max. Building Settlement (in)	S Differential Settlement	δ>1/2" or S>1/600?	Lateral Wall Deflection at Building Base (in)	Building Distortion	Lateral Strain	Principal Strain	Risk Category	Remarks	
			No. of Stories	Distance From Excavation (ft)	Building Base Depth (ft)	Building Width (ft)												
Wilshire/Rodeo	9385 Wilshire Blvd, Beverly Hills	4343005006	1	16	0	70	168	Yes	1.06	0.0009	Yes	0.75	0.00058	0.00037	0.00053	1	Building to be removed	
	9393 Wilshire Blvd, Beverly Hills	4343005005	1	16	0	70	168	Yes	1.06	0.0009	Yes	0.75	0.00058	0.00037	0.00053	1	Building to be removed	
	9397 Wilshire Blvd, Beverly Hills	4343005004	1	16	0	70	168	Yes	1.06	0.0009	Yes	0.75	0.00058	0.00037	0.00053	1	Building to be removed	
	155 N Crescent Dr, Beverly Hills	Multiple	5	62	12	171	153	Yes	0.46	0.0004	No	0.87	0.00042	0.00047	0.00055	1		
	Not Known	4343005024	1	56	0	81	168	Yes	0.57	0.0005	Yes	0.75	0.00043	0.00037	0.00047	0		
	Not Known	4343005023	1	102	0	109	168	Yes	0.20	0.0003	No	0.75	0.00025	0.00037	0.00041	0		
	9378 Wilshire Blvd, Beverly Hills	4331008023	3	16	42	158	115	Yes	0.88	0.0007	Yes	1.16	0.00074	0.00084	0.00098	2		
	9401 Wilshire Blvd, Beverly Hills	4343013028	12	17	27	186	134	Yes	0.96	0.0007	Yes	1.01	0.00069	0.00063	0.00078	2		
	205 N Canon Dr, Beverly Hills	Multiple	8	52	24	127	138	Yes	0.49	0.0005	No	0.98	0.00048	0.00060	0.00068	1		
	9429 Wilshire Blvd, Beverly Hills	4343013011	6	21	10	92	155	Yes	0.97	0.0008	Yes	0.85	0.00060	0.00045	0.00060	1		
	190 N Canon Dr, Beverly Hills	4343005001	5	175	12	131	153	No										
	9404 Wilshire Blvd, Beverly Hills	4331001002	No Building															Parking Lot
	9424 Wilshire Blvd, Beverly Hills	4331001001	5	17	12	157	153	Yes	1.02	0.0006	Yes	0.87	0.00063	0.00047	0.00063	1	Building to be removed	
	9430 Wilshire Blvd, Beverly Hills	4331001045	2	8	0	154	168	Yes	1.17	0.0006	Yes	0.75	0.00061	0.00037	0.00054	1	Building to be removed	
	9450 Wilshire Blvd, Beverly Hills	4331001049	11	14	24	154	138	Yes	1.03	0.0007	Yes	0.98	0.00069	0.00060	0.00075	2		
	9461 Wilshire Blvd, Beverly Hills	4343014022	10	21	35	83	124	Yes	0.85	0.0008	Yes	1.09	0.00069	0.00073	0.00087	2		
	268 Rodeo Dr, Beverly Hills	4343014021	4	16	12	42	153	Yes	1.04	0.0011	Yes	0.87	0.00063	0.00047	0.00063	1		
	9460 Wilshire Blvd, Beverly Hills	4328033001	9	5	25	144	136	Yes	1.18	0.0007	Yes	0.99	0.00075	0.00061	0.00078	2		
	9504 Wilshire Blvd, Beverly Hills	4328032014	8	22	12	158	153	Yes	0.95	0.0006	Yes	0.87	0.00060	0.00047	0.00062	1		
	9372 Wilshire Blvd, Beverly Hills	4331008024	1	84	0	107	168	Yes	0.32	0.0003	No	0.75	0.00032	0.00037	0.00043	0		
9355 Wilshire Blvd, Beverly Hills	4343005025	4	48	24	140	138	Yes	0.54	0.0005	Yes	0.98	0.00050	0.00060	0.00069	1			
Century City - Constellation Blvd	1875 Century Park East, Los Angeles	4319002060	24	14	13	450	178	Yes	1.10	0.0006	Yes	0.86	0.00056	0.00040	0.00055	1	On pile foundation	
	Not Known	4319002059	No Building														Parking lot	
	10131 Constellation Blvd, Los Angeles	4319002054	No Building														Parking lot	
	Not Known	4319002053	3	0	38	380	147	Yes	1.25	0.0007	Yes	1.07	0.00071	0.00061	0.00077	2	Vacant land (Future building)	
	1950 Avenue of the Stars, Los Angeles	4319002055	No Building															Vacant land
	1999 (Office) Avenue of the Stars, Los Angeles	4319003065	39	8	30	176	157	Yes	1.15	0.0006	Yes	1.00	0.00064	0.00053	0.00068	1		
	1999 (Parking) Avenue of the Stars, Los Angeles	4319003065	5	8	30	368	157	Yes	1.15	0.0006	Yes	1.00	0.00064	0.00053	0.00068	1		
	10250 Santa Monica Blvd, Los Angeles	4319003064	2	67	12	360	179	Yes	0.51	0.0004	Yes	0.85	0.00038	0.00040	0.00047	0		
	2029 Century Park East, Los Angeles (High-Rise)	4319016029	44	39	78	273	97	Yes	0.31	0.0004	No	1.41	0.00044	0.00120	0.00124	2		
	2029 Century Park East, Los Angeles (Small)	4319016029	3	35	85	140	89	Yes	0.26	0.0004	No	1.47	0.00041	0.00138	0.00141	2	Restaurant	
	2040 Avenue of the Stars, Los Angeles	4319016033	16	30	92	410	80	Yes	0.21	0.0004	No	1.35	0.00035	0.00141	0.00143	2		
	2025 Avenue of the Stars, Los Angeles	4319004109	0	14	30	71	157	Yes	1.06	0.0009	Yes	1.00	0.00062	0.00053	0.00067	1	Spiral ramp structure	
	2025 Avenue of the Stars, Los Angeles	4319004109	16	85	45	450	138	Yes	0.18	0.0003	No	1.13	0.00028	0.00068	0.00071	1		
2025 Avenue of the Stars, Los Angeles	4319004109	2	70	0	91	194	Yes	0.53	0.0005	Yes	0.75	0.00036	0.00032	0.00040	0			
Century City - Santa Monica Blvd Crossover	Not Known	4328001015	No Building														Parking lot	
	Not Known	4328001016	No Building														Parking lot	
	Not Known	4328001017	No Building														Parking lot	
	9949 Santa Monica Blvd, Beverly Hills	4328001018	1	3	0	38	150	Yes	1.26	0.0012	Yes	0.75	0.00072	0.00042	0.00062	1		
	9953 Santa Monica Blvd, Beverly Hills	4328001019	1	3	0	40	150	Yes	1.26	0.0012	Yes	0.75	0.00072	0.00042	0.00062	1		
	9975 Santa Monica Blvd, Beverly Hills	4328001020	3	3	15	37	132	Yes	1.25	0.0014	Yes	0.91	0.00081	0.00058	0.00078	2		
	9935 Santa Monica Blvd, Beverly Hills	4328001014	2	32	0	105	150	Yes	0.81	0.0006	Yes	0.75	0.00057	0.00042	0.00056	1		
	9876 Wilshire Blvd, Beverly Hills	4327028001	5	79	48	265	92	Yes	0.02	0.0001	No	1.27	0.00014	0.00115	0.00116	2		
	N/A Santa Monica Blvd, Los Angeles	4328001023	No Building															Vacant land
9900 Wilshire Blvd, Beverly Hills	4327028002	2	79	24	515	121	Yes	0.15	0.0003	No	1.01	0.00031	0.00070	0.00073	1			
Century City - Santa Monica Blvd	1800 Century Park East, Beverly Hills	4319001903	15	140	35	174	122	No										
	1801 Century Park East, Beverly Hills	4319002045	24	155	60	172	91	No										
	Not Known	4319001002	No Building														Vacant land	
	10000 Santa Monica Blvd, Los Angeles	4319001001	No Building														Vacant land	
	Not Known	4319003902	No Building														Traffic island/bus stop	

Station	Address	APN	Building Characteristics				Zone of Influence (ft)	Preliminary Screen (Within the Zone of Influence?)	δ Max. Building Settlement (in)	S Differential Settlement	δ>1/2" or S>1/600?	Lateral Wall Deflection at Building Base (in)	Building Distortion	Lateral Strain	Principal Strain	Risk Category	Remarks
			No. of Stories	Distance From Excavation (ft)	Building Base Depth (ft)	Building Width (ft)											
Westwood/UCLA	10921 Wilshire Blvd, Los Angeles	4363023032	13	10	12	170	141	Yes	1.13	0.0007	Yes	0.88	0.00071	0.00052	0.00070	1	
	10951 Wilshire Blvd, Los Angeles	4363023001	28	7	48	182	97	Yes	0.95	0.0009	Yes	1.25	0.00088	0.00108	0.00123	2	
	1100 Veteran Ave, Los Angeles	4363026905	1	44	0	180	156	Yes	0.67	0.0005	Yes	0.75	0.00050	0.00040	0.00052	1	
	10900 Wilshire Blvd, Los Angeles	4324001031	16	66	37	92	111	Yes	0.20	0.0004	No	1.14	0.00037	0.00086	0.00089	2	
	10920 Wilshire Blvd, Los Angeles	4324001900	18	47	41	162	106	Yes	0.36	0.0005	No	1.18	0.00052	0.00093	0.00100	2	
	10940 Wilshire Blvd, Los Angeles	4324001032	23	58	75	140	64	Yes	0.00	0.0001	No	1.29	0.00006	0.00168	0.00168	3	
	10960 Wilshire Blvd, Los Angeles	4324002028	24	64	38	110	109	Yes	0.21	0.0004	No	1.15	0.00038	0.00087	0.00091	2	On pile foundation
	10990 Wilshire Blvd, Los Angeles	4324002027	18	100	90	128	46	No									On pile foundation
GSA Crossover	Not Known	4363027901	1	154	0	14	152	No									Small brick monument
GSA Crossover	GSA Federal Building	4324017903	17	108	70	130	67	No									GSA Building
Westwood/VA Hospital	Not Known	4365008904	No Building														Parking and loan area

Appendix B - List of Properties around Entrance Excavations

Station	Address	APN	Building Characteristics				Zone of Influence (ft)	Preliminary Screen (Within the Zone of Influence?)	δ Max. Building Settlement (in)	S Differential Settlement	δ>1/2" or S>1/600?	Lateral Wall Deflection at Building Base (in)	Building Distortion	Lateral Strain	Principal Strain	Risk Category	Remarks
			No. of Stories	Distance From Excavation (ft)	Building Base Depth (ft)	Building Width (ft)											
Wilshire/La Brea	5217 Wilshire Blvd, Los Angeles	5507023018	12	112	16	162	98	No									
	5318 Wilshire Blvd, Los Angeles	5089001026	2	104	10	144	108	Yes	1.2	0.0000	Yes	0.59	0.0007	0.0004	0.0006	1	Building to be removed
	711 La Brea Ave, Los Angeles	5089001027	1	78	0	123	120	Yes	1.2	0.0002	Yes	0.50	0.0006	0.0004	0.0005	1	Building to be removed
Wilshire/Fairfax	6100 Wilshire Blvd, Los Angeles	5088002046	16	102	64	138	60	No									
	6101 Wilshire Blvd, Los Angeles	5510027035	1	9	10	63	86	Yes	1.6	0.0011	Yes	0.62	0.0009	0.0006	0.0008	2	
	6121 Wilshire Blvd, Los Angeles	5510027040	1	30	0	158	94	Yes	1.4	0.0006	Yes	0.50	0.0006	0.0004	0.0006	1	
	637 S Fairfax Ave, Los Angeles	Multiple	6	84	12	72	88	Yes	1.0	0.0001	Yes	0.64	0.0001	0.0006	0.0006	1	
Wilshire/La Cienega	8447 Wilshire Blvd, Beverly Hills	4334021060	6	6	0	129	96	Yes	2.1	0.0009	Yes	0.50	0.0009	0.0004	0.0007	1	Building to be removed
	8501 Wilshire Blvd, Beverly Hills	4334018072	3	106	35	223	72	No									
	8484 Wilshire Blvd, Beverly Hills	4333028015	10	113	42	96	68	No									
	113 N Hamilton Dr, Beverly Hills	4334021061	2	46	0	77	96	Yes	0.6	0.0005	Yes	0.50	0.0005	0.0004	0.0006	1	
	117 N Hamilton Dr, Beverly Hills	4334021062	3	69	12	96	88	Yes	0.3	0.0002	No	0.64	0.0002	0.0006	0.0006	1	
Wilshire/Rodeo	9401 Wilshire Blvd, Beverly Hills	4343013028	12	79	27	203	98	Yes	1.0	0.0002	Yes	0.75	0.0007	0.0007	0.0009	2	
	9429 Wilshire Blvd, Beverly Hills	4343013011	6	100	10	118	105	Yes	1.0	0.0000	Yes	0.59	0.0000	0.0005	0.0005	0	
	9424 Wilshire Blvd, Beverly Hills	4331001001	5	76	12	155	103	Yes	1.1	0.0002	Yes	0.61	0.0002	0.0005	0.0005	1	Building to be removed
	9450 Wilshire Blvd, Beverly Hills	4331001049	11	44	24	127	90	Yes	1.2	0.0004	Yes	0.73	0.0004	0.0007	0.0007	1	
	112 S Beverly Dr, Beverly Hills	4331001043	2	108	0	120	116	Yes	1.0	0.0000	Yes	0.50	0.0000	0.0004	0.0004	0	
	120 S Reeves Dr, Beverly Hills	4331001022	3	98	0	109	116	Yes	1.0	0.0001	Yes	0.50	0.0001	0.0004	0.0004	0	
	124 S Reeves Dr, Beverly Hills	4331001021	2	129	0	82	116	No									
Century City - Constellation Blvd	1999 (Office) Avenue of the Stars, Los Angeles	4319003065	39	128	30	158	124	No									
	2040 Avenue of the Stars, Los Angeles	4319016033	16	110	92	410	63	No									
Century City - Santa Monica Blvd	1800 Century Park East, Beverly Hills	4319001903	15	30	35	108	69	Yes	1.0	0.0005	Yes	0.83	0.0005	0.0010	0.0011	2	
	1801 Century Park East, Beverly Hills	4319002045	24	99	60	126	31	No									
Westwood/UCLA	10951 Wilshire Blvd, Los Angeles	4363023001	28	100	48	78	57	No									Future Building
	10900 Wilshire Blvd, Los Angeles	4324001031	16	19	37	156	48	Yes	0.4	0.0007	No	0.88	0.0010	0.0023	0.0024	3	
	10920 Wilshire Blvd, Los Angeles	4324001900	18	0	41	162	42	Yes	1.0	0.0012	Yes	0.92	0.0017	0.0026	0.0029	3	
	10960 Wilshire Blvd, Los Angeles	4324002028	24	129	38	112	69	No									On pile foundation



**APPENDIX C**  
**Description of Buildings (more than 3 stories  
high) Above Tunnel**

## 9740 WILSHIRE BLVD



9740 Wilshire Blvd is a five story structure. The building is located on the southwest corner of Linden Dr and Wilshire Blvd. The building is rectangular in plan with a width of approximately 105 feet along Wilshire and a depth of approximately 130 feet.

## 120 SPALDING DR



120 Spalding Dr. is a four story building. The building is located on the Southeast corner of Spalding Dr. and Wilshire Blvd. The building is rectangular in plan with a width of approximately 170 feet along Spalding Dr and a depth of approximately 110 feet.

## 125 SPALDING DR



120 Spalding Dr. is a four story building. The building is located mid block on the west side of Spalding Dr. between Wilshire Blvd and Charleville Blvd. The building is rectangular in plan with a width of approximately 100 feet along Spalding Dr and a depth of approximately 50 feet.

## 133 SPALDING DR



133 Spalding Dr is a four story parking garage. The building is located on the west side of Spalding Dr between Charleville Blvd and Wilshire Blvd. The building is rectangular in plan with a width of approximately 35 feet along Spalding and a depth of approximately 95 feet.

## 137 SPALDING DR



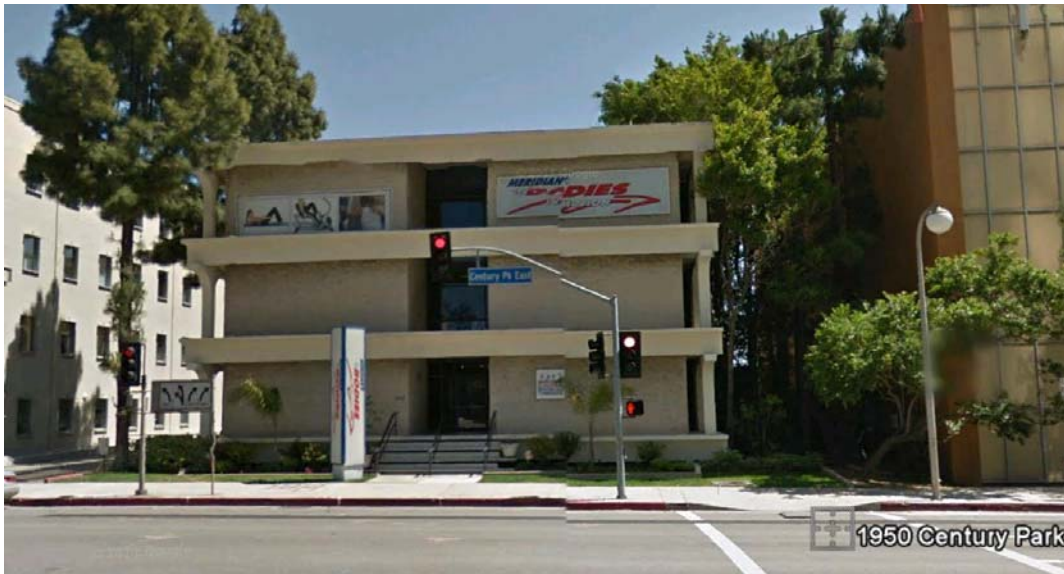
137 Spalding Dr. is a three story condominium. The building is located mid block on the west side of Spalding Dr. between Wilshire Blvd and Charleville Blvd. The building is rectangular in plan with a width of approximately 130 feet along Spalding Dr and a depth of approximately 90 feet.

## 223 LASKY DR



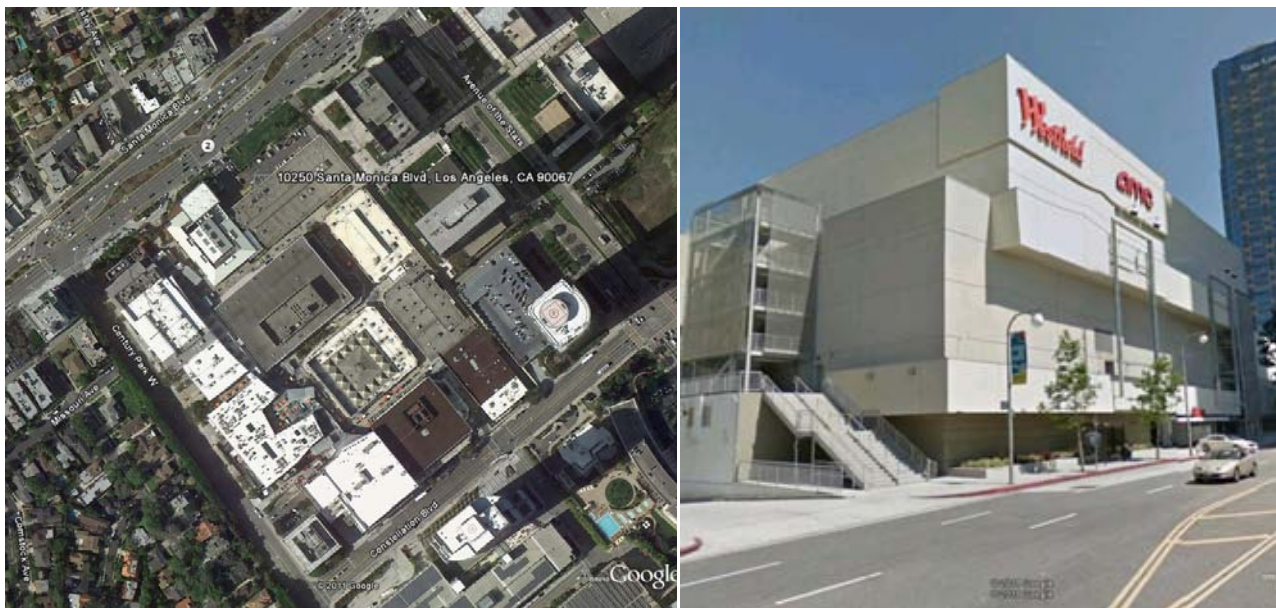
223 Lasky Dr. is a three story apartment. The building is on the southwest corner of Lasky Dr. and Robbins Dr. The building is triangular in plan with a width of approximately 100 feet along Lasky Dr. and a depth of approximately 70 feet.

## 1950 CONSTELLATION PARK EAST



1950 Century Park East is a three story exercise facility. The building is on east side of the intersection of Constellation Blvd. and Century Park East. The building is rectangular in plan with a width of approximately 70 feet along Century Park East and a depth of approximately 110 feet.

## 10250 SANTA MONICA BLVD



10250 Sana Monica Blvd is the Westfield Shopping Center. The building occupies the block bounded by Santa Monica Blvd on the northwest, Avenue of the Stars on the northeast, Constellation Blvd on the southeast and Century Park West on the southwest. There are several buildings and structures that compose the mall which spans approximately 1000 feet by 1000 feet.

## 10636 WILSHIRE BLVD



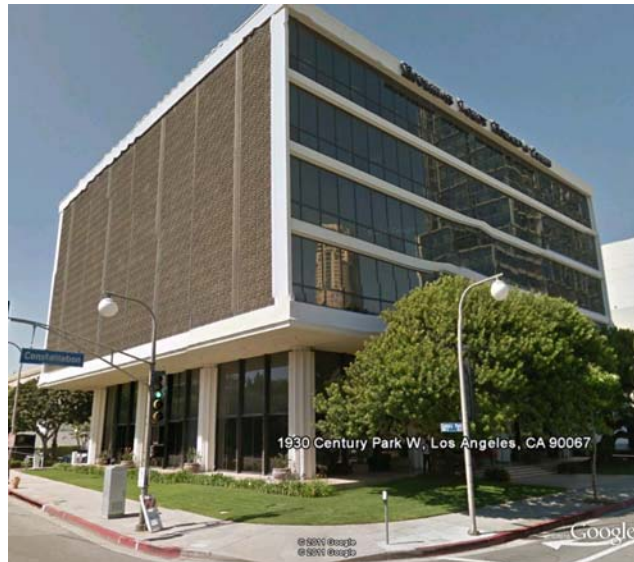
10636 Wilshire Blvd. is a seven story apartment. The building is midblock on the south side of Wilshire Blvd west of Manning Ave. and east Westholme Ave. The building is rectangular in plan with a width of approximately 85 feet along Wilshire Blvd. and a depth of approximately 152 feet.

## 10600 WILSHIRE BLVD



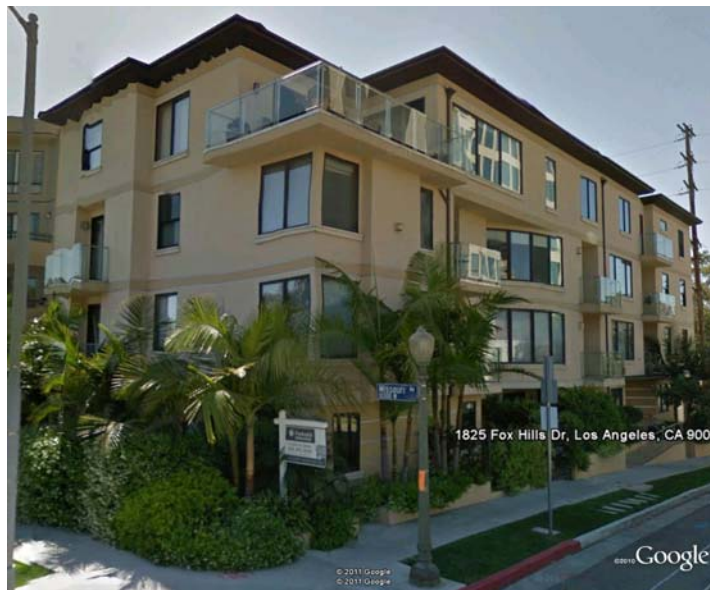
10600 Wilshire Blvd. is a seven story apartment. The building is midblock on the south side of Wilshire Blvd west of Manning Ave. and east Westholme Ave. The building is rectangular in plan with a width of approximately 230 feet along Wilshire Blvd. and a depth of approximately 170 feet.

## 1930 CENTURY PARK WEST



1930 Century Park West is a five story Office. The building is on the northeast corner of Century Park West and Constellation Blvd. The building is rectangular in plan with a width of approximately 120 feet along Constellation Blvd. and a depth of approximately 120 feet.

## 1825 FOX HILLS DR



1825 Fox Hills Dr. is a four story apartment. The building is on the west corner of Fox Hills Dr and Missouri Ave. The building is rectangular in plan with a width of approximately 115 feet along Fox Hills Dr. and a depth of approximately 50 feet.

## 10307 MISSOURI AVE



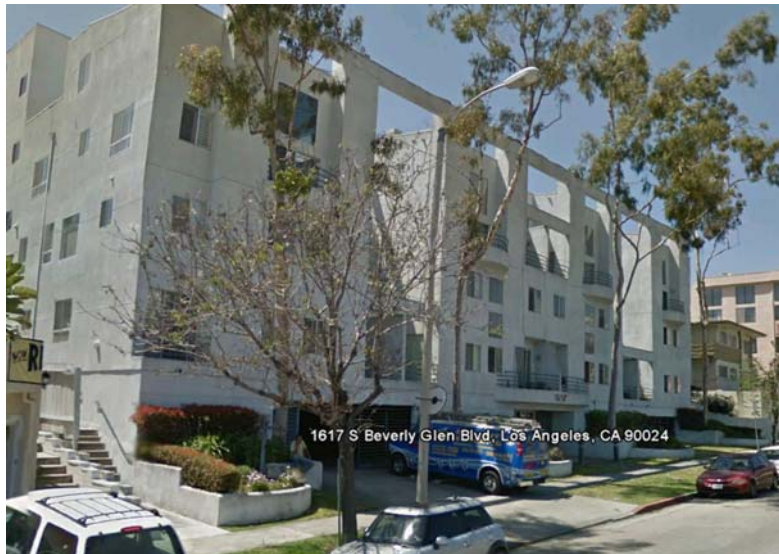
10307 Missouri Ave. is a five story condominium. The building is midblock on the northwest side of Missouri Ave southwest of Fox Hills Dr. and northeast Benicia Ave. The building is rectangular in plan with a width of approximately 40 feet along Missouri Ave. and a depth of approximately 110 feet.

## 1622 BEVERLY GLEN BLVD



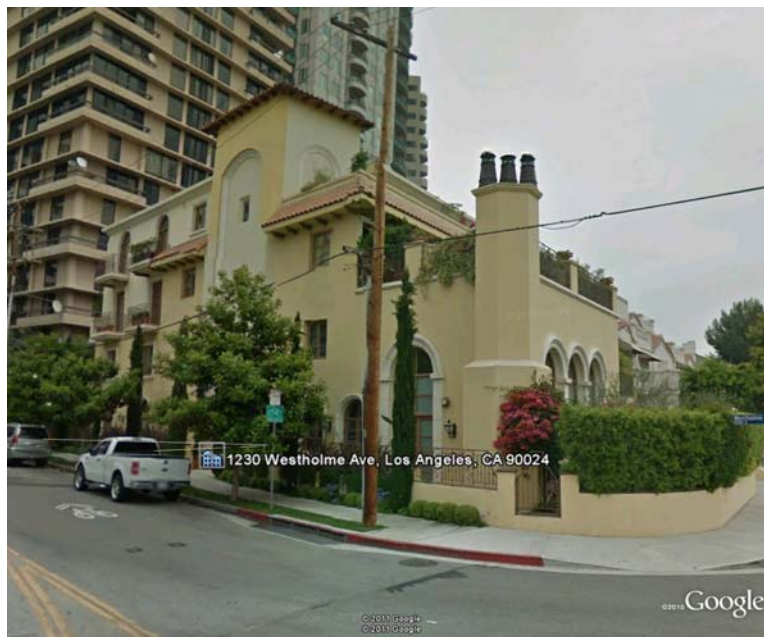
1622 Beverly Glen Blvd. is a three story apartment. The building is midblock on the east side of Beverly Glen Blvd north of Eastborne Ave. and south of Holman Ave. The building is rectangular in plan with a width of approximately 50 feet along Beverly Glen Blvd and a depth of approximately 100 feet.

## 1617 BEVERLY GLEN BLVD



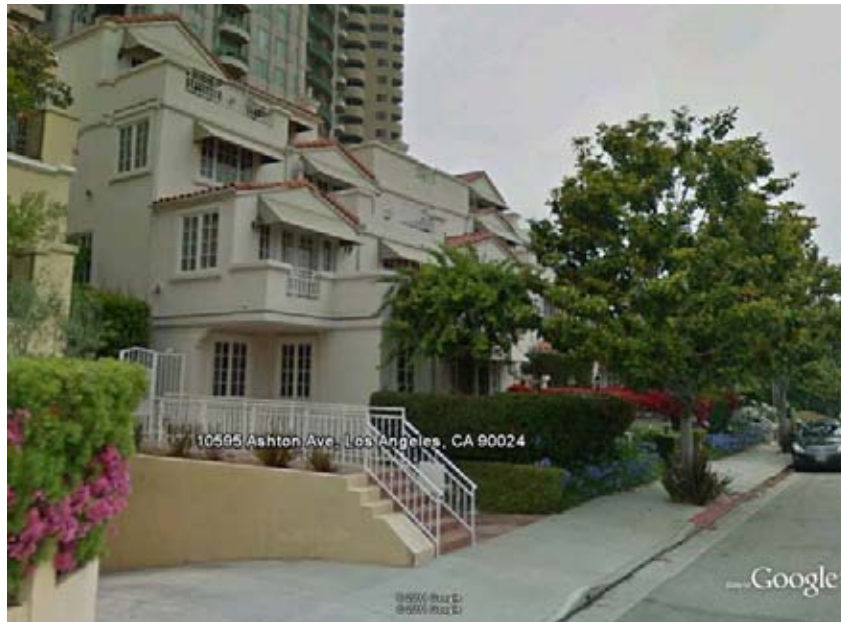
1617 Beverly Glen Blvd. is a five story condominium. The building is midblock on the west side of Beverly Glen Blvd north of Eastborne Ave. and south of Holman Ave. The building is rectangular in plan with a width of approximately 140 feet along Beverly Glen Blvd and a depth of approximately 90 feet.

## 1230 WESTHOLME AVE



1617 Beverly Glen Blvd. is a three story condominium. The building is on the northeast corner of Westholme Ave and Ashton Ave. The building is rectangular in plan with a width of approximately 90 feet along Westholme Ave and a depth of approximately 60 feet.

## 10595 ASHTON AVE



10595 Ashton Ave. is a four story condominium. The building is midblock on the west side of Ashton Ave north of Westholme Ave. and south of Thayer Ave. The building is rectangular in plan with a width of approximately 90 feet along Ashton Ave and a depth of approximately 90 feet.

## 10601 ASHTON AVE



10601 Ashton Ave. is a four story condominium. The building is on the west corner of Ashton Ave. and Westholme Ave. The building is rectangular in plan with a width of approximately 35 feet along Ashton Ave and a depth of approximately 100 feet.

## 10315 MISSOURI AVE



10315 Missouri Ave. is a three story condominium. The building is midblock on the west side of Missouri Ave south of Fox Hills Dr. and north of Benicia Ave. The building is rectangular in plan with a width of approximately 35 feet along Missouri Ave and a depth of approximately 110 feet.

## 10317 MISSOURI AVE



10317 Missouri Ave. is a four story condominium. The building is midblock on the west side of Missouri Ave south of Fox Hills Dr. and north of Benicia Ave. The building is rectangular in plan with a width of approximately 40 feet along Missouri Ave and a depth of approximately 110 feet.

## 10351 SANTA MONICA BLVD



10351 Santa Monica Blvd. is a four story office. The building is midblock on the west side of Santa Monica Blvd. south of Comstock Ave. and north of Beverly Glen Blvd. The building is rectangular in plan with a width of approximately 280 feet along Santa Monica Blvd and a depth of approximately 110 feet.

## 9830 WILSHIRE BLVD



9830 Wilshire Blvd. is a three story condominium. The building is on the southeast corner of Wilshire Blvd. and Santa Monica Blvd. The building is irregular in plan with a width of approximately 260 feet along Wilshire Blvd and a depth of approximately 220 feet.

## 10590 WILSHIRE BLVD



10590 Wilshire Blvd. is a sixteen story condominium. The building is on the southeast corner of Wilshire Blvd. and Westholme Ave. The building is rectangular in plan with a width of approximately 80 feet along Wilshire Blvd and a depth of approximately 160 feet.

## 1557 S BEVERLY GLEN BLVD



1557 Beverly Glen Blvd. is a five story condominium. The building is midblock on the west side of Beverly Glen Ave. between Woodruff Ave. on the north and Eastborne Ave. on the south. The building is rectangular in plan with a width of approximately 200 feet along Beverly Glen Blvd and a depth of approximately 110 feet.

## 1545 S BEVERLY GLEN BLVD



1545 Beverly Glen Blvd. is a five story condominium. The building is midblock on the west side of Beverly Glen Ave. between Woodruff Ave. on the north and Eastborne Ave. on the south. The building is rectangular in plan with a width of approximately 35 feet along Beverly Glen Blvd and a depth of approximately 75 feet.

## 1544 S BEVERLY GLEN BLVD



1544 Beverly Glen Blvd. is a four story apartment. The building is midblock on the east side of Beverly Glen Ave. between Woodruff Ave. on the north and Eastborne Ave. on the south. The building is rectangular in plan with a width of approximately 35 feet along Beverly Glen Blvd and a depth of approximately 110 feet.

## 1550 S BEVERLY GLEN BLVD



1550 Beverly Glen Blvd. is a three story apartment. The building is midblock on the east side of Beverly Glen Ave. between Woodruff Ave. on the north and Eastborne Ave. on the south. The building is rectangular in plan with a width of approximately 40 feet along Beverly Glen Blvd and a depth of approximately 110 feet.

## 1556 S BEVERLY GLEN BLVD



1556 Beverly Glen Blvd. is a four story apartment. The building is on the corner of Beverly Glen Ave. between and Holman Ave. on the south. The building is rectangular in plan with a width of approximately 40 feet along Beverly Glen Blvd and a depth of approximately 85 feet.



Appendix D  
Tieback Survey

**Appendix D TIEBACK SURVEY**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
<b>Western Station - West End</b>						
	4525 Wilshire	3	3	1981	Raker against north wall. Tiebacks on three sides.	No
	4750 Wilshire	3	3	1983	Cantilever wall + tiebacks	No
	4751 Wilshire	3	2 to 3	1982	Rakers + Soldier piles (max depth of 45'). Tiebacks with bell anchor beyond 35 degree wedge	No
	4848 Wilshire	3	1	2008	Soldier pile shoring with 1 level of tiebacks to 22' deep.	No
	5115 Wilshire	5	2	2005	Tiebacks to 20' beyond active wedge	No Details
<b>La Brea Station - East End</b>						
	5200-5220 Wilshire	7	2	Proposed	1 level of tieback support (1.0 to 1.75" Dywidag bars 150 ksi rod) lengths of 55' to 69'	
<b>La Brea Station - West End</b>						
	5550 Wilshire	5	2	2007	33 soldier piles along Wilshire. 31 were W18x40 (8-ft embedment), with 1 level of tieback (Ground = El. 195. Tieback at El. 185, sloped at 25 degrees. Length = 61' with 8" dia concrete. 2 soldier piles @ NW corner were W16x46 (16' embedment). Tieback El. = 184, sloped at 45 degree to avoid utility, Length = 58' in 10" dia shaft. All tiebacks used 1.75" steel.	No
	5665 Wilshire	1	1 to 2	1994	Drilled CIP pile with wood lagging with 1 level of tiebacks into Wilshire	No
	5700 & 5750 Wilshire	5 to 6	3	1985	Likely - tieback with 24-inch belled anchors	No
	5900 Wilshire	32	4	1970	Tiebacks indicated on CLA utility drawings. No	Yes

**WESTSIDE SUBWAY EXTENSION PROJECT**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
					details available to date.	
<b>Fairfax Station - East End</b>						
	6067 Wilshire – LACMA		2	2005	Tieback (25' long beyond 35 degree wedge) - Located far away from Wilshire	No Details
	6100 Wilshire	16	5	1986	56' Tiebacks beyond 35 degree; 4 levels. No details available yet.	Yes
<b>Fairfax Station - West End</b>						
	6222-6226 Wilshire	6	3	1985	Soldier piles with drilled frictional tieback, 6' on center	Possible
	6300 Wilshire	21	4	1970	Soldier piles with tiebacks with belled anchors - 15' beyond 35 degree	Possible
	6418 - 6420 Wilshire	19	4 to 5	1970	Tieback encountered during borings for new 6434 Wilshire building	Likely
	6500 Wilshire	24	5	1982	No details available to date.	Likely
<b>La Cienega Station - East End</b>						
	8484 Wilshire	10	4	1970	Tiebacks with drilled concrete anchors at 25' beyond wedge. No details available.	Yes.
<b>La Cienega Station - West End</b>						
	8501 Wilshire	3	3	1983	Tiebacks per MACTEC field survey	Possible
	8536 Wilshire	3	4	2004	Tiebacks per MACTEC field survey	Yes
	8641 Wilshire	3	3	1986	Tiebacks per MACTEC field survey	No Details
	8670 Wilshire	3	3	1982	Soldier piles with 12" tiebacks @ 5' spacing. Tieback extends 25' beyond active wedge. Shotcrete lagging	No Details
	8767 Wilshire	4	4	2011	Tieback and corner brace/Raker (seen in aerial photo)	No Details
	9378 Wilshire	3	4	2009	Tiebacks per MACTEC field survey	
<b>Rodeo Station - East End</b>						

**WESTSIDE SUBWAY EXTENSION PROJECT**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
	9401 Wilshire	12	3	1971	Tiebacks per MACTEC field survey	No Details
	9454 Wilshire	12	3	Not known	Tiebacks per MACTEC field survey	No Details
	9461 Wilshire	10	3 to 3.5	1972	Tiebacks per MACTEC field survey	No Details
<b>Rodeo Station - West End</b>						
	2 Rodeo Drive	3	4	1990	Tiebacks (evidenced by patching of concrete walls in basement levels. Raker along portion of wall along east perimeter). No details available to date.	Yes.
	9595 Wilshire	10	4	1970	Tie anchor extend 20-25' beyond active wedge	No Details
	9570 Wilshire	5	3 to 3.5	1993	Cantilever soldier pile at 6-ft centers at top. Tiebacks with frictional anchors 25' beyond 35 degree wedge at bottom	No Details
	9830 Wilshire	3	2 to 4	1988	Tiebacks extending 30' beyond active wedge	No Details
	1875 & 1925 Century Park East	24	1 to 3	1979	Tieback for garage only, Not located on Wilshire	No Details
	2029 & 2049 Century Park East	44	6	1973		Yes
<b>Century City Station - East End</b>						
	2000 Ave of the Stars	16	6	2004		Yes
	1999 Ave of the Stars	39	3	1990	Tieback anchors 20-ft beyond active wedge. Assuming a length of 46', they extend 30' into street.	Yes
<b>Century City Station - West End</b>						
	10587 Wilshire	7	3	2004	2 levels tiebacks – El. 294 & 280	No Details
	10601 Wilshire	20	3	1980	Tiebacks on south & east walls. Rakers on west and north.	No Details

**WESTSIDE SUBWAY EXTENSION PROJECT**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
	10700 Wilshire	6	3	2008	Tieback Support	No Details
	10724 Wilshire	15	3	1982	Soldier pile (tip El. 300) & 1 level of tieback at El. 318. Total tieback length varies from 39' to 43' (unbonded length = 11'. Bond length varies with design load. (16" dia hole+ 1.25" rod & 32' bonded length = 80 kip; 16" dia hole + 1.25 rod & 28' bonded length = 71 kips, and 12" dia hole, 1-inch rod and 32' bonded length = 60 kips). Tieback at 20 degree sloped.	
	10727 Wilshire	23	3	1981	Tiebacks (to depth of 33') Possibly removed during foundation backfill.	No Details
	10750 Wilshire	18	4	1980	19 Soldier piles (W16x36 at tip El. 293) with 10" thick gunite lagging & 2 levels of tiebacks. Tiebacks were 1.375" rod, installed in 18" dia hole, & inclined 20 deg. 1st level at El. 333 length of 53', 2nd level at El. 316 of 43'	
	10776 Wilshire	24	4	2008	Along Wilshire - 26 Soldier pile W18x65 & W18 x 73 with 10' to 26' embedment. 2 levels of 26 tiebacks ea (El. 325, 12 at El. 307. Length of Level 1 = 64' and Level 2 = 50'. All top level tieback inclined at 35 deg, to avoid utilities. Rakers on all other sides. All tiebacks were detensioned. Top 20' of tieback facing Wilshire was removed.	
	10790 Wilshire	19	4	1979	Installed drilled friction anchors tiebacks on all sides except facing south. Soldier piles on south supported with 30 degree sloped raker at 8-ft center, gunite lagging between.	
	10800 Wilshire	23	3	2005	26 tiebacks at 8-ft center along Wilshire.	

**WESTSIDE SUBWAY EXTENSION PROJECT**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
	10840-10850 Wilshire	13	2 to 3	1971	Total 37 10WF45 to 49 soldier beams (tip Elev 275) with 3 - 4 levels of belled anchor tieback at 15' bonded length beyond 35 degree wedge angle. # of Tieback at depth = 37@7', 37@18', 34@29', and 9@31'. Tieback = 3,000 psi, 12-inch diameter grout column, belled to 36'inch at base. Slope angle = 30 degree down. Use 1.25" to 1.375" steel rods with a 8" Sq x 2" steel anchor plate. Similar to construction at 10880 Wilshire.	
	10877 Wilshire	25	6	1985	6 levels tiebacks along Wilshire & 4 levels elsewhere. Depth at 12', 20', 26', 40', 50' and 60' along Wilshire. Tieback at 20 deg angle, development length behind 35 deg wedge. Length of anchor = 28' (bottom), 40 - 46' at top 5 levels. 1.375" 150 ksi Dywidag wire installed in 16-inch dia, 3000 psi cement backfill.	
	10880 Wilshire	23	4 to 5	1970	Soldier Piles at 6'-8" apart with 5 levels of tiebacks. Tiebacks were 12" dia grouted with anchor belled to 36" at base and reinforced with 1-inch dia rod.	
	10900 Wilshire	16	3	1980	Soldier Pile (tip El. of 249, with min 10-ft embedment) - Gd El. 302 to 258. Tiebacks at three levels - El. 293: 47' long, 16" dia hole with 1.25" steel rod El. 270-277: 40' long 16" dia hole with 1.25" steel rod El. 265: 32' long, 16" dia hole with 1.25" steel rod Tieback inclined at 20 degree for top 2 levels, and at 25 degree at bottom level.	
<b>UCLA Station - East End</b>						
	10920 Wilshire	18	4	1980	Tieback facing Wilshire at 25' beyond wedge. No details available to date.	Yes

**WESTSIDE SUBWAY EXTENSION PROJECT**

Subway Station	Building Address	No. of Story	No. of Basement	Yr Built	Tieback Shoring	Within Tunnel Envelope
UCLA Station - West End	10940 Wilshire	23	5	1986	2' thick slurry wall to 7-ft below footing. 4 levels of (dywidag bars) tiebacks at 13', 25', 38' & 54' below grade. Tiebacks sloping down at 20 deg and bonded for 37'(for 1st 3 levels) and 30' for lower level beyond 35 deg wedge. 20 tiebacks per level. Slurry wall and steel plates at tieback locations exposed in garage. Raker against 10920 Wilshire.	Yes